The Luminin

A Visual Instrument

by

Ofer Shouval

ABSTRACT

Just as a musical instrument transmutes the movements of a skilled musician into intricate arrangements of sonic vibrations, The Luminin, a "visual instrument," converts the physical motion of its performer into a dazzling display of light. It consists of a controller, which, mounted to an instrument or held in a hand, collects kinematic data from an accelerometer and transmits it to a Raspberry Pi. The Pi runs a Processing Script which interprets this data, generating interactive animations in real time which it displays across two LED screens. This system is intended as proof of concept for a cheap, DIY lighting system that could provide musicians and performers with the tools they need to create their own innovative light shows and control them from the stage.

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CHAPTER 1

LIVE MUSIC AND A PANDEMIC

It almost seems like a lifetime now since the coronavirus pandemic began sweeping across the planet, killing millions and forcing the rest of us to stay away from each other. Obviously, my life has been profoundly impacted by the pandemic, not least because my thesis is primarily concerned with the visual augmentation of live music performance spaces. And yet the project itself has changed only minimally.

I've thought a lot about whether it should change more. Will live music ever actually return? Will the communities that have been so instrumental to my life and my art ever reassemble? Should I adapt my project to augment the virtual spaces in which we've all been forced to congregate? Ultimately I sense that there is no replacement for the feeling of being crammed together in a small venue with a hundred friends and strangers, feeding off each other's energy until, momentarily, time ceases to exist, the self ceases to exist, and everyone moves to the same rhythm.

As we start getting vaccinated and beginning to trickle into venues again, can us musicians see this break as an opportunity to step away from the well-worn paradigms of the pre-pandemic era? Can we reassemble the industry in a way that gives more creative power to the artists? Can we build a community that preserves the magic of getting the band together and playing your heart out in front of an audience, but that is also able to adopt and implement new technologies to create experiences powerful enough to free the audience from this small screen, hyper-distracted, dopamine-addicted cultural milieu? These were the questions that inspired my thesis project before the pandemic, and if anything, they are even more relevant now.

REGARDING THE STATE OF THE MUSIC INDUSTRY

I've been playing in bands since high school. Music became the center of my life in college, but as I got older, I started having to think about questions like how do I pay rent? What kind of a job can I get that offers health insurance? I needed to seriously consider whether chasing a dream career in a youth-dominated industry that was being financially decimated by new technology was still viable.

Obviously, this was a very hard pill to swallow, because music, and in particular the act of performing it live to an audience, has long been a hopeless addiction. The pre-show panic, manifesting itself in the tightness of chest and the tingling of fingers. The intense rush as all this potential energy becomes kinetic, an intense state of unconscious concentration, mediated and transmitted through the movement of the hands, the body, the mouth, the vibrations coursing through your chest. The sense of oneness with the audience as you simultaneously generate and ride waves of collective emotion. Live performance seemed to be the most meaningful activity I had ever engaged in.

I And yet, this addiction had real costs on my well-being, physically, financially, emotionally. What had started as an expression of pure love had become fraught with drawbacks, and like many addictions, there was no "easing up." I could not do it casually. The minute I exposed myself to it, picked up an instrument and started writing, I found myself pulled back into its grasp. The simple truth is that music is the artistic medium where I feel most effective in communicating complex ideas to the world.

But perhaps more than any other art form, technological changes have had massive effects on the music industry. Record sales, long the bread and butter of the industry, is no

longer a viable way to make a living for all but a tiny fraction of professional musicians. Instead, musicians must tour relentlessly to make ends meet.

Meanwhile, the cost of producing a record has plummeted; where 20 years ago one would need to rent a studio and hire an engineer, anyone can now produce a record in their bedroom. As a result, hip hop and electronic music, genres that don't require a live band to perform, have come to dominate popular music. These forms are at the forefront of artistic innovation in production but even more so in live performance. Freed from having to play their instruments, these musicians are able to fill transform stages with visual elements that create an enveloping experience for an audience.

But there's still a certain quality about a group playing instruments in front of an audience that can never be replaced: risk. The sense that things can fall apart at any moment. David Byrne, lead singer of the late 20th century art rock band the Talking Heads, puts it like this: "Audiences love it when a performer walks the tightrope in front of them; like sports fans, they feel like their support is what keeps the team winning."1 This quality gets lost when the all the performer has to do is get on stage and press play.

Here's current the paradigm as I see it: Due to technological advances, it has become increasingly possible for people to put together musical performances that don't include playing instruments. Performers have been able to innovate on the visual aspects of their performances, so much so that audiences now expect to be immersed in an audiovisual experience when they go to a concert. Unfortunately, due to the nature of playing an instrument, it's been very difficult for anyone who continues to play their instruments on stage to keep up.

Seeking to preserve that element of risk associated with "playing it live," I've been designing a system which allows instrumentalists like myself to have our cake and eat it too: a system that allows us to run a dynamic light show from the stage, while simultaneously

playing our instruments. Recalling Leo Theremin's innovative electronic instrument, I've taken to calling this system the "Luminin."

LUMININ 1.0

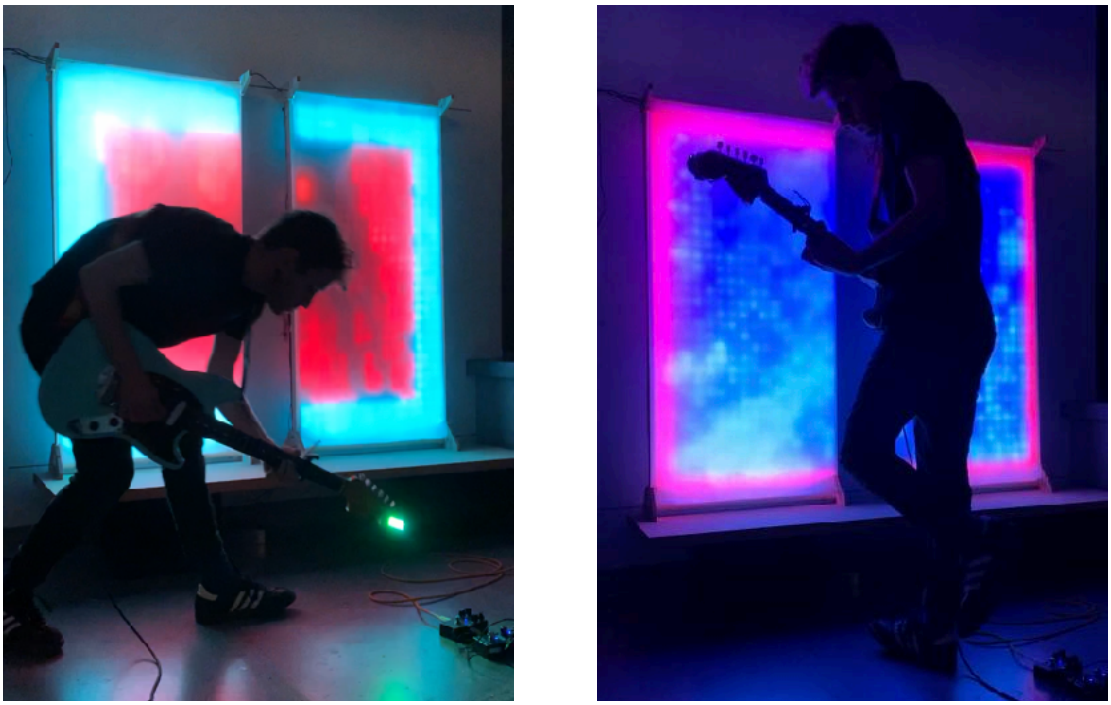

Fig 1. Playing the Luminin 1.0

I want to take a moment to differentiate between the concept of a Luminin and the tangible Luminin 1.0 which is being presented in this thesis.

Conceptually, a Luminin is a flexible, modular, lighting system which can be made to fit in many different kinds of spaces. Much in the same way a musical instrument converts the practiced movements of its player into intricate constellations of sound, the Luminin is a "visual instrument," a device which transforms the motions of its user into emotive patterns of light. Whatever physical form it may take in the future, the basic idea will be the same— it converts performative motion into dynamic lighting, giving performing artists the power to radically transform their visual environment with a flick of the wrist or a swivel of the torso.

The current iteration of this concept, Luminin 1.0, consists of a "controller," (mounted on my guitar headstock) which uses an accelerometer to collect motion data and send it over the air to a Raspberry Pi. The Pi runs a Processing sketch which uses the data from the accelerometer to generate and animate patterns and display across two custom built LED screens.

My long-term goal is to streamline the software, source the materials, and create a toolkit which lowers the bar for other musicians and allows to design and build their own Luminins. As such, I went into this project with three major stipulations. I wanted it to be:

1. **Reliable + Portable** - so musicians can pop it in the trunk and take it to the venue
2. **Cheap to build** - so musicians can afford it
3. **Easy to program** - for obvious reasons.

Of course, these stipulations tend to tangle with each other, which I will expand upon in the technical section. Not every one of these interlinking issues has been solved. I certainly couldn't just hand the system over to some random musician and let them run with it, so it is best to think of the Luminin 1.0 as a proof of concept, a working example on top of which I will continue to build. Which is not to say that it isn't working very well in a controlled environment. It is.

CHAPTER 2

INFLUENCES

Anyone who's ever turned on a lightbulb, or opened the curtains, or lived a day and a night on the planet knows that light has the power to transform a space. This is not exactly a piece of esoteric knowledge. But the impact that lighting has on, well, everything, often goes under appreciated by musicians like me. Indeed, I tend to close my eyes when I'm listening to music, or when I'm on stage.

When I close my eyes, I often find myself enveloped by the sound. It becomes difficult to differentiate between hearing and vision at this point - my brain is running its own light show. But this perceptual experience, often called "synesthesia", is as fragile as it is internal. When I open my eyes, I become distracted by the prosaic nature of the world around me. The messy bedroom. The seedy venue. And it pops me out of my reverie.

In an interview with PBS, the artist James Turrell stated: "I look at the eye as the most exposed part of the brain, as something that is already forming perception."[2] Despite my obsession with all things audio, this observation completely squares with my experience too. After all its no coincidence that I describe this synesthesia in visual terms. In my minds eye, I can see the sounds. I don't hear the lights.

When putting on a show, one draws the audience in, and keeps them engaged, the musician must engage with this fact. Our audiences consist of a group of visual animals, we cannot ignore this crucial aspect of perception. The question is, how?

Figure 2. The Flaming Lips Light a Cymbal on Fire

> We're gonna blow up some balloons, and we're gonna sing happy birthday, and I'm gonna throw some blood on my hands, and we're gonna sing some songs about death, and life, and love, and that's what it means to be alive.[3]

I've long sought to internalize the sentiments behind this quote from Wayne Coyne, lead singer of The Flaming Lips, because it demonstrates an attitude towards performance and to life that I find useful. Coyne's attitude is steeped in the sentiment that, regardless of circumstance, an individual or a group of people has the power to make the world around them more beautiful, more meaningful. Money, access to technology, technical knowledge… while all of these things are extremely important, they are not completely deterministic.

Indeed, the Flaming Lips didn't have access to the trappings of power and influence when they began their careers in Oklahoma City in the late 80s. They were just a weird group of working-class hippies, navigating their way through the constraints imposed on them by a prevailing conservative Christian culture. Nevertheless, they used whatever materials were available to create an environment which immersed their audiences in a different

world—a world where transformative change was possible. This is an aesthetic and an ethos that they've managed to maintain and expand upon throughout a career that spans multiple decades.

In January 2021, during the height of the third wave of the Covid-19 pandemic in the United States, I saw them play an in-person concert in Oklahoma City. The entire audience, around 200 people in total, sheltered in hundreds of separate inflatable plastic bubbles.

The atmosphere was, as one might expect, very strange. The sound was rather muffled, and everyone was confined to a plastic bubble, a bubble which would periodically fog over until we could signal an attendant in a hazmat suit to stop by and give us some new air via a leaf blower. Yet despite these bizarre distractions, or perhaps *because* of them, the concert had a profound emotional effect on me. It was moving due to the risks involved and the enormous efforts that the organizers took to mitigate them. It viscerally demonstrated that big problems can be overcome with creative solutions. That circumstance is not the sole driver of artistic expression. That even if a familiar medium is mangled by the existence of a deadly virus that forces us into separate plastic bubbles, the power of the message can remain, and even be strengthened.

DAVID BYRNE + DETERMINISM

It has to be said though, this can-do attitude, a belief in the transformative power of the individual, is something deeply ingrained in American culture. But this view seems to exist in a state of perpetual conflict with a more deterministic, perhaps more realistic, view of the nature of power and freedom, one which has become increasingly pervasive in recent years, as the wealth gap continues to grow and many people find themselves stuck in a state of economic subjugation. So which idea is more true?

Fig 3. A Live Audience in Bubbles, January 2021

For the purposes of this thesis, I will simply state that I believe it to be a false dichotomy. It all depends on one's frame of reference. On an individual level, it is obviously

important to believe in one's own transformative power, or "to make lemonade when life gives us lemons" as the popular idiom goes. On a societal level, clearly circumstances have a massive effect on opportunity, just as the context has a massive impact on the nature of the art. Together, these forces shape the world around us, so by holding on to both in tandem, we can begin cut an epistemological path for ourselves.

In his 2012 book, *How Music Works,* David Byrne presents his very deterministic understanding on the nature of art:

> I had an extremely slow-dawning insight about creation. That insight is that context largely determines what is written, painted, sculpted, sung, or performed. That doesn't sound like much of an insight, but it's actually the opposite of conventional wisdom, which maintains that creation emerges out of some interior emotion, from an upwelling of passion or feeling, and that the creative urge will brook no accommodation, that it simply must find an outlet to be heard, read, or seen… In a sense, we work backward, either consciously or unconsciously, creating work that fits the venue available to us.[4]

At first, this can seem like a bit of an odd position for Byrne to hold. How can someone who has played a monumental role in subverting and reshaping the semiology of music throughout his long career hold such a view? I propose, however, that this understanding of the effect space has on the art is precisely what has made Byrne so effective at breaking rules.

In what is probably his most defining work, the stage production which eventually became the 1984 film, *Stop Making Sense*, Byrne broke what is often considered a classic rule of performance: the magician must never reveal their secrets. He did this by taking the stage apart and making its assembly part of the performance. In his words:

> I decided to make the show completely transparent. I would show how everything was done and how it had been put together… Following this concept to its natural conclusion meant starting with a bare stage. The idea was that you'd stare at the emptiness and imagine what might be possible. A single work light would be hanging from the fly space, as it typically does during rehearsals or when a crew is moving stuff in and out. No glamour and no "show"—although, of course, this was all part of the show.[5]

If the venue in some way determines the nature of the art, does revealing the nature of the venue free the artist from some of its constraints? “Consciously or unconsciously,” it seems to me that this is the question that Byrne was attempting to answer.

Did it work? Did David Byrne free himself from the constraints of space? I think the answer is a resounding yes—as the show progresses and more elements are added to the sound and to the stage, we see their effects on his freedom to express himself, on his power to inspire. He is still on a stage and he is still in a venue, but by presenting the stage as blank canvas, he opens up a whole new avenue of expression and we get watch it get painted on.

As I design my device and reflect on how I intend to use it as part of my live performances, I stand on the shoulders of these artists, and many more. It is easy to allow a light show to become “eye candy”: just some pretty lights, lacking in deeper meaning. We can eas-

Fig 4. David Byrne, Alone on Stage, *Stop Making Sense*

Fig 5. Byrne and Tina Weymouth Play as Drums Get Wheeled On

Fig 6. The Complete Band, Lit to Create Shadows

Fig 7. David Byrne playing the… Lamp

ily say “Wow! Look at how the lights transform the space!” but what is our goal here? What are we transforming it into?

These are pertinent questions which we will be returning to over the course of this thesis. But before we do that, let’s discuss the details of the Luminin, and get into some of the specifics of what it allows you to do.

CHAPTER 3

EXPLORATIONS IN FORM AND FUNCTION

Before I settled on the final designs for the Luminin 1.0, I created a series of series of sketches and installations exploring the interplay of light and texture mediated by interactive animation. In the earliest examples of these, I wrote Processing sketches to generate dynamic animations and projected them onto different kinds of materials.

These pieces were not intended to be used on a stage, but were instead concerned with understanding the interplay of light, space, and material, something I needed a better understanding of before I could begin designing for the stage. I was trying to reinvent and break out of the limitations of the screen, so I began by experimenting with different kinds of surfaces: through strips of translucent beads, as in fig. 8 "Untitled," rear projection onto thin paper in "Refracture" and fluorescent acrylic sheet in "Sun Deity."

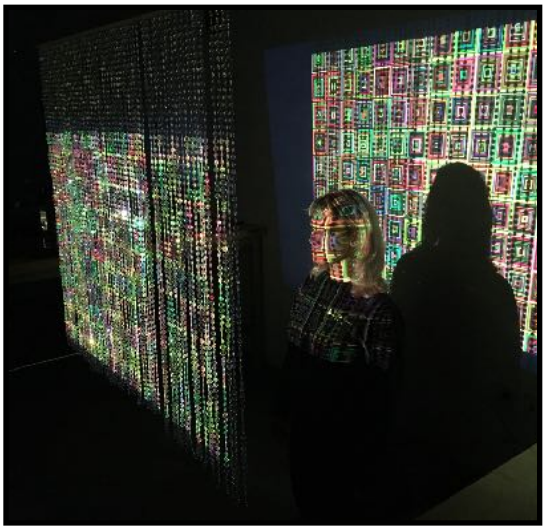

Fig 8. *Untitled*, 2018

Fig 9. *Refracture*, 2018

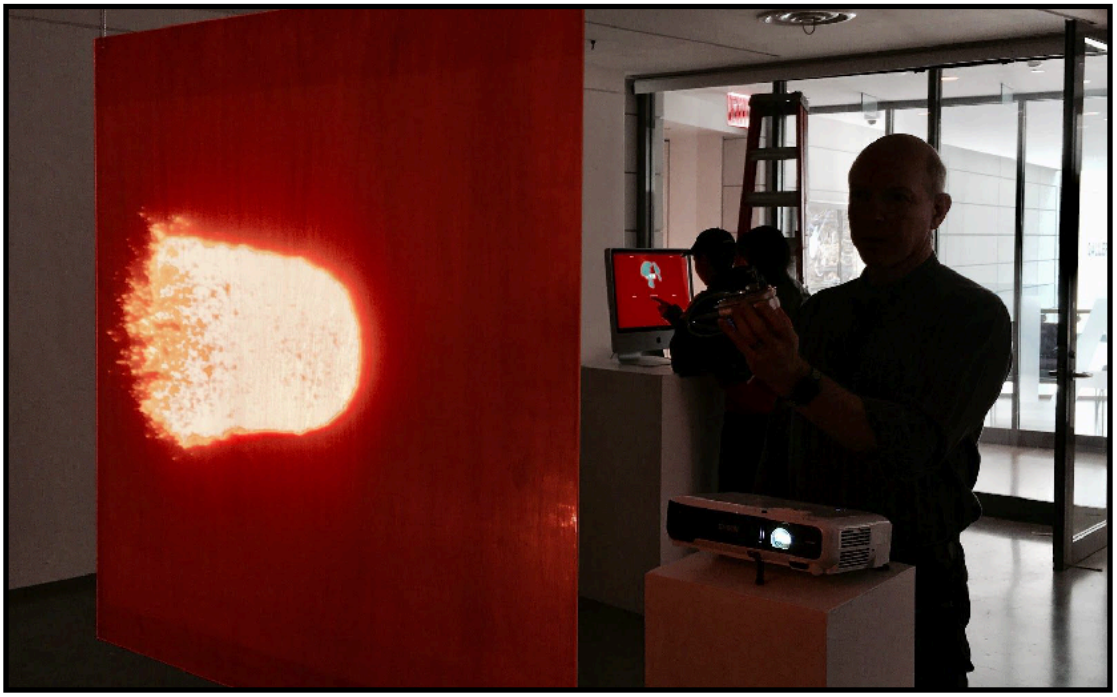

Fig 10. *Sun Deity,* 2019

At the same time I was becoming very interested in creating dynamic interactive animations using programming languages like Processing and Touch Designer. These started out as simple video filters (such as in “Refracture”), but as I continued my exploration I began building devices that measured accelerometer data, using that data to generate animations. I found naturalistic algorithms which use forces to control particles and other objects to be particularly

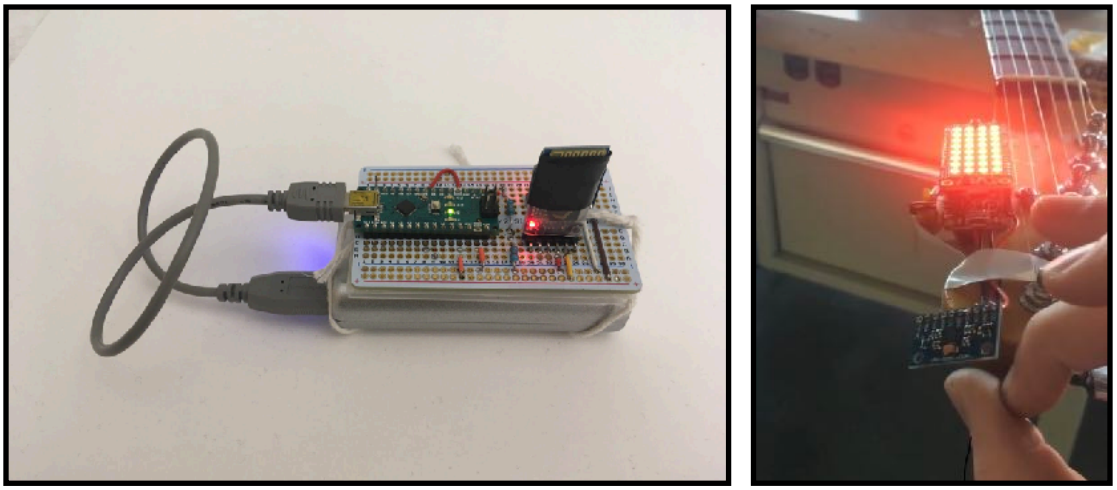

Fig 11. Two Early Controller Designs

interesting because they allow you to essentially reapply the forces your motion exerts onto the accelerometer onto a set of virtual objects, especially if the resulting animation is seen outside of the context of a traditional screen. In a sense, “Sun Deity” is a meditation on the concept of power. As anyone who’s ever played a video game will tell you, there is a certain excitement associated with the exertion of power on an entity, even if it’s virtual. By breaking out of the traditional formulation of a screen, “Sun Deity” blurs the lines of the physical and the virtual, opening up the mind up to new abstract possibilities.

I continued to play around with these ideas over the summer of 2019. While interning for Point in Passing, I wrote a series of p5js algorithms that drive the motions of a set of DOM elements across the page. As you navigate through the site (which can be seen at https://pointinpassing.com/) it is easy to become wrapped up in playing with the motion of these elements across the screen. Many of the techniques I used to create these pleasing interactions have since been incorporated into the creating the programs that drive the Luminin.

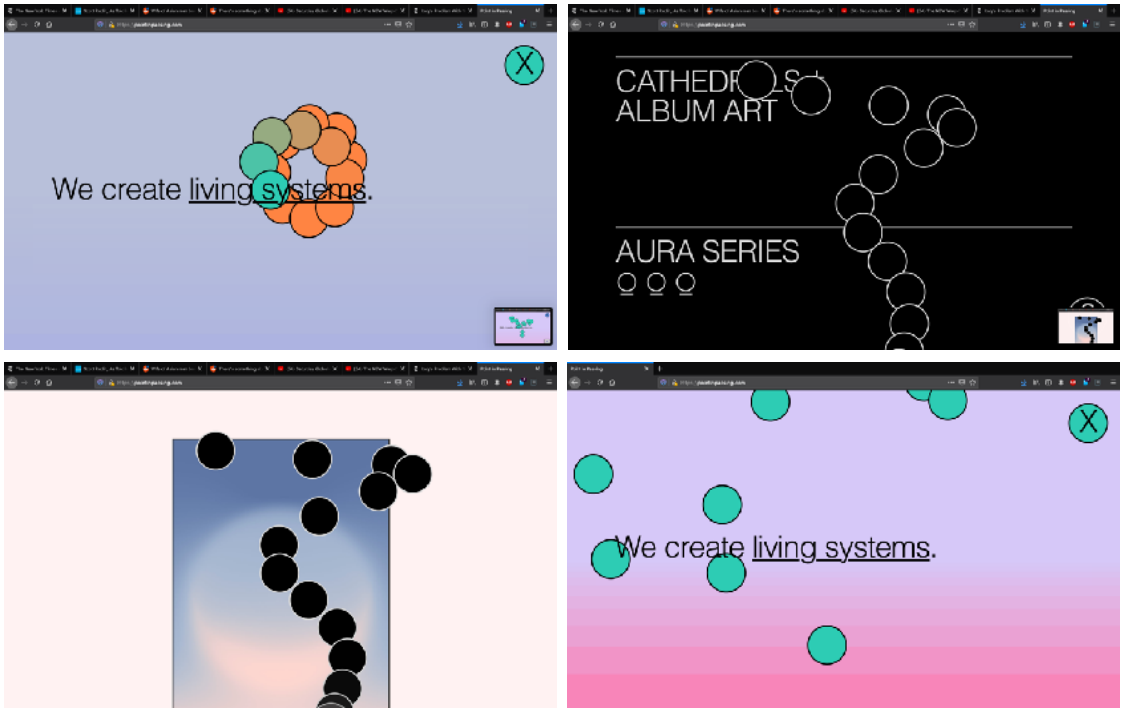

Fig 12. Point in Passing Website, 2019

Fig 13. *Ghost Harp,* 2019

As I continued to zero in on the physical structure of the Luminin, I moved away from projection. I wanted to build something that didn't rely on a backdrop, and so I began working with addressable LEDs. But before settling on the more practical conception of the Luminin as a device that could be moved from place to place, I wanted to further deconstruct the concept of a screen by sculpting the LEDs in three dimensions. This line of thought led me to "Ghost Harp," an installation I put together in the fall of 2019 that consisted of columns of LED backlights stretched from the ceiling to the floor in a form inspired by the aesthetic beauty of a string instrument.

The piece takes MIDI signals and converts them into waves that scatter across the individual LEDs, allowing one to literally "play the lights" with anything that can export MIDI—an electric piano, a drum pad, etc. This was a very different concept than the motion-based Luminin 1.0, but something that I will potentially return to in the future.

Fig 14. Luminin Prototype #1, 2020

I started small because the pandemic had just hit and I was at my parents' house in Texas, all the LEDs I'd purchased stuck in my studio in New York. I was nevertheless very happy with early results. I'd essentially done what I'd set out to do: I had created from very cheap materials an extremely portable digital animation screen that could be controlled by swinging around a wireless controller. Expanding on some of the concepts I'd picked up from working

with projection surfaces, I used newsprint paper to obscure the very low resolution, and the result was very pleasing, looking almost like watercolor.

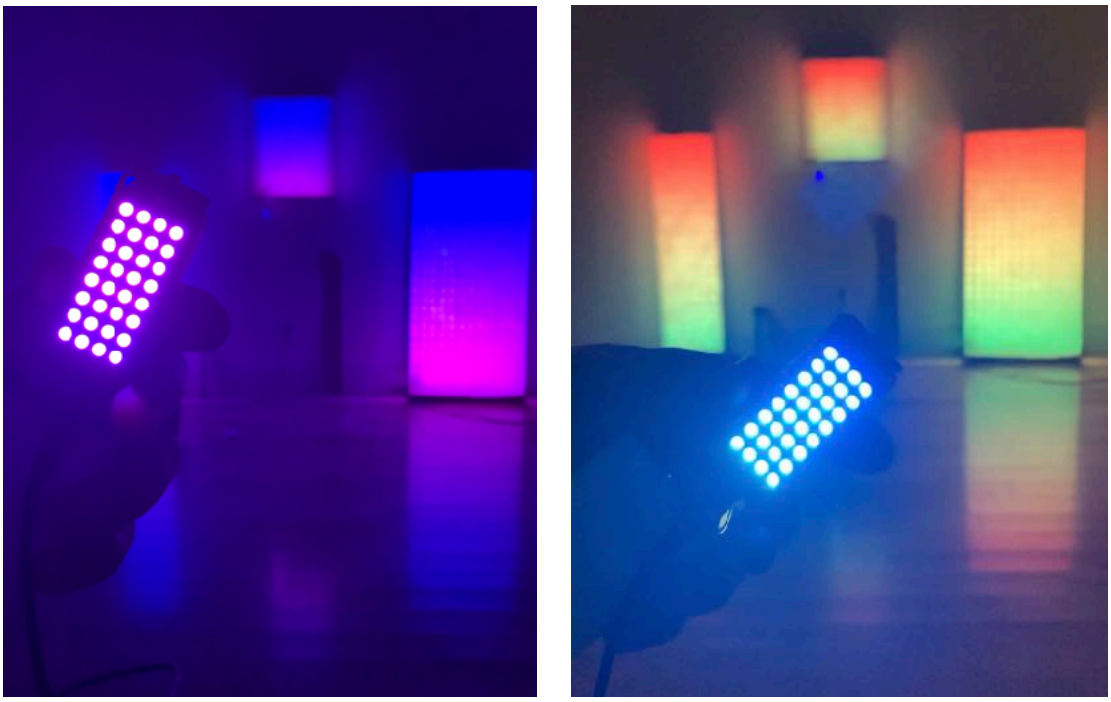

Fig 15. Demonstration of Modularity

This iteration achieved two of the three major qualities I wanted for my device. It was very cheap,:each screen ran on a $3 ESP8266 microcontroller and the low resolution of LEDs meant that all three screens combined cost around $300 to build. The materials for the controller cost me about $70.

They were also very reliable and portable. I used the ESP-NOW wireless protocol to communicate between screens and controller, and this meant that I would never have to worry about connecting to a new wireless router—I only needed to turn everything on and it would connect automatically, no matter where I was.

The issue was that it was very hard to program. I was using Arduino to control an array of LEDs, which meant there were no shortcuts; I had to send a new command to each LED every frame, and there was no way to see what I was doing, making iteration practically impossible. Additionally, the microcontrollers I was using were unable to achieve the refresh rates I needed to make smooth looking animations, a problem that I knew would only grow if I wanted to create anything larger or at a higher resolution. So despite the progress I'd made, I decided to look for another option. I settled on a preprogrammed hardware/software plat-

Fig 16. Luminin Screen Under Construction

form called "Fadecandy" which allowed me to display the output of a Processing sketch (and a number of other visual programming libraries) directly on an LED screen. I replaced the cheap ESP8266 microcontrollers with a more expensive (but still highly affordable) Raspberry Pi and went to work constructing couple of new screens. With this new level of detail that this change in software would allow me to pursue, I would want a higher resolution to capture more nuance.

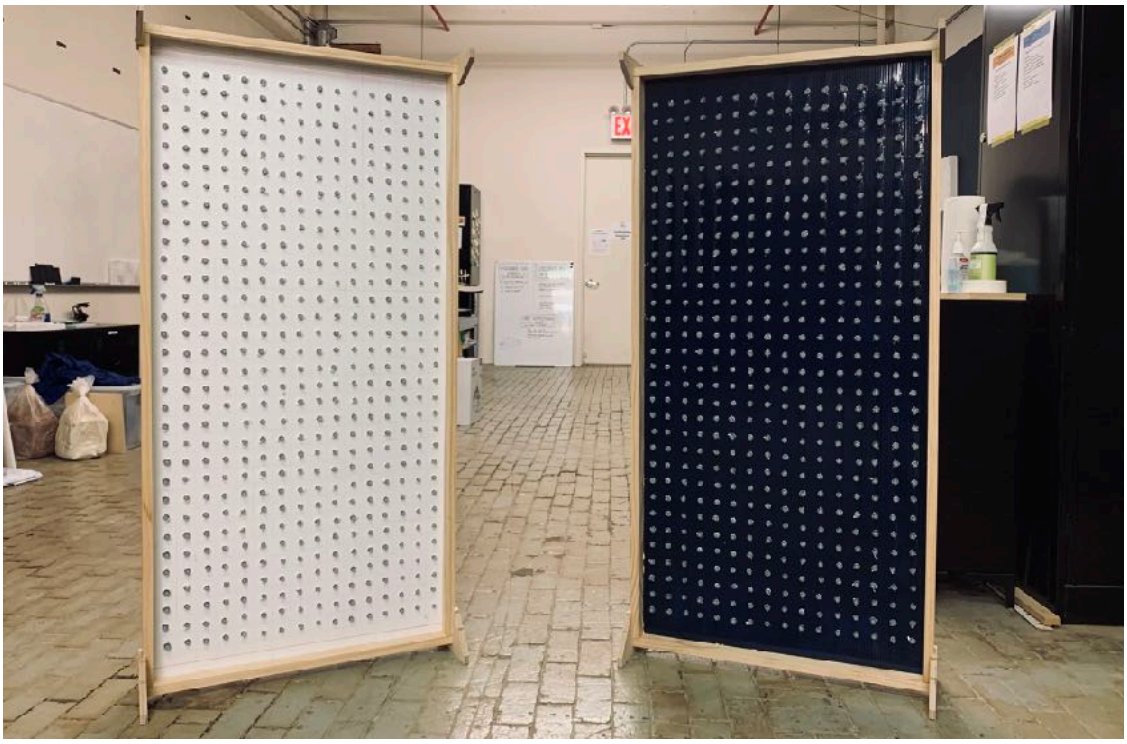

Fig 17. Two LED Screens, Framed and Ready for Action

As shown in figures 19 and 20, Fadecandy samples colors directly from Processing window, and sends the color data to the screens. This workflow makes it much easier to iterate, to play around with color and form, making it much easier to generate complex patterns and imagery that match your vision.

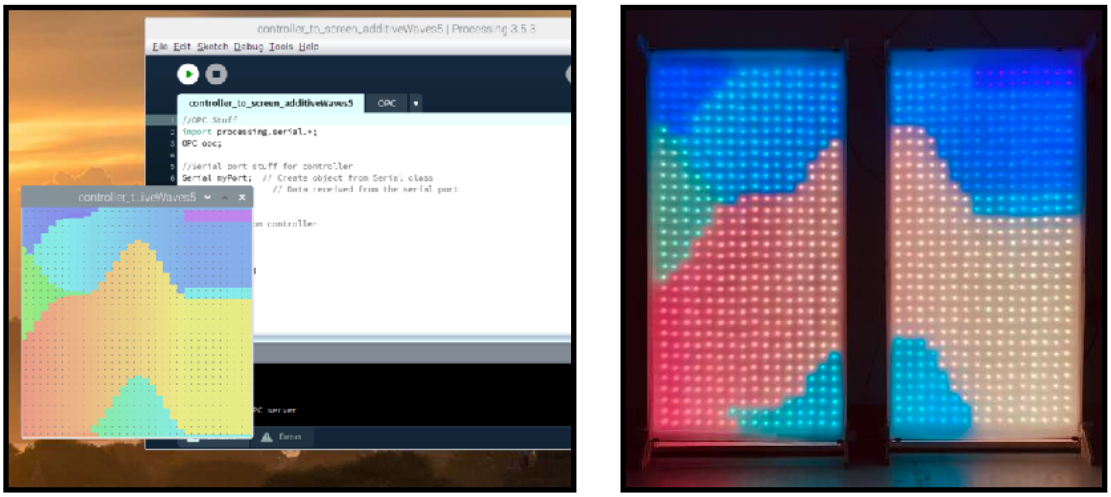

Figure 18. Processing Sketch on the RPi, mirrored on Display

When compared to earlier iterations, this set up has a few drawbacks. It is more expensive, and since it relies on more constituent parts, it is somewhat less portable and reliable. However, being able code in Processing was an absolute game changer. All of a sudden, I was able to create complex visual interactions using workflows similar to the one I had refined at my internship at Point in Passing.

Before, I had been stuck on simple gradients and fade functions. Now, I could base my sketches on far more complex mathematical ideas: flocking algorithms, flow fields, spring systems, additive waves, or raycasting functions. I played around with manipulated video inputs and kinetic typography. The possibilities are endless really, but as I continue to develop this toolkit, I've found myself returning to a pretty basic question: what kind of imagery does the music call for?

CHAPTER 4

THE AESTHETIC CONSIDERATIONS OF RUNNING LIGHTS

In a sense, the Luminin is more like the canvas than the painting itself. The actual art, or at least the conceptual and emotional aspects of it, are the *sketches* you produce for the Luminin. In this section I'm going to delve into the philosophical and aesthetic concepts that might go into writing an effective sketch for the Luminin, one that augments a song rather than just drawing attention to itself.

Before we begin to delve into the specifics, I think it is very important to be clear about the role that the Luminin, and actually lighting as a whole, plays in the grander scheme of a performance. To this point, here is an analogy that I find helpful: a light show is to the song as a film score is to the film. In other words, the light show is *subservient* to the song it's meant to accompany, and therefore we must let our choices in creating a sketch be guided by the emotional content of the song.

This can be tricky balance, so perhaps we can draw on the wisdom of film composers to help us wrap our heads around it. In a public radio interview, the minimalist classical composer Philip Glass said on the matter:

> If someone is selling you a car on television, and you listen to that music, that's a commercial jingle of a kind. Now you're not supposed to think about anything, you're supposed to come away thinking, 'I got to go buy that car.' That's all that music is supposed to do, right? If you take the same strategy and try to put it in a film, it becomes impossible to watch the film, because the music is telling you too much — more than you need to know. What you really need to do, is to leave the audience the space to understand the film in the way that becomes personal for them.[6]

Just as Philip Glass doesn't want his music to overpower the narrative structure of the film, we don't want the lights overpowering the song. We want the lights to *accentuate* the emo-

tional core of the music, and therefore we must be careful not to visually overload our audience with sensory input.

Given that the Luminin is a performative instrument, some of that responsibility falls on the performer. If they're jumping around during the quiet bits,, the lights will behave accordingly. Nevertheless it's absolutely crucial that we don't set them up for failure.

Part of this is technical. We really don't want our performer to accidentally trigger a behavior that's meant to accentuate a climactic moment, so we need to carefully consider and refine our sketches to prevent this. But beyond these technical considerations lie important aesthetic questions, and the answers to these questions ought to be guided by the music.

A LIGHT SHOW FOR UNFAMILIAR STATE'

In the accompanying video documentation, you will see me performing a song I wrote several years ago called 'Unfamiliar State'. In this section I'm going to discuss the aesthetic choices that went into creating a Luminin sketch to accompany it.

In the video documentation that accompanies this this thesis, you will see the results of the process that I am discussing here, so for the purposes of this next section it might be helpful to take a look at that before you continue further. Regardless, I will also do my best to describe it in words. Here are the lyrics:

- Intro -

Verse 1:
Take a day, wake up whenever you want
Find yourself avoiding everything you ought
To be receptive to
The things I'm sending you

Verse 2:
Sooner or later I'll be plotting an escape
End up all alone in an unfamiliar state
But I'll remember you
And all the little things you'd do

Chorus 1:
Though someone else might fill the space in my day
Another addiction pushing everything away
Loving you is a part of me that I'll never escape
I know the aftertaste is bitter, but it goes away

- Key Change + Guitar solo -

Chorus: 2:

I was only trying to keep my head in the game
And now I'm struggling to remember your name
And when I wake up I feel better,
knowing I might end up old and bitter,
Eventually.

- End -

The song opens introspectively, atmospherically. In the recording, a piano repeats a sequence of arpeggiated chords in the key of E major while a set of sonic textures mingle in the background. The drums only come in at minute 1:20, and when they do, they redefine the location of the rhythm in relation to the piano. At minute 1:35, I start singing, slightly lower than my comfortable range, straining to be heard, but as the song progresses, the vocal melody begins to rise into my range and the song begins to settle into itself, its disparate textures giving way to a sense of forward motion.

The song hits an inflection point around minute 3:00 with the line "but it goes away." With the key change to C# Minor comes a mood change. The song had started ethereally, but is now thick with substance and psychedelia. A solo enters, recalling the angular melodic style of George Harrison, and after 6 bars, my voice returns, but now the melody is

in the upper reaches of my range, allowing me to belt. When I do, the lyrics are full of excuses and desperation: “I was only trying to keep my head in the game, now I’m struggling to remember your name.” The angst is over quickly though, releasing itself like a good night’s sleep; the last line is one of resignation. A shrug.

Let’s return our attention to the beginning of the track. To me, the texture of these sounds evokes the idea of flowing water. A babbling brook perhaps. Percolation comes to mind. So I began looking for an algorithm that could visually produce this sense of flow.

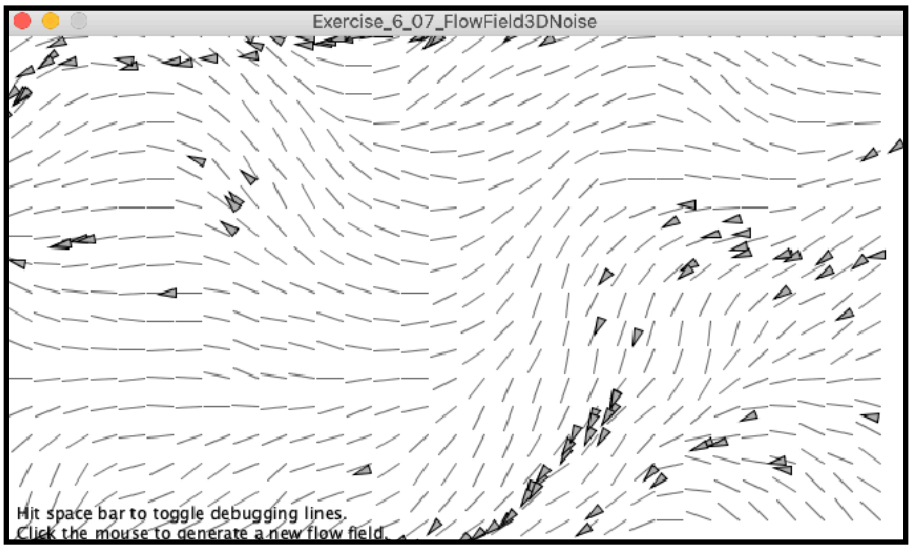

Fig 19. Flow Field Populated With Sprites, *Nature of Code*

I settled on a type of algorithm called a flow field. A flow field is simply a grid of vectors which can made to simulate all kinds of forces. To create interesting visual effects, flow fields are typically populated with an array of “sprites,” objects that, as they pass over any section of the grid, adopt a certain amount of directionality from the vectors they pass over. Figure 19 is an example of a Perlin noise-based flow field taken from Daniel Schiffman’s web series, *The Nature of Code*.

The wonderful thing about using Processing to produce these sketches is ease of iteration. With just a few quick modifications to Schiffman's example code we can begin to produce some interesting results:

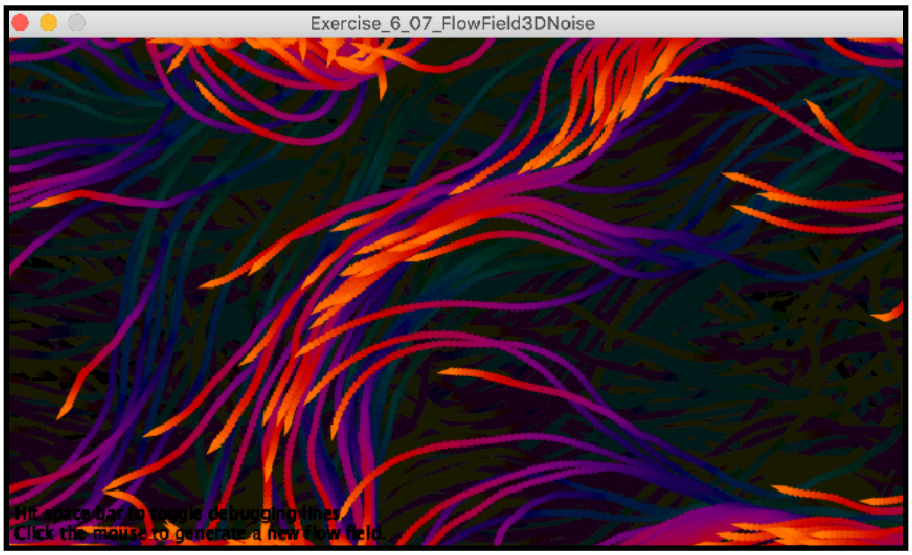

Fig 20. Quick Modification of Figure 19

The Luminin 1.0, however, has just 16x32 LEDs per display, so though the above figure 19 looks interesting on a high resolution computer screen, it would not necessarily translate to the LED displays. To succeed, we must recall the idea that the displays are a kind of canvas, and to consider the sprites as "brushes" that leave temporary trails of "paint" as they move. Then, you have to make a series of decisions—the shape of the sprites, their colors, how they move, and the amount of time their trails persist before fading away—all of which have a large effect on the mood you end up with.

For this example, I gave my sprites a circular shape with a three pixel stroke and no fill, (an adjustment I made partially to save computing power as there is no need to calculate

rotation). Since you can't really make out the details of the lines on the displays, and some LEDs are skipped as the sprites pass through, which creates a shimmering effect.

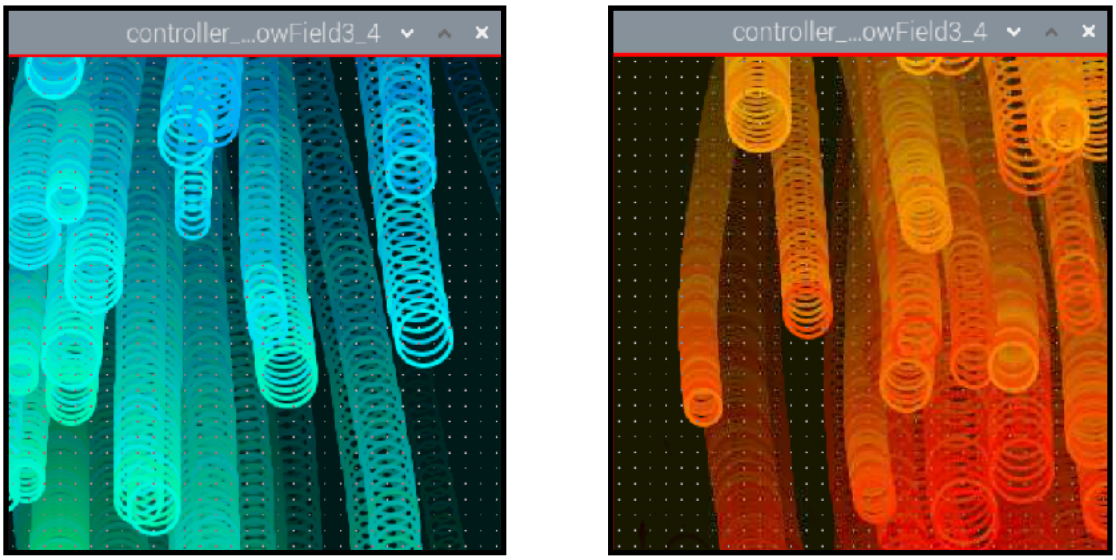

Fig 21. Default guitar position (left) and downwards tilt (right)

Color has a strangely profound effect on human emotion; I wanted to create that sense of calm, that flowing imagery of water, so I felt that the sketch for it should default to a kind of flowing cascade of blue/green. I wanted to be able to change this quality, however, so I connected color to the tilt of my guitar ; tilting it downwards turns it the scene into a fiery red/orange.

I created the downward motion by restricting the angle range of the elements of the flow field (generated from a 3D Perlin noise algorithm) to a number between $\pi/2+0.3$ and $\pi/2-0.3$. I wont get into the math of this, but the effect is that the lines that guide the sprites must always face within ~35° of each other facing down. But I also wanted my motion to also have an effect on this cascade, so I created another variable, "rotation",

and mapped it to the gyroscope which detects the forward and backwards rotations of guitar. Thus, by swinging the guitar around, I can effect the flow of the elements on the displays.

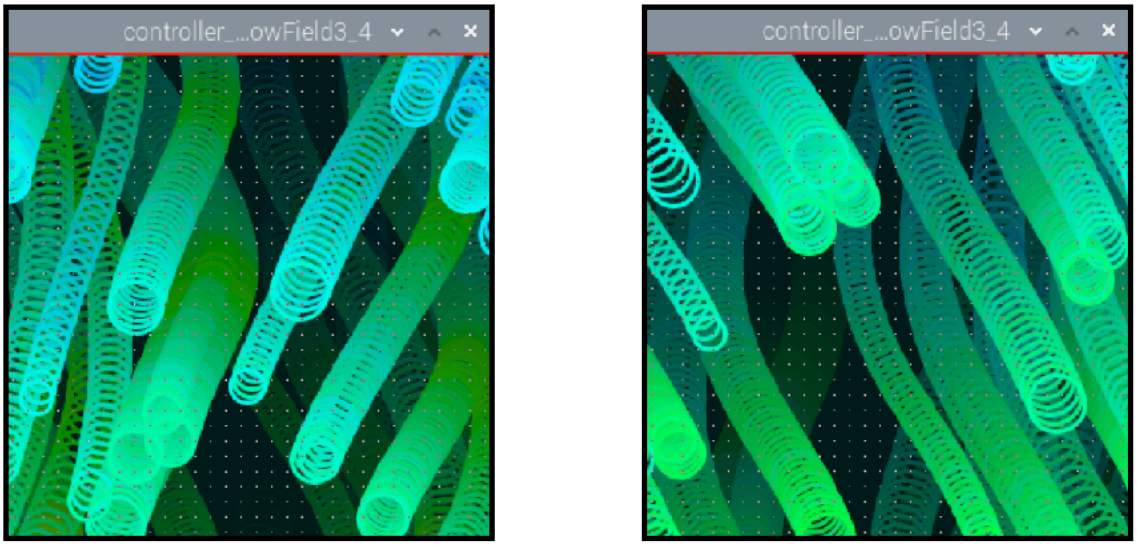

Fig 22. Rotating the guitar changes the direction of flow.

Finally, to complete the sketch, I needed a way to add some drama at the right moments. I'd created several variables in the Arduino code for the controller which get triggered by a deliberate sharp jerky motion in 4 directions, 'upJolt', 'downJolt', 'forwardJolt' and 'backJolt', and I wanted to use a couple of these triggers to spawn animations which would dramatically alter the underlying vibe.

To create this effect, I decided to alter several elements of the animation - first, I wanted something bold, clear and attention grabbing, and so I added a bright, boldly colored border to the scene which would shine brightly when triggered and fade away after a few seconds. Second, I increased the stroke width, and allowed the trails to persist longer before fading, making everything brighter. And third, I wanted to create a sense of lasting

consequence for these dramatic motions, so I had ‘upJolt’ change the direction of the flow. Once it gets triggered, the sprites do a 180 and start moving from the bottom of the screens to the top; until downJolt gets triggered.

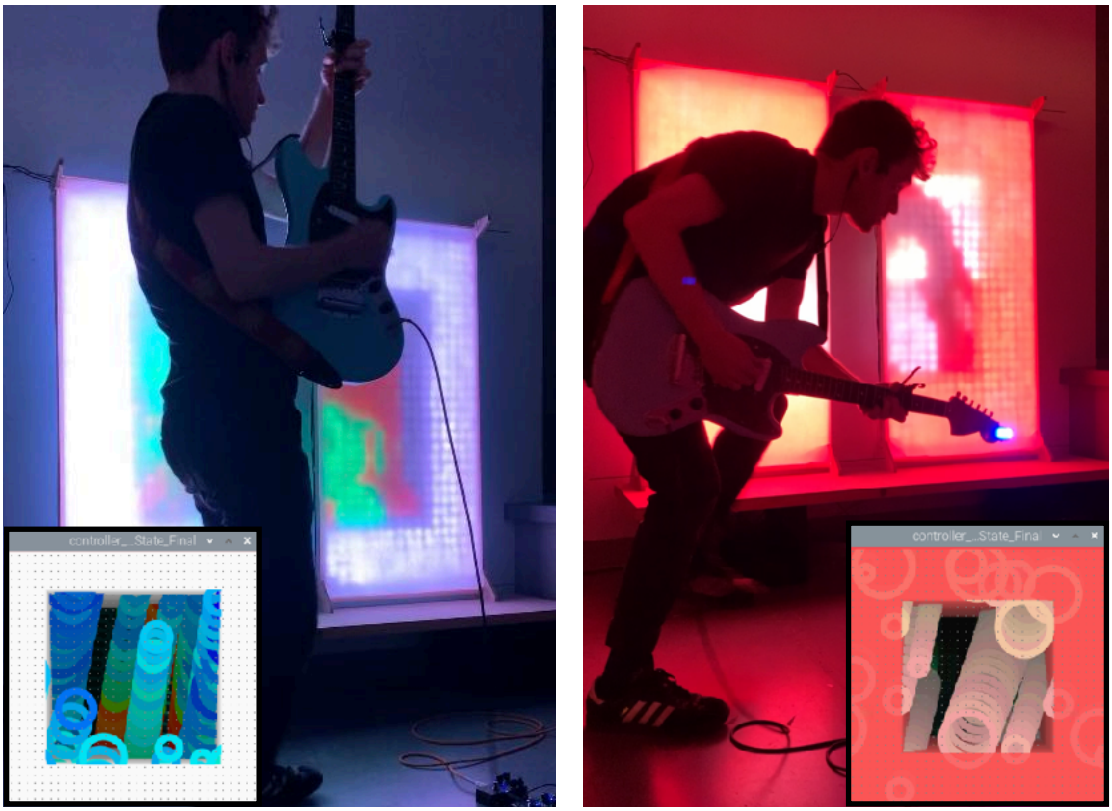

Fig 23. Jerky motions trigger dramatic effects

And that just about sums it up for this particular sketch, but the avenues of exploration for new sketches are vast. For example, off the top of my head - filtered video footage, kinetic typography, other kinds of mathematical algorithms, the possibilities are endless - the key is to understand the dynamics of the music you’re working with, and then playing around until you get something you like.

CHAPTER 5

TECHNICAL ISSUES

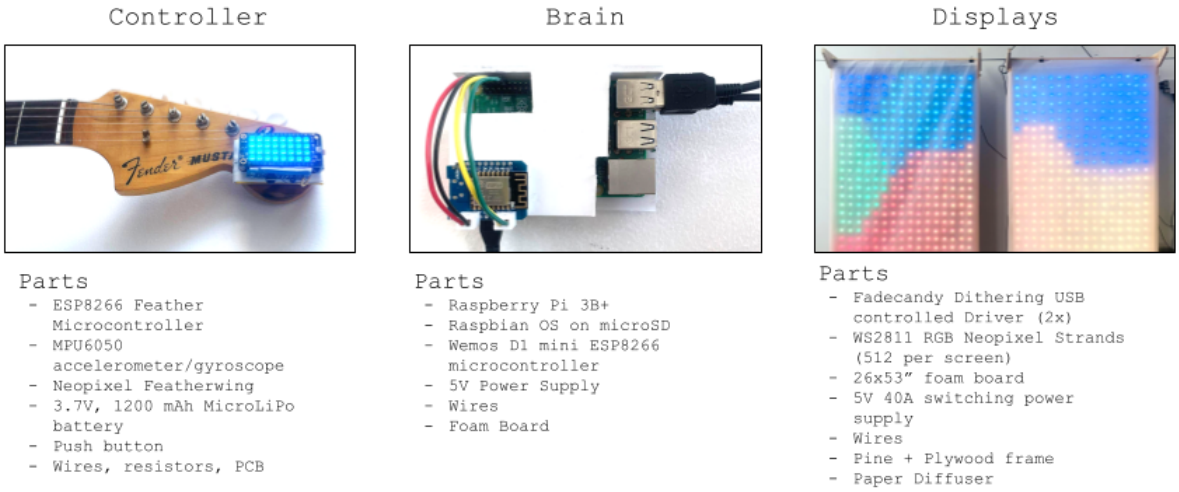

Fig 24. Parts List

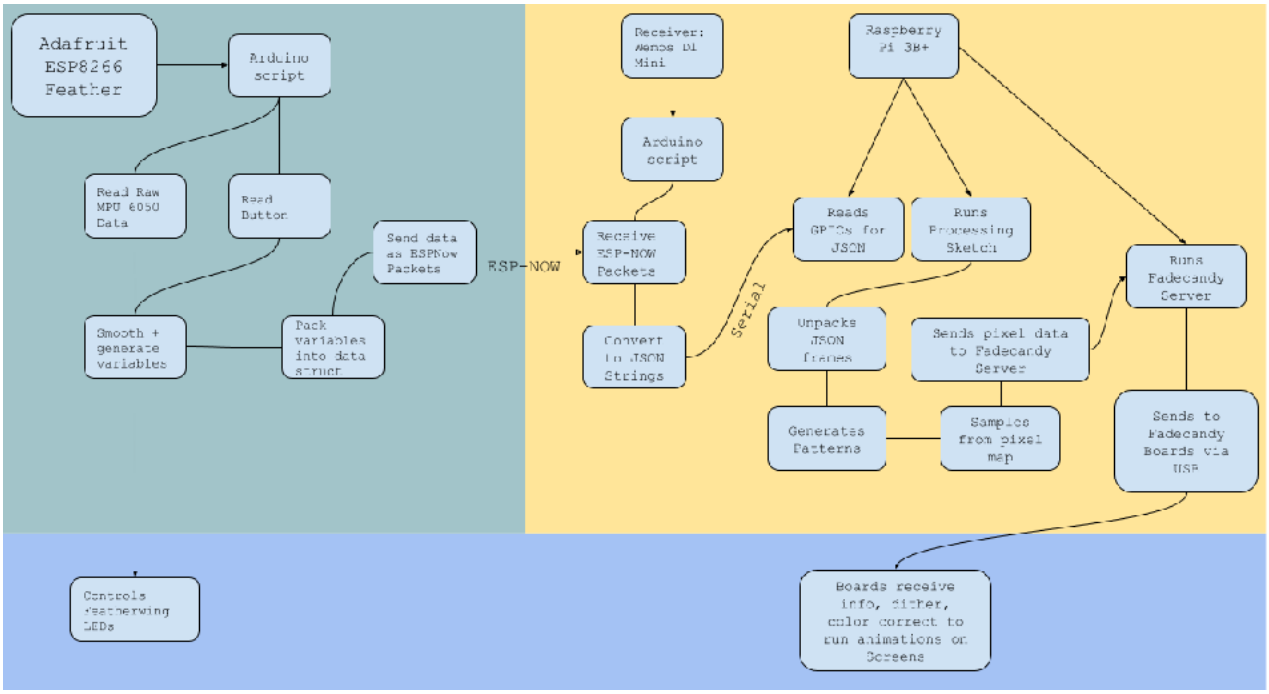

Fig 25. Data Flowchart

While I've gone into quite a bit of detail on the development of the Luminin 1.0, I haven't gone into as much detail about its constituent parts and what they do. In this chapter I'm going to break things apart into three main areas—the controller, the brain, and the screens—and discuss how each part works. Figure 23 provides a list of constituent parts, and Figure 24 looks data structure of the system as a whole. Feel free to refer back to these as you peruse the next section.

CONTROLLER

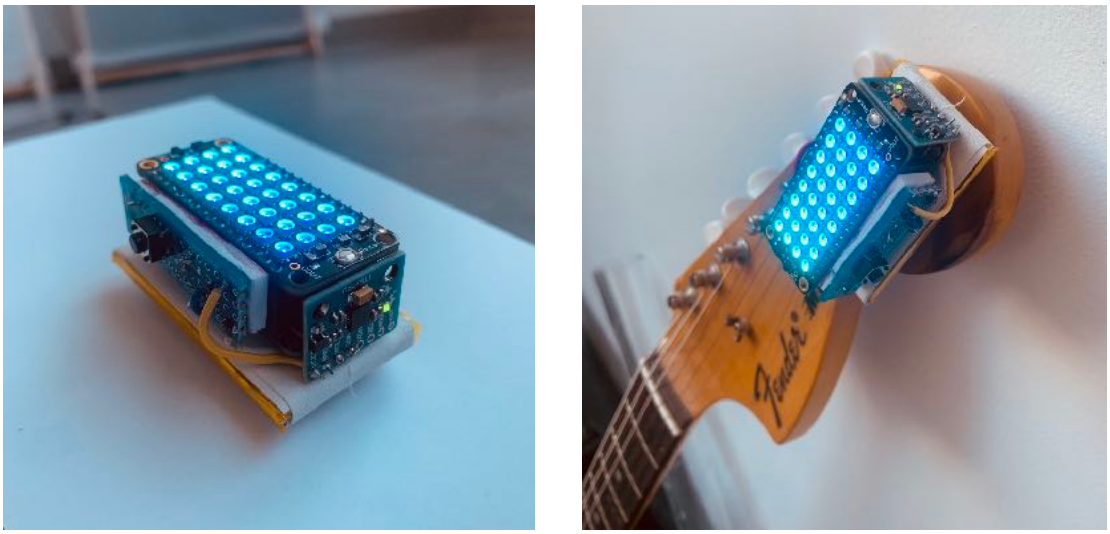

Fig 26. Controller

The Controller consists of Adafruit's ESP8266 based "Huzzah" Feather microcontroller, a MPU6050 accelerometer/gyroscope, an 8x4 RGB LED "Featherwing" hat, a pushbutton, a 3.7V microLiPo 1200 mAh battery, and various wires, protoboards, resistors, and little doodads required to assemble it all. The microcontroller runs an Arduino script which does the following:

1. Gets data from the MPU6050 and the button.
2. Smooths accel and gyro input through linear interpolation, debounces data from the button.
3. Calculates a series of different kinds of useful variables. Some variable, like xTilt and lerpedGyroX, are extrapolated directly from the sensor. Others, like downJolt and vibes, define more complex motions.
4. The variables are packed and sent to the Brain using the ESP-NOW data protocol: a lightweight and very stable method for sending data packets between ESP modules without having to worry about connecting to a router.
5. Sends signals its onboard LED matrix.

The MPU6050 is a very useful and interesting sensor. Often used to control drones and other vehicles that need to understand their orientation, it measures acceleration and gyroscope data along three axes.

These data need to be cross-referenced in order to begin interpreting motion on a larger scale. The accelerometer is a device which measures acceleration through the piezo-electric effect. It's very good at ascertaining the direction in which the sensor is tilted relative

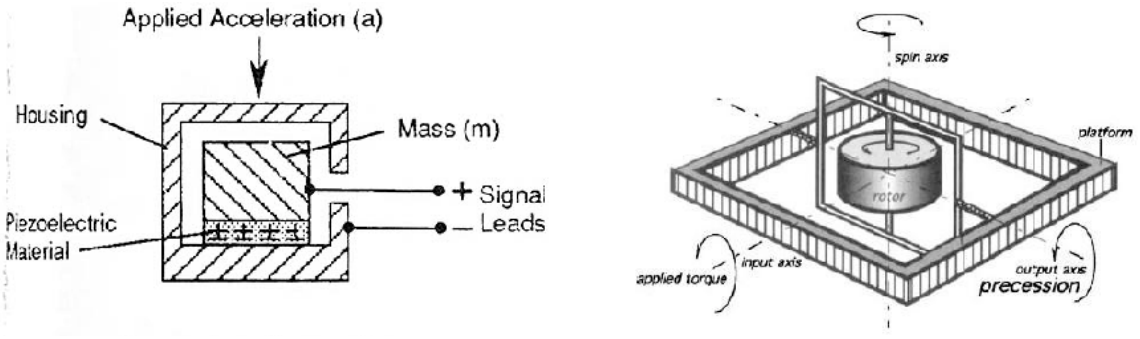

Fig 27. Accelerometer (left), Gyroscope (right)

to the earth because the Earth always exerts a 9.8 m/s^2 downwards acceleration on it. However, it isn't particularly good at picking up large movements.

The gyroscope is much better at picking up those large movements, however, it is constantly drifting. In addition, both sensors are strongly effected by the vibrations of instrument, which throws quite a bit of noise into your data. But by smoothing and cross referencing both inputs it becomes possible to generate meaningful data out of the motion exerted on the sensor. In theory.

In reality, this took quite a lot of experimentation. The serial Plotter in Arduino was a very useful tool in helping me visualize what was going on. Below are a couple of examples of visualized motion in Arduino.

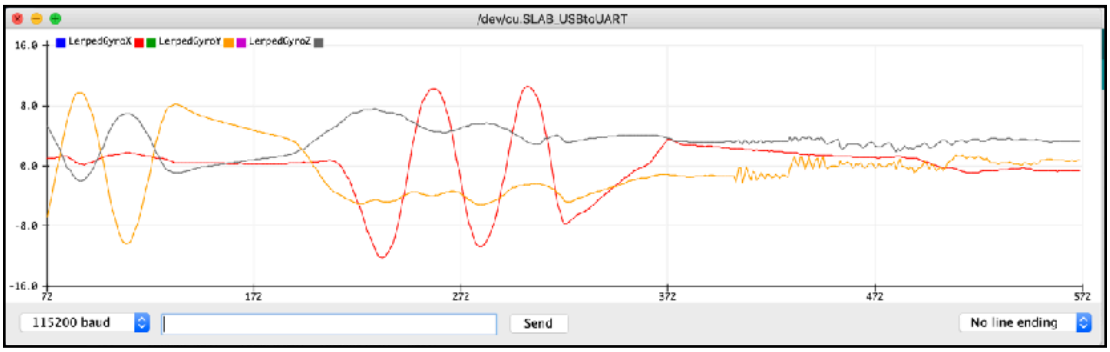

Fig 28. Gyroscope data across 3 axes. Up/down motions the left, back/forwards swinging motions in the middle, on the right vibrations from a chord

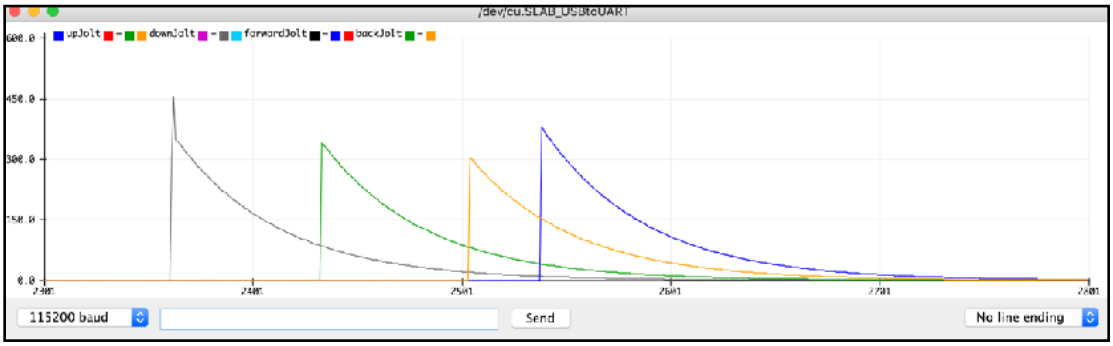

Fig 29. These 'jolt' curves are created by latching a strong deliberate directional motion and fading it over time. Useful for preventing accidental activation of a deliberate effect.

The button was an important element that I added recently. I'm using it to flick between modes in Processing, which will allow me to switch up the visuals between songs.

BRAIN

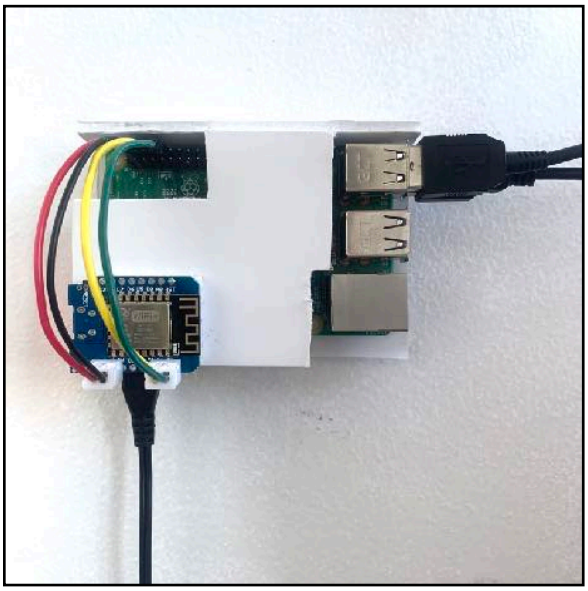

Fig 30. Luminin 'Brain'

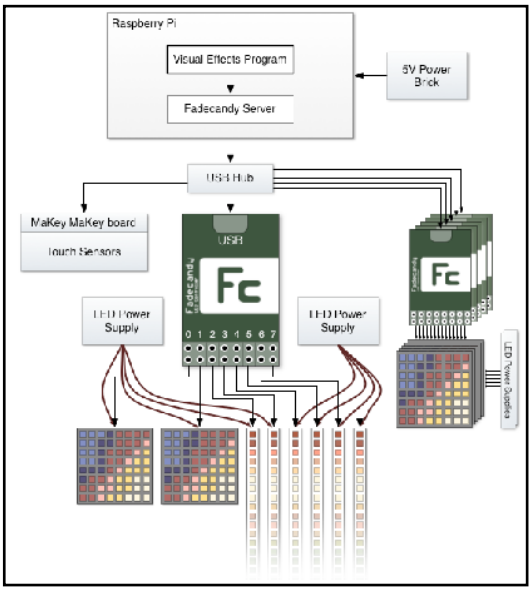

Fig 31. Fadecandy server flowchart [7]

The "brain" of this device is built around a Raspberry Pi 3+. The Pi receives data from the controller through a serial connection with another ESP8266 microcontroller, the Wemos d1 Mini. This microcontroller is programmed to act as a kind of relay, receiving data packets from the receiver (over the air through ESP-Now wireless protocol), packing them into them to JSON strings, and sending them on to the Pi. The Pi then executes two main functions: It sets up the Fadecandy server, and it runs the relevant Processing sketch. The Fadecandy server then outputs data to the outboard microcontrollers that run the displays.

DISPLAYS

The displays are 26x54-inch hand-built LED screens. They contain 512 addressable “Neopixel” LEDs, assembled in a 16x32 array and painstakingly fitted and glued into holes I drilled into a foam board. Each display is controlled by a Fadecandy board (designed by Scanlime, sold by Adafruit). Using the Teensy 3.0 microcontroller as a base, each board comes preloaded with firmware that interprets data from the server and sends this data to each individual LED in the display.

The frames I built from pine and the corners/stands I cut out of plywood on a CNC machine. I designed these with corner slots that enable you to hang sheets of paper from them. The resulting structure is stable enough that I would feel comfortable using it at a venue without worrying about it falling down.

Each display with its 512 LEDs, draws an absolute maximum 30.72 amps, if every LED is set to white at its maximum brightness. I prevented this from occurring in the server code and decided to power both screens together with a single 5V 40A switching power supply, which works adequately.

I had originally intended to build a more distributed system where each display could receive its data wirelessly from the brain, thus making the set up much easier and more akin to the early, hard to control versions discussed earlier. I ran out of time to implement this idea however.

Finally, a quick aside for future reference: as of 2021, Fadecandy is an old and deprecated LED driver which hasn’t been actively updated in several years. Each board can only run 512 LEDs of a specific kind of LED (RGB “Neopixels”), and they have to be broken up and driven through 8 individual ports 64 LEDs per port. However, other systems are actively being developed at the moment which I may turn to for future designs. One that I have

a particular interest in is called the “PixelBlaze.” I used this in some early experiments but abandoned it as it lacked the ability to integrate Processing and other similar programs, but this seems to have changed in the last month, so I may return to it in the future.

CONCLUSION

Well. Here we are. It's been quite a 3 year journey and looking back I can't quite believe how much progress I've made, and how much I've learned in the process. I tend to move the goal-posts on myself, but I set out wanting to create a lighting system that I could control from the stage, - I think that goal has absolutely been accomplished.

Do I trust that it won't break down right before my set? Probably not. Is it developed to the point where other people, (people who don't have the privilege of spending 3 years in an interactive art graduate program), could easily build on it? No. I think solving all of these issues might end up requiring collaboration with some experienced software developers and industrial designers. Despite this, however, it's hard to over-emphasize how much potential this project has demonstrated - especially in the last month or so, once the structure of the current iteration had been finalized. And actually, let's forget potential - this thing is fun as hell already.

Hopefully, one day soon, as the pandemic ends and we can all start going to shows again, you'll be able to catch me and my band playing a set, with the Luminin 1. 0 in the background, making everyone go 'ooooooh' and 'aaahhhhh' until they forget about the elements and lose themselves in the show.

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