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Blending Modes: Learning Digital Synthesizer Technology to Create an Instrument for an Improvised Performance with Audio Reactive Visuals

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Abstract

For my creative project, I created a digital synthesizer with audio-reactive visuals in the program Max. I learned the core components of a digital synthesizer and how they worked as well as the methods of creating reactive visuals. I implemented what I had learned to create a bespoke instrument made for improvisational performance. The goal was to create a synthesizer that had enough control outside of the mouse and keyboard such that it felt as comfortable as a non-digital instrument. In addition to synthesizing music, I also wanted to synthesize visuals that would be reactive to the music.

Introduction

If I had to sum up my creativity in one word, it would be “experimental”. Experimental describes both my scientific approach to my projects and the genre of music I wanted to pursue for this project. When I take on a creative venture, whether it be music, art, movies, etc., I tend to treat it like a study. What motivates and excites me is trying something new and working at it until I succeed. I have a burning desire to research and try new ideas until I understand a concept. This desire to learn through experimentation is what pushed me towards synthesizers for my thesis project. I would be constantly learning new things and solving problems while creating an instrument that is unique to me.

I have loved music for as far back as I can remember. From playing instruments as a kid, to high school when I bought a home recording setup and software to start making music electronically, to now in college where I am studying to become a professional music producer. Music production has a lot of overlaps with sciences like physics or engineering. I enjoy the serendipity that comes with music production and audio engineering. I have learned about physics, electrical engineering, psychoacoustics, and phonology while studying how to become a better audio engineer. Additionally, needing to approach making music from a more scientific perspective satisfied a long-standing desire I have had to understand why music and art behave like they do.

One substantial change in my academic and creative outlook came after watching a video from Freya Holmèr on YouTube (Holmér). In her video, Holmér explains and demonstrates how she makes shaders for video games. She shows how to use math to create the art for her games because colors can be represented with numbers you can manipulate with math. This made a new connection in my brain that flipped how I approached art and subsequently music. I was treating art as a magical thing that can be attempted to be explained with science- but in reality, art was science all along. And similarly, science was art all along. This way of approaching art in an interdisciplinary way helped a lot of things click into place. The video was also presented very well with good graphics to demonstrate her points. But I realized those graphics were also math, the same math she was using with colors, so she was able to use her math and art to communicate her ideas. Math, art, communication, and the interplay between them became especially important to me from that point onward.

My thesis is the culmination of my explorations into music, art, and science. I have three goals for this project. The first goal is to make a versatile digital synthesizer in software Max. The second goal will be to create interactive visual elements for the synthesizer using the Jitter side of Max. The third goal is to incorporate various midi controllers to reduce the need for a mouse and keyboard as much as possible. When completed, I will put on an improvised performance of my synth with accompanying audio-reactive visuals.

Literature Review

I grew up during a time when synthesizers (commonly referred to as ‘synths’) were already so mainstream in pop music that I did not take notice of their use. The first time I remember hearing a synthesizer was when I would play retro video games. I loved the 8-bit soundtracks of games like *Super Mario Bros.* and *Kirby’s Dreamland*. After becoming more interested in synthesizers I started to look to Teenage Engineering’s OP-1 and Korg’s Microkorg as synths I aspired to own. Years later as I began my journey in music production I had access to virtual synthesizers in the form of software plugins. I have found that the more I have learned about synthesizers the more questions I have about their mechanics and operations. In my opinion, synthesizers have become one of the most important and complex instruments used in music (despite its relatively brief time incorporated into music). In this essay, I will explore the history of synthesizers along with questions such as, “What were the cutting-edge synthesizers that influenced modern-day synths?”, “What were the techniques that synth makers implemented?”, and “What is the lasting impact of synthesizers on the music industry?” I hope by learning this history I can better understand what makes a quality synthesizer for my thesis project.

Early Developments. There were a few instruments that had key functions that later integrated into synthesizers. By exploring these inventions one can understand how modern-day synths came to be and what technologies one may include when creating a synthesizer. The first of these instruments is the theremin. A theremin consists of two radio tubes. The pitch and volume are controlled by moving one’s hands closer or further from the tubes. “The ability to amplify, and the principle of taking difference tones from ultra-high-frequency signals (called heterodyning) inspired Léon Termen to develop the Theremin in 1922” (Hass). Another significant instrument was the Telharmonium, invented in 1897 by Thaddeus Cahill. “The Telharmonium can be considered the first significant electronic musical instrument and was a method of electro-magnetically synthesizing and distributing music over the new telephone networks of Victorian America” (Crab). I find the Telharmonium interesting because Cahill designed it for the purpose of sharing music with people. It also started the trend in which innovators use technological advancements to create new instruments.

Before diving into what many would consider conventional synthesizers, I would like to highlight the RCA Mark I. This was the “missing link” between synthesizers and their predecessors. RCA wanted to create an instrument that could record a part in one take without error. “The resulting RCA Mark I machine was a monstrous collection of modular components that took up a whole room at Columbia University’s Computer Music Center (then known as the Columbia-Princeton Electronic Music Center). The ‘instrument’ was basically an analogue computer; the only input to the machine was a typewriter-style keyboard where the musician wrote a score in a type of binary code” (Crab). Despite its size, Harry Olson and Hebart Belar created a machine with the components that would lay the groundwork for what a synthesizer would be.

Analog Synthesizer Era. Analog synthesizers were about to take the world by storm, and it was largely due to Robert Moog. He would pioneer consumer synthesizers, and his company Moog continues to make some of the best synthesizers available. Crab says, “The first instrument, the Moog Modular Synthesizer, produced in 1964 became the first widely used electronic music synthesizer and the first instrument to make the crossover from avant-garde to popular music” (Crab). Moog’s synthesizers also set forth precedents that modern-day synths still follow. Crab says, “Moog’s designs set a standard for future commercial electronic musical instruments with innovations such as the 1 volt per octave CV control that became an industry standard and pulse triggering signals for connecting and synchronizing multiple components and modules” (Crab). “Incorporating different components such as Voltage Controlled Oscillators (VCOs) and noise generators, Moog became one of the pioneers of analog synthesizers” (“The Origins of the Synthesizer”) Mark Vail concurs. Synthesizers from this era are still highly sought after by musicians. “Analog synthesizers became known and adored for their characteristic warbling pitch. The sounds were both futuristic and quaint” (“The Origins of the Synthesizer”). While I love the sound produced by analog synthesizers, there are significant barriers to entry with these synthesizers. Between the cost of parts, electronics background needed, and size, there are a lot of reasons I did not make an analog synthesizer. However, the signal flow of analog synthesizers is important in understanding how any synthesizer operates. Whether a synthesizer is analog or digital, a signal is created by the synth and then manipulated by filters, envelopes, and LFOs to create a new signal. Understanding how analog synthesizers work often helped me implement features in my digital synthesizer.

Digital Revolution. The 1980s was a decade filled with cultural and technological advancements, and no other invention screams the 80s like digital synthesizers. The king of digital synthesizers at the time was the Yamaha DX7. “Polyphonic analog synths such as the Sequential Circuits Prophet-5 ruled the roost at the time, but the DX7 shattered all previous synth-sales records and offered a powerful new form of digital synthesis—linear frequency modulation (FM)—at a price many players could afford. Together with digital samplers, the digital synths including the DX7 practically buried interest in analog synthesis for nearly a decade” (Vail). It is hard to state how big of a legacy the DX7 has. It is used in everything from the *Twin Peaks* television show theme to the *Mario 64* video game soundtrack, to a-ha's song "Take on Me". It is inspirational how this synthesizer has seen so much use in different genres. Similarly to previous synthesizers, the DX7 could not have existed without the technological advances of the digital age. "… the Yamaha DX7 is still the main staple of many electronic musicians and their studios, though the technology has been expanded on time and again since then. As the digital revolution affected just about everything from photography to clockwork to sound design, soft-synths were born" ("The Origins of the Synthesizer").

While this next synthesizer does not have the impact that the DX7 had, the Fairlight Computer Musical Instrument or CMI brought innovations that were ahead of its time. "The CMI I featured a 73-note keyboard, a central unit with two 8″ floppy disk players, an alphanumeric keyboard, monochrome monitor, a light pen and ran using their proprietary QDOS operating system, a variant of the MDOS Motorola system" (Crab). Its workflow is similar to today's Digital Audio Workstations, so it makes sense why this synthesizer appealed to pop producers at the time. Vail lists some of the best producers of the time used the Fairlight CMI, "However, the original Fairlight Computer Musical Instrument (CMI), which included additive synthesis capabilities and first appeared in 1979, certainly proved adequate for Stevie Wonder, Kate Bush, Jan Hammer, Peter Gabriel, Mike Oldfield, Thomas Dolby, Jean-Michel Jarre, Keith Emerson, and many others who made it a centerpiece in their studios" (Vail). The Fairlight is very inspiring to me and paved the way for my synthesizer and all other computer powered synths.

Early Computer Music. To begin discussing the development of computer music is to talk about Max Matthews. In 1957 Matthews developed *MUSIC I* while he was an engineer at AT&T Bell Laboratories. This program could only produce crude in its abilities. It could play back a sequence of programmed pitches and volume over time as a single, monophonic triangle wave. But *MUSIC I* was just the start of Matthews' contributions to computer music. "Not only were MUSIC (or *MUSIC I,* as it was later referred to) and its early descendants the first music programming languages widely adopted by researchers and composers they also introduced several key concepts and ideas which still directly influence languages and systems today" (Collins and Escrivan). In 1958, Matthew developed *MUSIC II* which added more functionality like the ability to program up to four voices. *MUSIC III*, developed in 1960, came with one of the most significant concepts to computer music, Unit generators or Ugens for short. Unit generators are "small, modular programs for generating sound and could be combined and driven using text commands to build instruments that could be stored. These programs could define parameters such as control rates and audio rates for sound generators" (Holmes). An example of an Ugen would be an oscillator or filter. One of the limitations of the hardware at the time was the long processing time required for *MUSIC N (*referring to *MUSIC I* and its descendants). A two-minute-long piece could take upwards of nine hours to process. The goal of decreasing the processing time of these programs is what ushered in the next wave of progress in computer music known as realtime systems.

In 1969, France founded IRCAM (Institut de Recherche et Coordinantion Acoustique/Musique or Institute for Research and Coordination in Acoustics/Music) to research computer applications in the arts. It was at IRCAM where Miller Puckette implemented the first version of Patcher, the program that would later evolve into Max/MSP.

> Miller S. Puckette implemented the first version of Max (when it was called Patcher) at IRCAM in Paris in the mid-1980s as a programming environment for making interactive computer music. At this stage, the program did not generate or process audio samples; its primary purpose was to provide a graphical representation for routing and manipulating signals for controlling external sound synthesis workstations in realtime. Eventually, Max evolved at IRCAM to take advantage of DSP (digital signal processing) hardware on NeXT computers (as Max/FTS, FTS stands for 'faster than sound'), and it was released as a commercial product by Opcode Systems in 1990 as Max/Opcode. In 1996, Puckette released a completely redesigned and open-source environment called Pure Data, or Pd for short (Puckette 1996). At the time, Pure Data processed audio data whereas Max was primarily designed for control (MIDI), Pd's audio signal processing capabilities then made their way into Max as a major add-on called MSP (MSP either stands for Max Signal Processing or for Miller S. Puckette, authored by Dave Zicarelli. Cycling 74, Zicarelli's company, distributes the current commercial version of Max/MSP. (Collins and Escrivan)

Today Max/MSP is widely used by musicians, composers, and multimedia artists.

> Composers who dabble in programming their own audio-processing routines often use Max/MSP to control the performance of such routines. Being essentially designed for multitasking, Max/MSP can trigger audio-processing routines at the same time that it manages other aspects of a performance, such as the spatial distribution of sound to loudspeakers, the triggering of MIDI devices, and the multitrack recording of the outcome. The time needed to master an audio development environment such as Max/MSP can be daunting, just as learning any programming language. With the

> increased power of modern laptops, new avenues of exploration have opened up for creative artists. Using programs such as Max/MSP/Jitter it is now possible to have real-time control of video, use open GL to create 3D animations, employ FFTs to shape and convolve the spectrum of audio signals in real time, and use convolution reverbs that are digitally modeled spaces into which you can place your sound or performance. (Holmes)

Contemporary Trends. While not a new invention, many of today's synth enthusiasts make their own synths with eurorack modules. "A Eurorack modular synthesizer system containing modules from Synthesis Technology. Modular users can rearrange and swap in/out modules as they see fit" (Vail). Eurorack is infinitely customizable and personable, which makes it very appealing to hobbyists and professional musicians. Since manufacturers only need to design modules instead of an entire instrument, companies can sell unique and innovative modules with less risk compared to full synthesizers. Many of the most interesting ways to control a synthesizer that are commercially available come from eurorack. Some examples are modules that can be controlled with copper contacts or by light level. Another place where synthesizers are found and used today is in digital audio workstations like Ableton Live. "' Ableton Live was originally intended for DJs,' notes the synthesist and composer Gary Chang, 'but it has evolved into a much more extensive and creative tool. Together with [Cycling '74] Max for Live, it can record everything—audio and control data—and it will replicate any movements that you've made. We're after the gestures, not just the "freeze." We don't want snapshots; we're actually after capturing human information interactively.'" (Vail). Through VSTs (Virtual Studio Technology) or plugins that emulate retro synthesizers or built-in instruments, synthesizers have never been more accessible. Most of my experience with synthesizers before this project has been VST synthesizers and I've had positive experiences with them.

From festivals and dances, through opera, theatre and shadow plat, from Wagner's *Gesamtkunstwerk* (total artwork), to cinema and virtual reality, the arts have often confronted the problems and potential of engaging many human senses (modalities) at once" (Collins and Escrivan). What started as simple light shows in the '60s to enhance audience members' experience evolved into VJ's (video jockeys) and computer-generated visuals in today's club scenes. French film theorist and composer Michel Chion describes the effect of audio and visuals together as Synchresis. "Synchresis (a word I have forged by combining synchronism and synthesis) is the spontaneous and irresistible weld produced between a particular auditory phenomenon and visual phenomenon when they occur at the same time" (Chion et al.). "Certain experimental videos and films demonstrate that synchresis can even work out of thin air—that is, with images and sounds that strictly speaking have nothing to do with each other, forming monstrous yet inevitable and irresistible agglomerations in our perception" (Chion et al.). There are now many tools at one's disposal to create audio-visual works.

> There are contrasts of visual-only generators (packages like Arkaos V] or Motion Dive for example) and integrated environments for both audio and video signal networks (such as Max/MSP with Jitter or Pd with GEM). Many programs support intercommunication with other software via MIDI or network protocols like OSC, enabling a user to blend their favoured visual and audio packages. Indeed, a general multi-modal trend is evident in the audio field, as video support is becoming a standard in previously audio-only packages, from NRT media-composing software like Pro Tools or Logic, to live sequencers such as Ableton Live. (Collins and Escrivan)

I have used Jitter to create the visuals for my project. Cycling '74 describes Jitter as "an open-ended toolkit for patching video and graphics in Max. With Jitter you can extend your patches with added video, 3D graphics, effects, and more" (*Jitter - Visuals for Max*). Cycling '74 released Jitter in 2003 as an extension to Max that added real-time video capabilities. Now Jitter is a fully featured and integrated part of Max/MSP. The power of Jitter comes from its ease in communicating with existing Max Objects. It is easy to convert audio data into visual data and vise vera, all done in the same programming environment. Since I already planned on using Max/MSP for the audio side of the project, making the visuals in Jitter seemed the obvious option.

Impact on Music. Synthesizers have ushered in a new era of music. Not having synthesizers in modern music is often a sign of a stylistic choice like an "acoustic cover." But synthesizers may not have become so widely adopted if not for the efforts by one trailblazer. "We would probably not have heard of the Moog synthesizer at all if it had not been for Wendy Carlos, who laboriously assembled electronic music in the studio and produced the sensational album *Switched-On Bach* (1968)" (Pinch and Trocco). "The album topped the Billboard Classical Albums chart from 1969 to 1972 and inspired a pantheon of synthesizer albums, including *Switched-On Rock* by the Moog Machine, *Switched-On Country* by Rick Powell, Sy Mann's *Switched-On Santa*, and *Music to Moog* By Gershon Kingsley. In just six years, the album had sold more than one million copies. It later became the second classical album to be certified Platinum—and won Carlos three Grammy awards" ("Switched-On Bach: How the World Met Moog"). It has become a defining feature in genres of music and has led to the creation of brand-new genres. One genre that has been heavily influenced by the synthesizer is Hip-Hop. "If ever an instrument deserved credit as the catalyst of a music genre—in this case hip-hop—it would be the Akai MPC60. Turntable and scratch artists contributed in major ways, but the MPC60 clicked with hip-hop producers, as it did with those doing rap and R&B" (Vail). The Akai MPC60 is a synthesizer that can record short snippets of audio to then play back in a process called sampling. "The explosion of electronic music and hip-hop could not have happened without a machine as intimately connected to the creative process as the MPC. It challenged the notion of what a band can look like, or what it takes to be a successful musician. No longer does one need five capable musicians and instruments. And the fact that an MPC can sample music, chop it up, change the pitch, slow it down, and put it on loop, allowed lone musicians and producers to put together symphonic, experimental music relying only on the box, a few buttons, and 16 gray pads. No manual required" (Aciman). My synthesizer's drums work off of samples and step sequencers which in some ways mimic the functions of the MPC60.

Synthesizers have had a massive impact on music and musicians. "Rick Wakeman of Yes famously loved the MiniMoog – sometimes using 30 keyboards on stage at once – while Pink Floyd's 'Dark Side of the Moon' riff was made by a sequencer on the EMS VCS3 synth. Meanwhile, a 21-year-old Stevie Wonder - looking for new ways to make his music – met synth pioneers Tonto's Expanding Head Band in the early 70s, and it was the meeting of very different musical minds. *On The Great Bleep Forward*, Malcolm Cecil, one half of the duo, revealed: 'Once we introduced [Wonder] to the synthesizer it was like the tapping of a well – all these songs would come flowing right out of him'" (Finamore). The sound of '80s synthesizers are still captivating for modern-day audiences. "Blinding Lights" by The Weekend is built almost entirely of retro-sounding synthesizers and it is the most streamed song on Spotify and number one on Billboard's Greatest of All Time Hot 100 Songs list ("Greatest of All Time Hot 100 Songs").

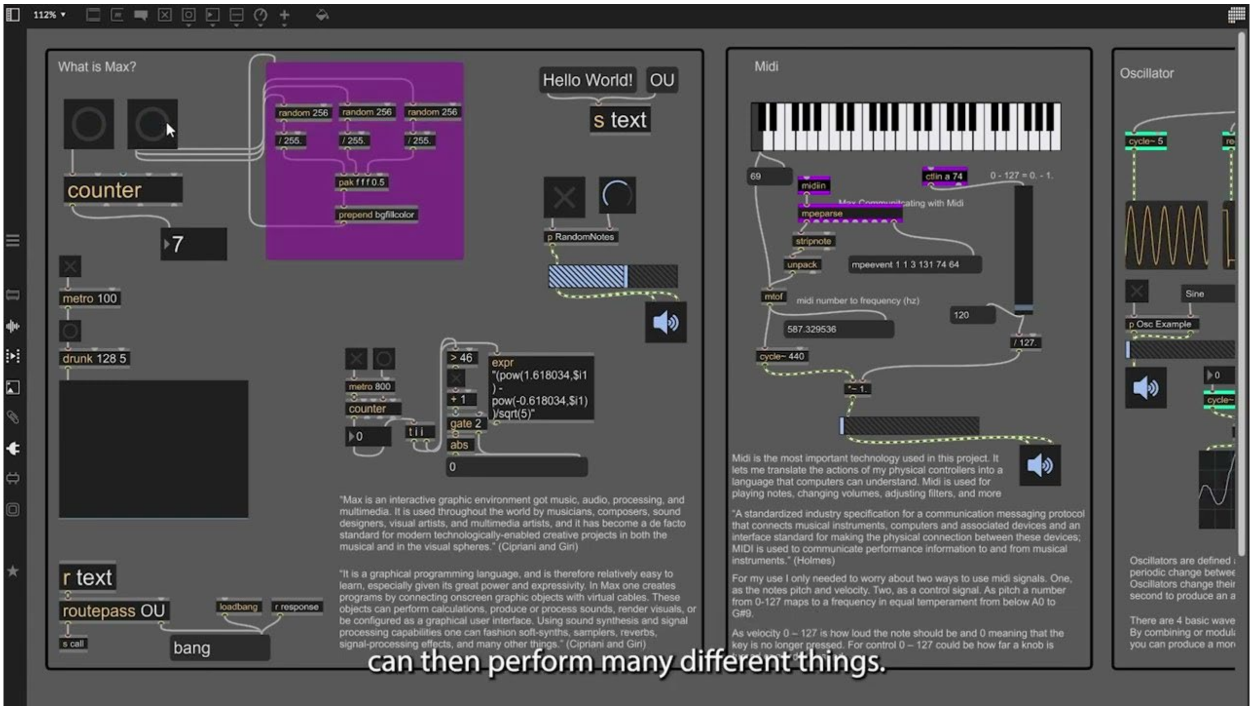
Synthesizers have played a significant role in Movie and TV soundtracks. Finamore says, "Oram and Derbyshire revolutionized TV soundtracks with the use of synths, and the instrumental continues to be vital for film and television scores today. The original *Star Trek* theme featured the Ondes Martenot – whose eerie sound is often mistaken for a woman's voice – and synths have been used to create atmospheric themes for shows like *Knight Rider*, *Twin Peaks* and, more recently, *Stranger Things*" (Finamore). The big screen has also harnessed the power of synths. In the '70s and '80s, compelling synth sounds were used to score everything from sci-fis and thrillers to horror films, such as *A Clockwork Orange*, *Apocalypse Now*, *The Fog* and *Manhunter*. In recent times, Cliff Martinez used synths to bring a dark ambience to *Drive* and *Solaris*" (Finamore).

Process

The goal of this project is to create a synthesizer and integrate audio reactive visuals. When deciding what method to use, the first question was whether to make an analog or digital synthesizer. While making an analog synthesizer would be interesting there are quite a few hurdles that method presents. The first hurdle would be price since the parts for analog synthesizers can cost hundreds of dollars. The second hurdle would be how unforgiving mistakes are. It is a lot easier to roll back a version of software instead of ordering replacement parts and waiting for them to arrive in order to continue. So, making a digital synthesizer seemed like the way to go. The next question to answer was," What program should I use?" The biggest barrier to entry for me was my lack of coding experience. But I do have experience in graphical programming environments such as Blender. Max/MSP uses a graphical programming environment, has great documentation and decades of helpful forum posts, and it includes Jitter for the creation of visuals. But most importantly, Dr. Robert McClure, the Ohio University Associate Professor of Music Composition/Theory, teaches Max/MSP which made him an invaluable in-person resource.

The first semester working on this project was guided by the instructions in Alessandro Cipriani and Maurizio Giri's *Electronic music and sound design* volumes 1 through 3. It provided a great foundation of understanding on many concepts that I would use, and it also gave me starting points to work from for different patches that I would implement. Below I have recordings of the key concepts that make up the synthesizer that I created. Below you will find any text that I included in these videos to help with legibility.

What is Max?

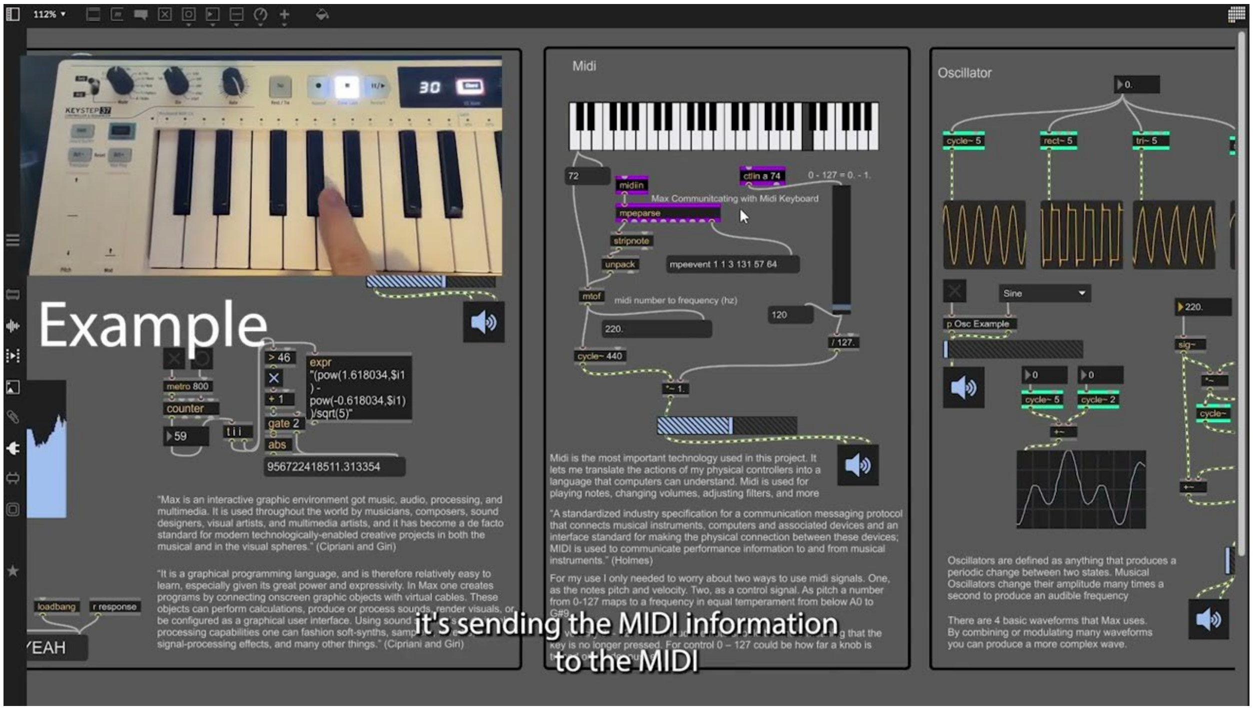


https://youtu.be/fqgZZteh6bM

“Max is an interactive graphic environment got music, audio, processing, and multimedia. It is used throughout the world by musicians, composers, sound designers, visual artists, and multimedia artists, and it has become a de facto standard for modern technologically enabled creative projects in both the musical and in the visual spheres” (Cipriani and Giri).

“It is a graphical programming language, and is therefore relatively easy to learn, especially given its great power and expressivity. In Max one creates programs by connecting onscreen graphic objects with virtual cables. These objects can perform calculations, produce or process sounds, render visuals, or be configured as a graphical user interface. Using sound synthesis and signal processing capabilities one can fashion soft-synths, samplers, reverbs, signal-processing effects, and many other things" (Cipriani and Giri).

Midi



https://youtu.be/sxyKeyetlBY

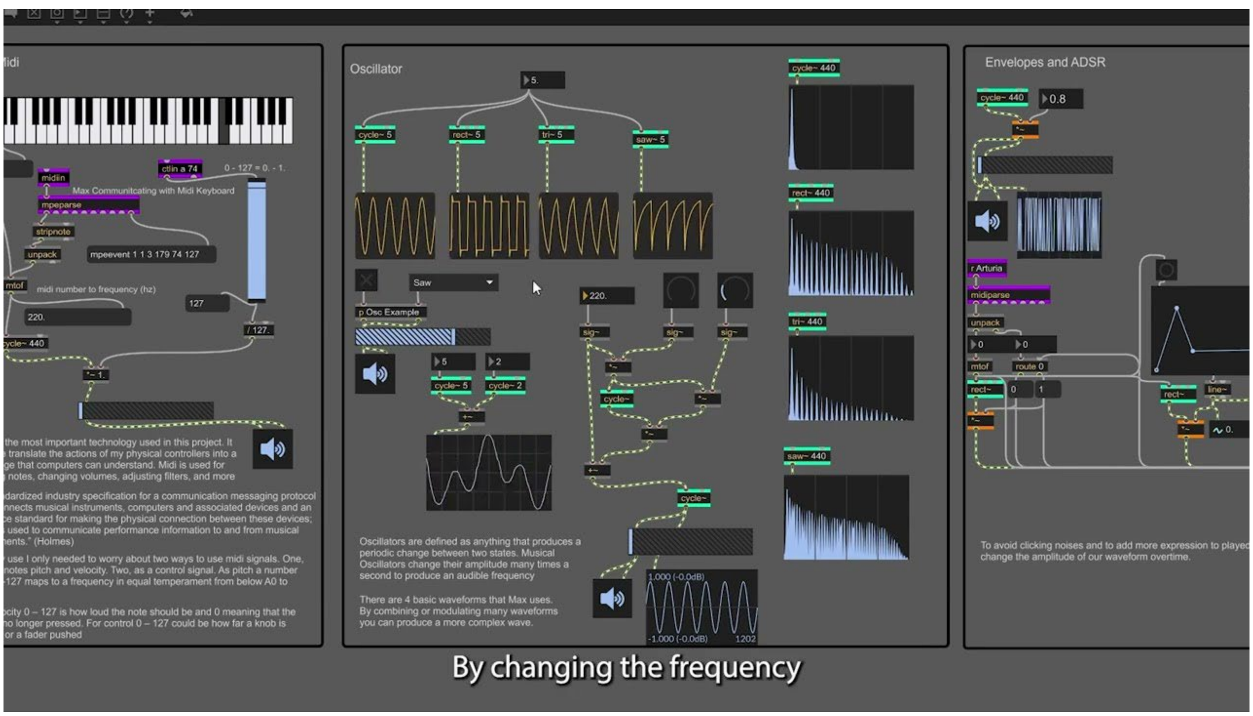
Midi is the most important technology used in this project. It lets me translate the actions of my physical controllers into a language that computers can understand. Midi is used for playing notes, changing volumes, adjusting filters, and more.

"A standardized industry specification for a communication messaging protocol that connects musical instruments, computers and associated devices and an interface standard for making the physical connection between these devices; MIDI is used to communicate performance information to and from musical instruments" (Holmes).

For my use I only needed to worry about two ways to use midi signals. One, as the notes pitch and velocity. Two, as a control signal. As pitch a number from 0-127 maps to a frequency in equal temperament from below A0 to G#9.

As velocity 0 – 127 is how loud the note should be and 0 meaning that the key is no longer pressed. For control 0 – 127 could be how far a knob is turned or a fader pushed.

Oscillator

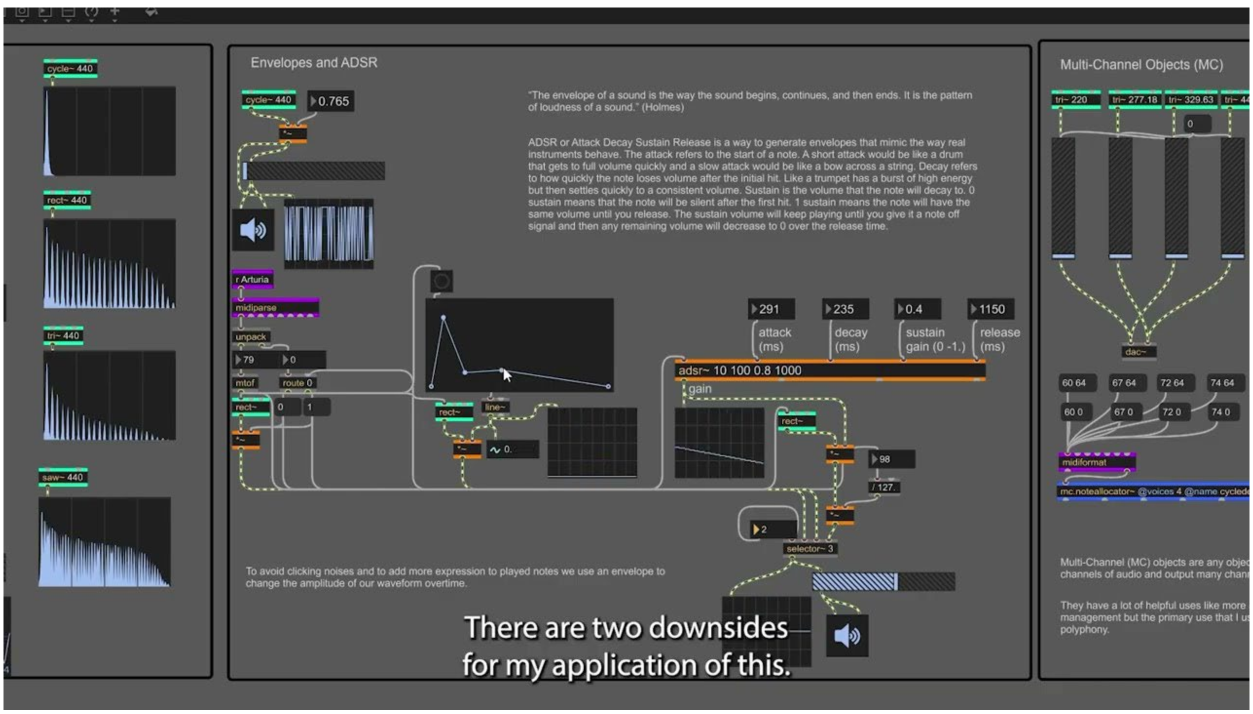


https://youtu.be/ZLunSVSHo50

Oscillators are defined as anything that produces a periodic change between two states. Musical Oscillators change their amplitude many times a second to produce an audible frequency.

There are 4 basic waveforms that Max uses. By combining or modulating many waveforms you can produce a more complex wave.

Envelopes and ADSR



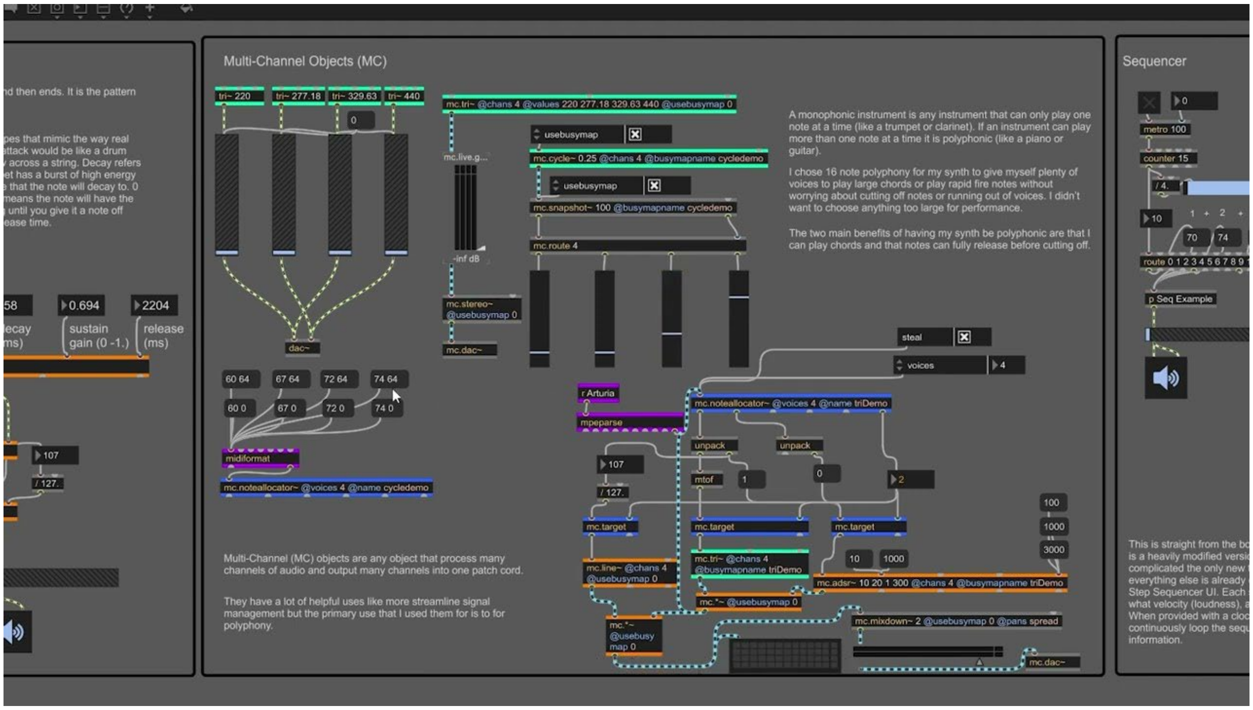
https://youtu.be/lZOvz2Gv27g

“The envelope of a sound is the way the sound begins, continues, and then ends. It is the pattern of loudness of a sound” (Holmes).

ADSR or Attack Decay Sustain Release is a way to generate envelopes that mimic the way real instruments behave. The attack refers to the start of a note. A short attack would be like a drum that gets to full volume quickly and a slow attack would be like a bow across a string. Decay refers to how quickly the note loses volume after the initial hit. Like a trumpet has a burst of high energy but then settles quickly to a consistent volume. Sustain is the volume that the note will decay to 0 sustain means that the note will be silent after the first hit. 1 sustain means the note will have the same volume until you release. The sustain volume will keep playing until you give it a note off signal and then any remaining volume will decrease to 0 over the release time.

We use an envelope to change the amplitude of our waveform over time, to avoid clicking noises, and to add more expression to played notes.

Multi-Channel Objects (MC)



https://youtu.be/G2S47JaRbVk

Multi-Channel (MC) objects are any object that processes many channels of audio and outputs many channels into one patch cord.

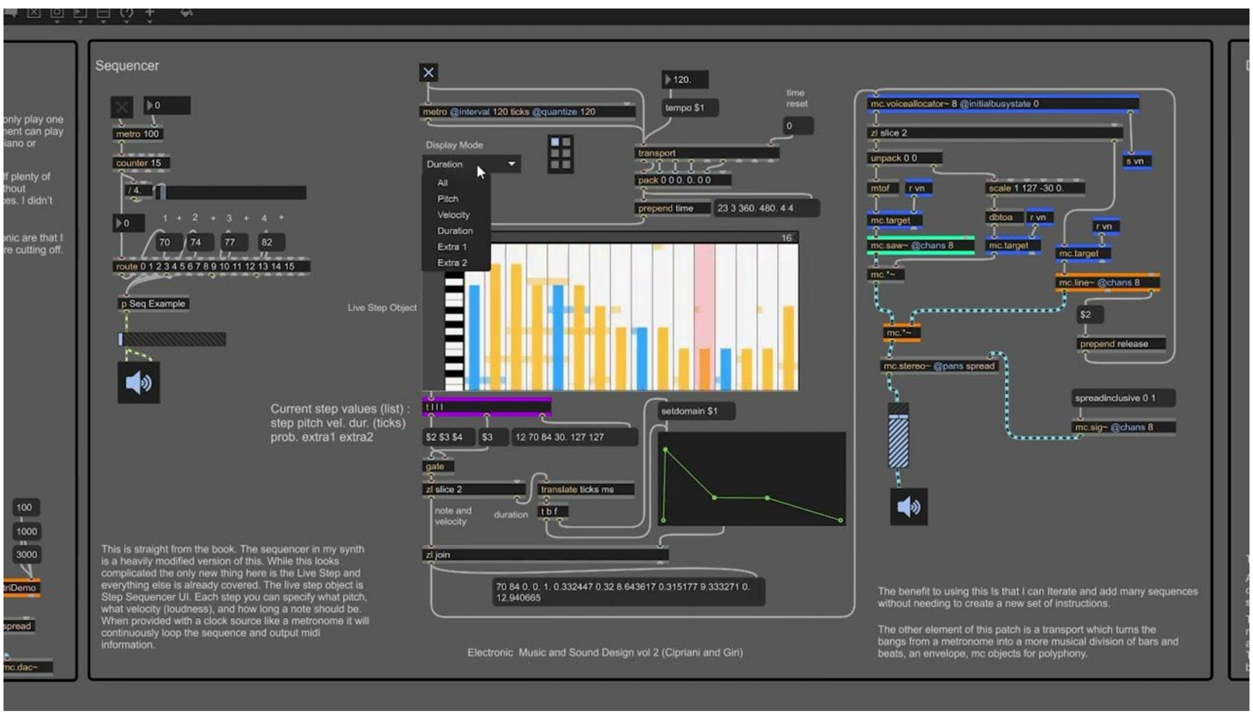
They have a lot of helpful uses like more streamline signal management but the primary use that I used them for is to for polyphony.

A monophonic instrument is any instrument that can only play one note at a time (like a trumpet or a clarinet). If an instrument can play more than one note at a time it is polyphonic (like a piano or a guitar).

I chose 16 note polyphony for my synth to give myself plenty of voices to play large chords or play rapid fire notes without worrying about cutting off notes or running out of voices. I didn't want to choose anything too large for performance.

The two main benefits of having my synth be polyphonic are that I can play chords and that notes can fully release before cutting off.

Sequencer



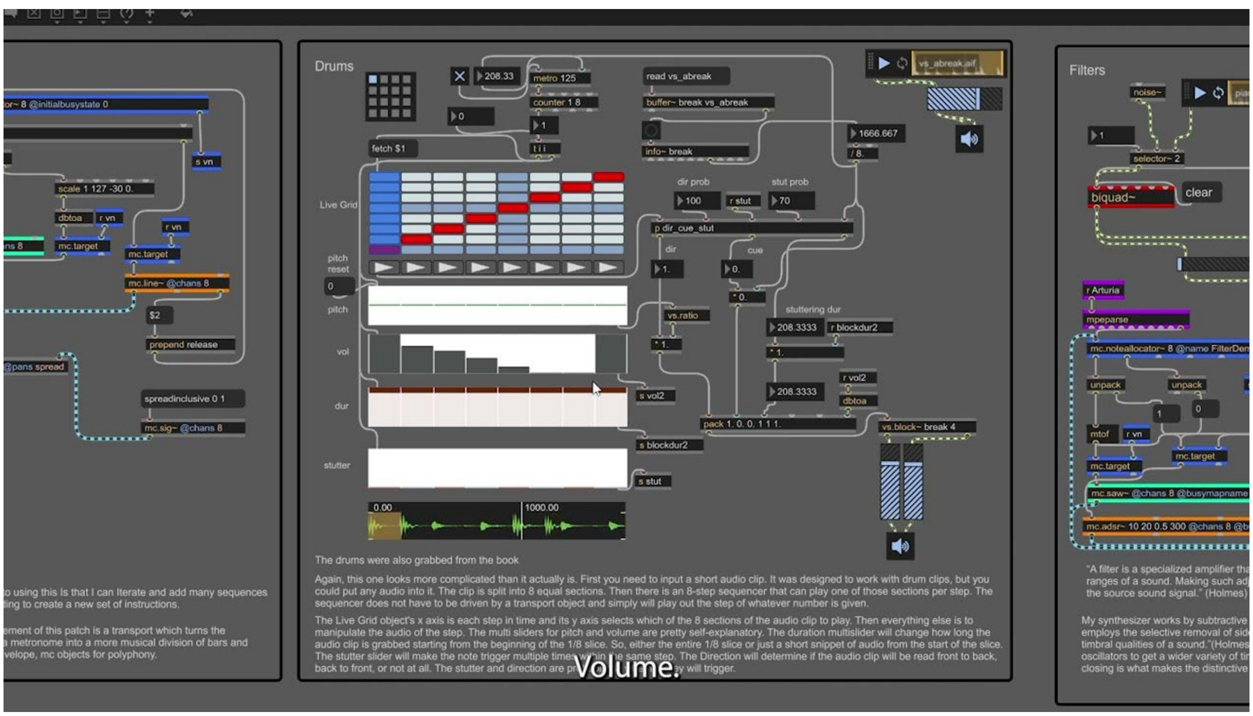
https://youtu.be/mUReVtZCwPw

These objects are straight from the book (*Electronic music and sound design* volume 2). The sequencer in my synth is a heavily modified version of this. While this looks complicated the only new thing here is the Live Step and everything else is already covered. The live step object is Step Sequencer user interface. Each step you can specify what pitch, what velocity (loudness), and how long a note should be. When provided with a clock source like a metronome it will continuously loop the sequence and output midi information.

The benefit to using this is that I can iterate and add many sequences without needing to create a new set of instructions.

The other element of this patch is a transport which turns the bangs from a metronome into a more musical division of bars and beats, an envelope, and MC objects for polyphony.

Drums



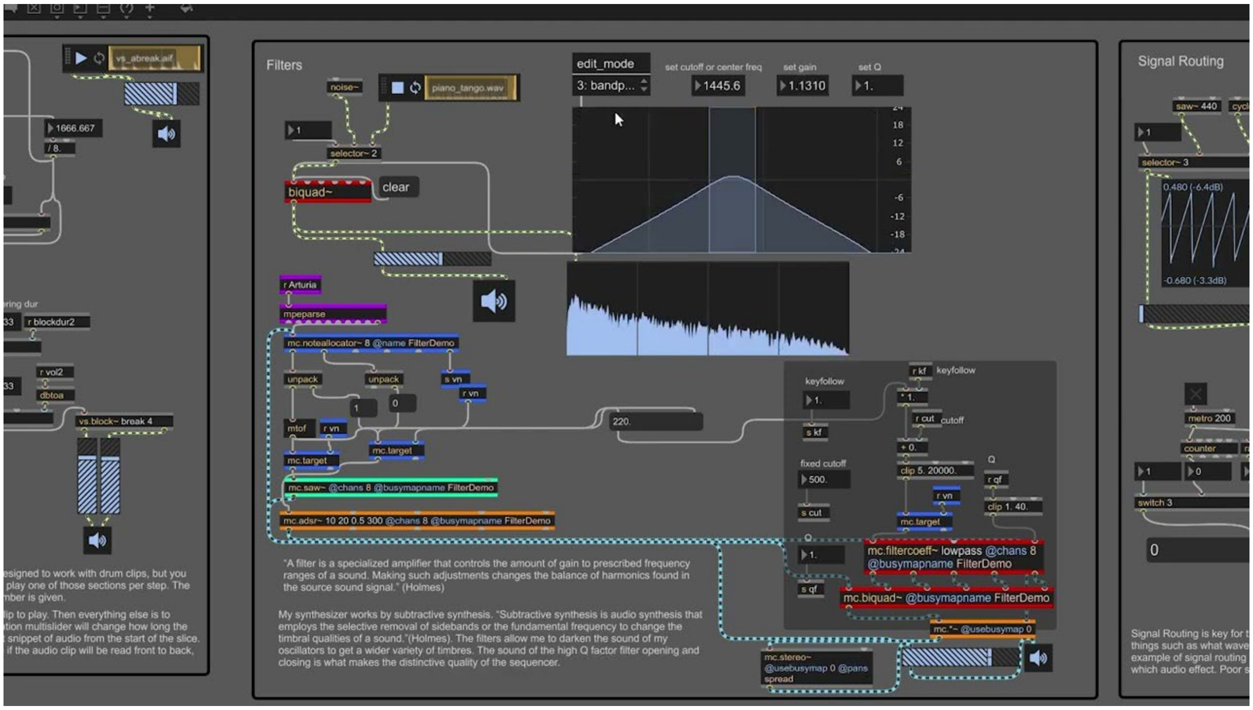
https://youtu.be/0p0E3iJA7r0

The drums were also grabbed from the book (*Electronic music and sound design* volume 2).

Again, this one looks more complicated than it actually is. First you need to input a short audio clip. It was designed to work with drum clips, but you could put any audio into it. The clip is split into 8 equal sections. Then there is an 8-step sequencer that can play one of those sections per step. The sequencer does not have to be driven by a transport object and simply will play out the step of whatever number is given.

The Live Grid object's x-axis is each step in time and its y-axis selects which of the 8 sections of the audio clip to play. Then everything else manipulates the audio of the step. The multisliders for pitch and volume are pretty self-explanatory. The duration multislider will change how long the audio clip is grabbed starting from the beginning of the 1/8 slice. So, either the entire 1/8 slice or just a short snippet of audio from the start of the slice. The stutter slider will make the note trigger multiple times within the same step. The direction will determine if the audio clip will be read front to back, back to front, or not at all. The stutter and direction are probabilistic whether they will trigger.

Filters

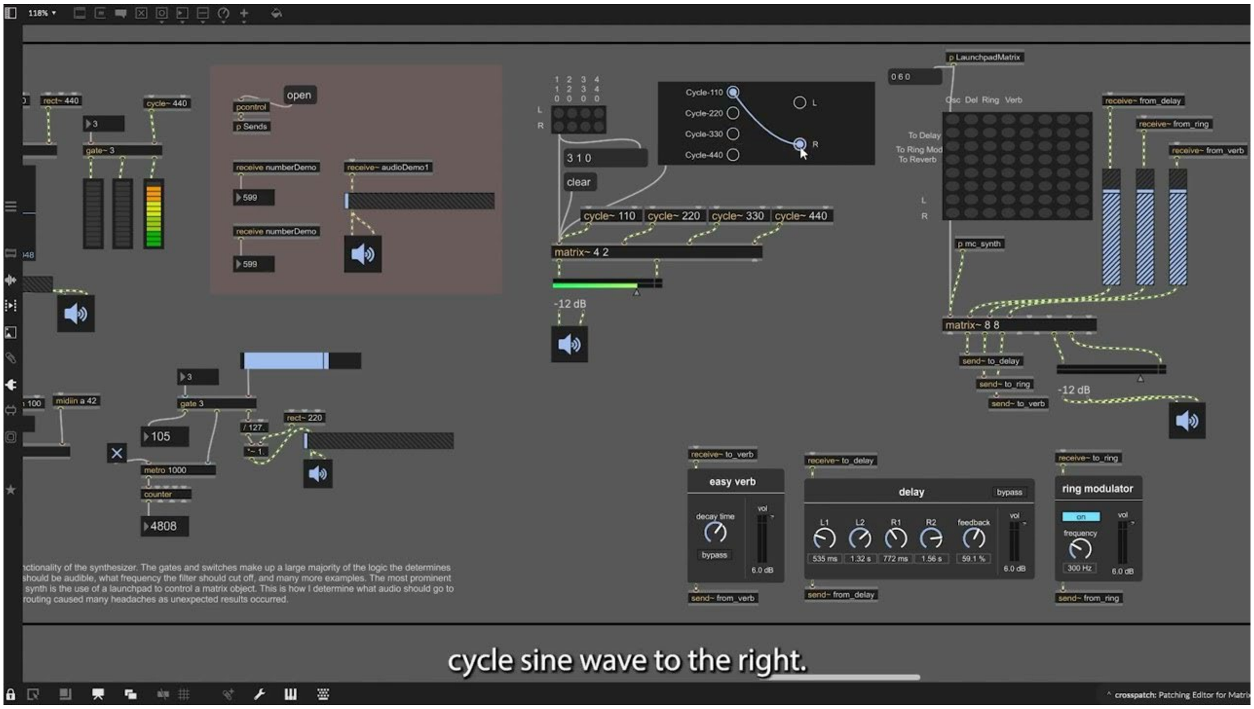


https://youtu.be/r_oMPPlZrLQ

“A filter is a specialized amplifier that controls the amount of gain to prescribed frequency ranges of a sound. Making such adjustments changes the balance of harmonics found in the source sound signal” (Holmes).

My synthesizer works by subtractive synthesis. “Subtractive synthesis is audio synthesis that employs the selective removal of sidebands or the fundamental frequency to change the timbral qualities of a sound” (Holmes). The filters allow me to darken the sound of my oscillators to get a wider variety of timbres. The sound of the high Q factor filter opening and closing is what makes the distinctive quality of the sequencer.

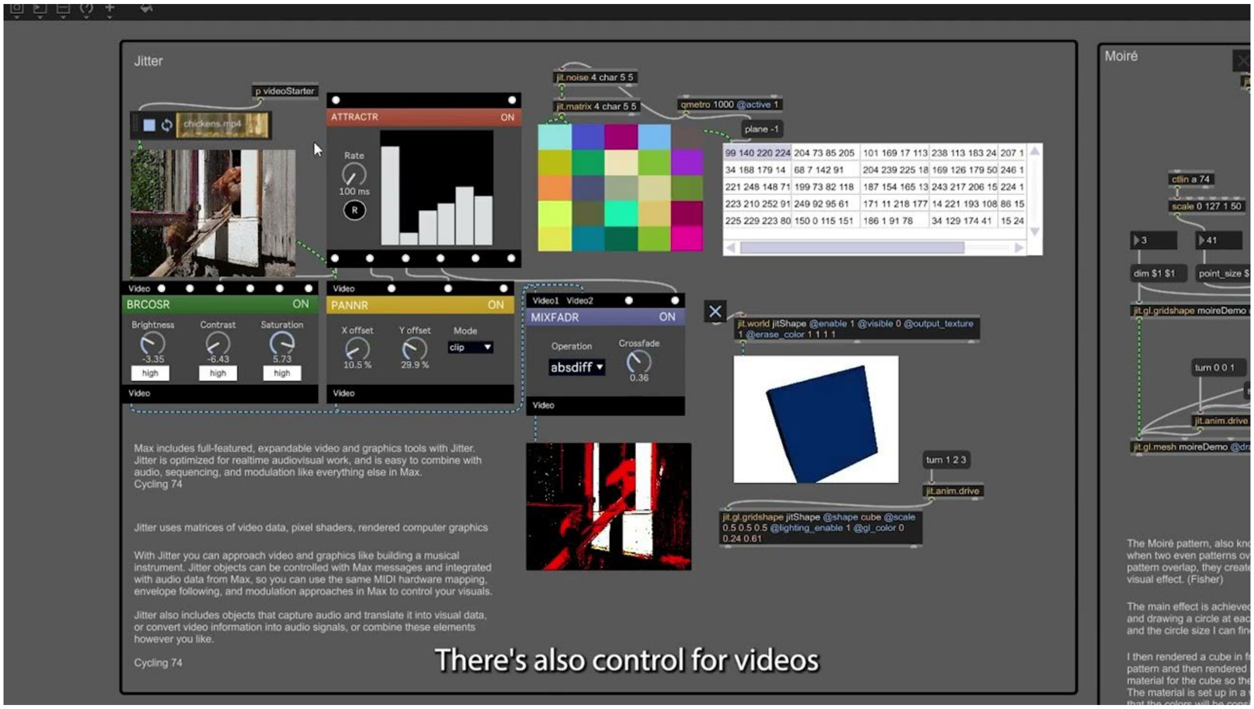
Signal Routing



https://youtu.be/fnvLWxuwwS0

Signal Routing is key for the functionality of the synthesizer. The gates and switches make up a large majority of the logic the determines things such as what waveform should be audible, what frequency the filter should cut off, and many more examples. The most prominent example of signal routing in my synth is the use of a launchpad to control a matrix object. This is how I determine what audio should go to which audio effect. Poor signal routing caused many headaches as unexpected results occurred.

Jitter



https://youtu.be/QcgYGI3_A1w

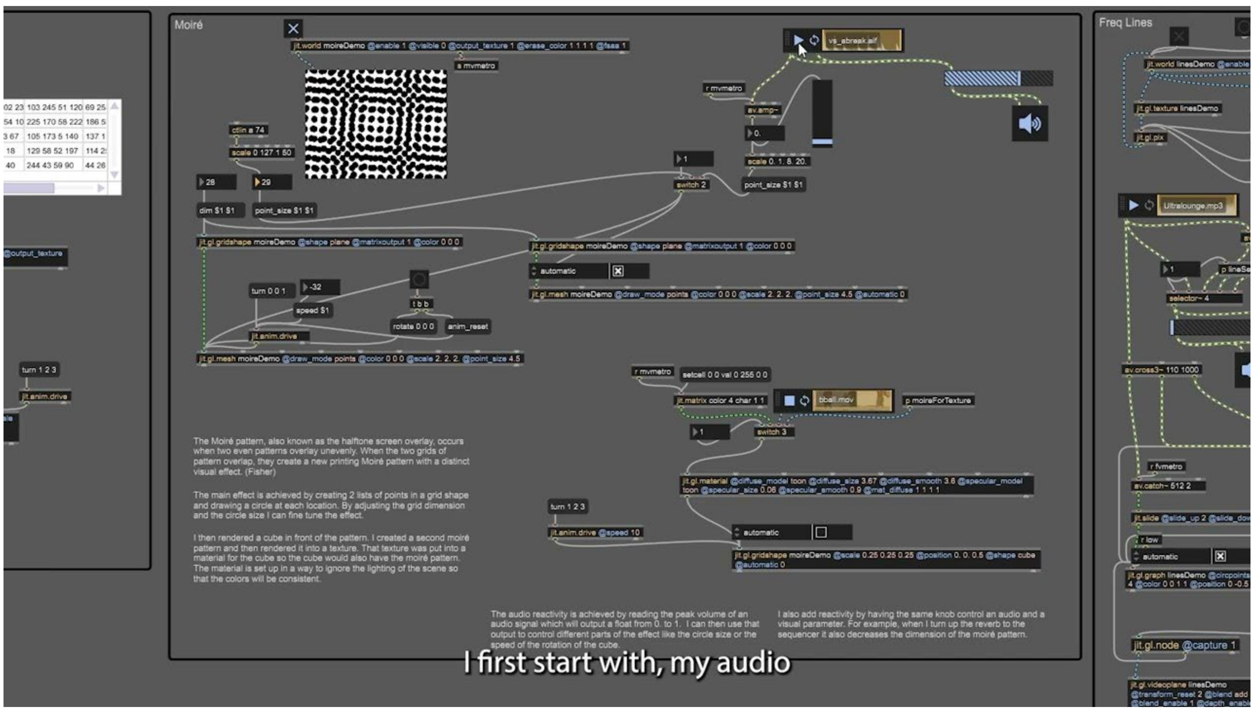
“Max includes full-featured, expandable video and graphics tools with Jitter. Jitter is optimized for realtime audiovisual work, and is easy to combine with audio, sequencing, and modulation like everything else in Max” (Cycling ’74).

Jitter uses matrices of video data, pixel shaders, and rendered computer graphics to create real-time visuals that can be easily manipulated.

“With Jitter you can approach video and graphics like building a musical instrument. Jitter objects can be controlled with Max messages and integrated with audio data from Max, so you can use the same MIDI hardware mapping, envelope following, and modulation approaches in Max to control your visuals" (Cycling '74).

"Jitter also includes objects that capture audio and translate it into visual data, or convert video information into audio signals, or combine these elements however you like" (Cycling '74).

Moiré



https://youtu.be/uuXgfGewx5Y

"The Moiré pattern, also known as the halftone screen overlay, occurs when two even patterns overlay unevenly. When the two grids of pattern overlap, they create a new printing Moiré pattern with a distinct visual effect" (Fisher).

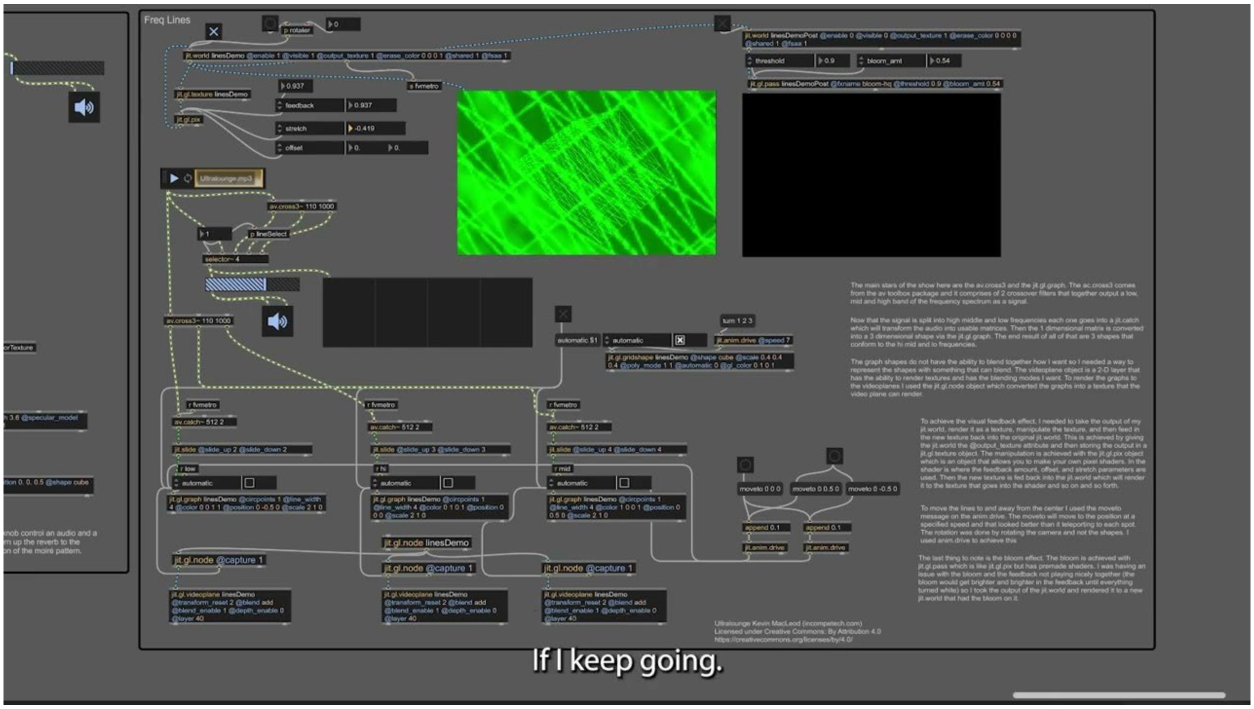
The main effect is achieved by creating two lists of points in a grid shape and drawing a circle at each location. By adjusting the grid dimension and the circle size I can fine tune the effect.

I then rendered a cube in front of the pattern. I created a second moiré pattern and then rendered it into a texture. That texture was put into a material for the cube so the cube would also have a moiré pattern. The material is set up in a way to ignore the lighting of the scene so that the colors will be consistent.

The audio reactivity is achieved by reading the peak volume of an audio signal which will output a float from 0 to 1. I can then use that output to control different parts of the effect like the circle size or the speed of the rotation of the cube.

I also add reactivity by having the same knob control an audio and a visual parameter. For example, when I turn up the reverb to the sequencer it also decreases the dimension of the moiré pattern.

Freq Lines



https://youtu.be/N1UnZL3E38I

The main stars of the show here are the av.cross3 and the jit.gl.graph. The ac.cross3 comes from the av toolbox package and it comprises of 2 crossover filters that together output a low, mid and high band of the frequency spectrum as a signal.

Now that the signal is split into high, middle, and low frequencies, each one goes into a jit.catch which will transform the audio into usable matrices. Then the 1-dimensional matrix is converted into a 3-dimensional shape via the jit.gl.graph. The end result of all of that are 3 shapes that conform to the hi, mid, and lo frequencies.

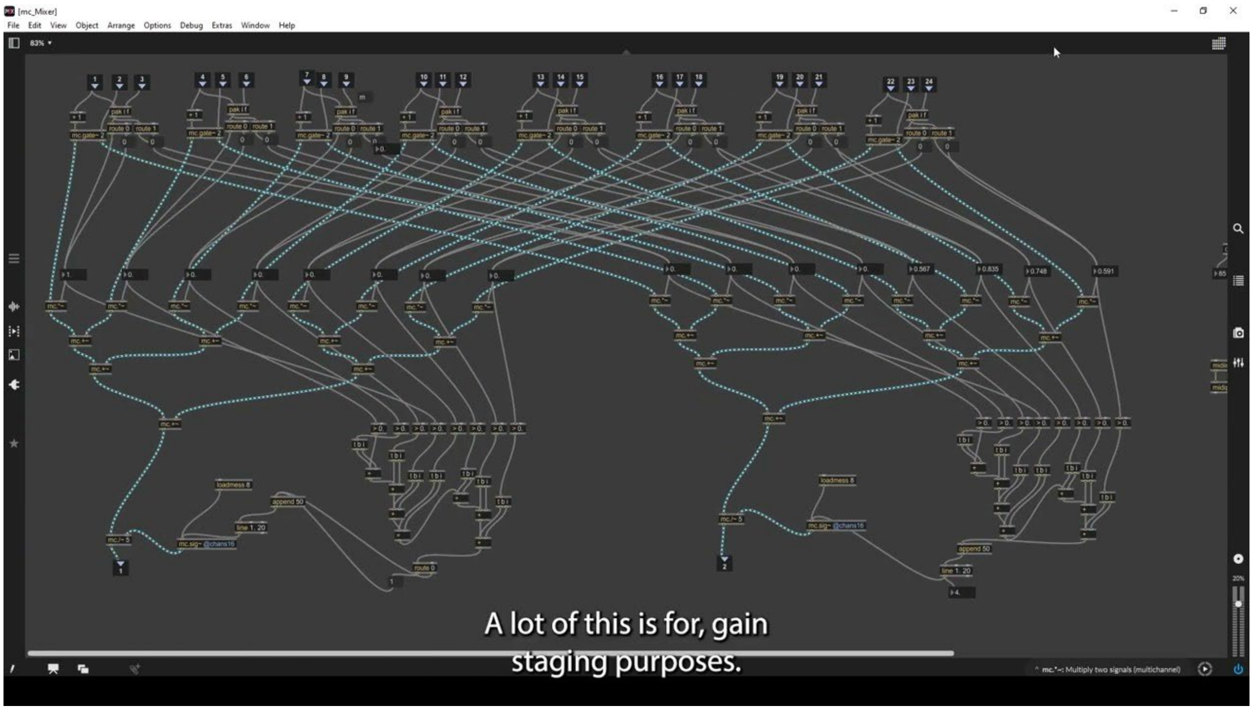
The graph shapes do not have the ability to blend together how I wanted so I needed a way to represent the shapes with something that can blend. The video plane object is a 2-D layer that has the ability to render textures and has the blending modes that I wanted. To render the graphs to the videoplanes I used the jit.gl.node object which converted the graphs into a texture that the video plane can render.

To achieve the visual feedback effect, I needed to take the output of my jit.world, render it as a texture, manipulate the texture, and then feed in the new texture back into the original jit.world. This is achieved by giving the jit.world the @output_texture attribute and then storing the output in a jit.gl.texture object. The manipulation is achieved with the jit.gl.pix object which is an object that allows you to make your own pixel shaders. In the shader is where the feedback amount, offset, and stretch parameters are used. Then the new texture is fed back into the jit.world which will render it to the texture that goes into the shader and so on and so forth.

To move the lines to and away from the center I used the moveto message on the anim.drive. The moveto will move to the position at a specified speed and that looked better than it teleporting to each spot. The rotation was done by rotating the camera and not the shapes. I used anim.drive to achieve this.

The last thing to note is the bloom effect. The bloom is achieved with jit.gl.pass which is like jit.gl.pix but has premade shaders. I was having an issue with the bloom and the feedback not playing nicely together (the bloom would get brighter and brighter in the feedback until everything turned white) so I took the output of the jit.world and rendered it to a new jit.world that had the bloom on it.

Final Synth Patch Walkthrough



https://youtu.be/aG1v3zTQLcc

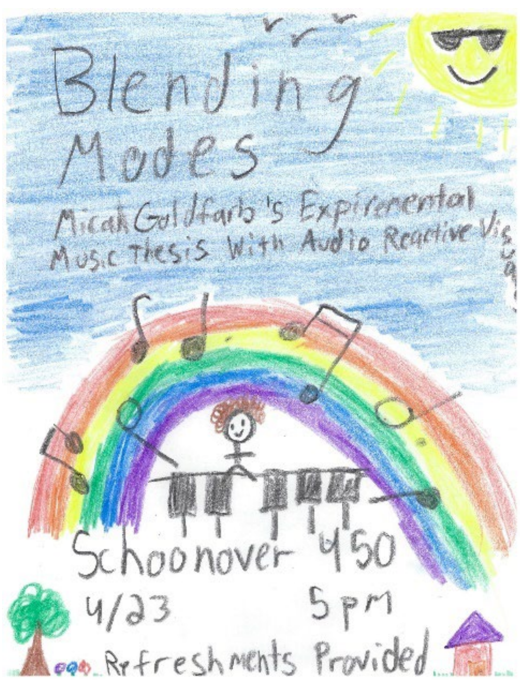
This video is an unscripted walkthrough of the synth patch. Even though the presentation patch (where the previous videos have been analyzed) helps with clarity and comprehension, I still think there's insight to gain from the synth patch. This patch was not built to be neat so be warned

Project Reflection

The culmination of my year of work was presented as a live performance. I had a large classroom booked with three large projector screens to display the visuals and my personal studio monitors to play the sound. The program for the night was my performance, followed by a presentation of my work, and finishing with a Q&A section. The last month of work on my thesis was largely dedicated to designing and practicing the performance piece. What I landed on was six sequencer patterns that would provide the harmonic and rhythmic backing while I improvised melodies on my MIDI keyboard. The two visual scenes both had their variations, so each scene and the variation were assigned to trigger with one of the sequencer patterns. The result was a six-to-ten-minute piece that had planned out moments and sections of high and low energy and emotion but still had the space to have impromptu moments of creative choices.

Playing in front of a crowd gave me a lot of insights. There was a different mindset that I was in while performing to a crowd compared to practicing alone. I made different choices when deciding where the cutoff frequency sits for my keyboard or how long I stayed on a particular sequencer pattern. While one could conclude this was simply due to performance anxiety, I would rather think that it was due to sharing the audio-visual experience. We were engaging two of our senses of perception (three if you count the cookies and other refreshments) so for the time of this performance we were engaging in a shared reality, one that was weird and experimental. It was my responsibility to shepherd us through this shared reality and my decisions would influence whether it would be an enjoyable ride.

The poster I made for the Blending Modes performance



The silly version of the poster I made for the Blending Modes performance

Overall, I am thrilled with the success of this project. I wanted a topic that I could dig my teeth into, that would challenge me and would be creatively gratifying. This project ended up checking all of those boxes. The first thing I want to reflect on is the initial scope of the project. The goal was to use a program that I had no prior experience in and make a complicated synthesizer with audio reactive visuals, without prior knowledge on how to build a synthesizer or audio reactive visuals. In retrospect, that goal was probably too ambitious. However, I think for me it served as great motivation to keep pushing further out of my comfort zone and stopped me from settling with the easy path. I could always scale the project back if I needed to. However, I am also proud to say that I achieved that goal despite how lofty it was.

I think if I were to do all this again, I would approach it in a different way. One of the problems I encountered in this project was that my patch would use too much CPU power causing audio issues. There are many possible reasons why this was the case, but I think the most obvious answer is that my patch ended up being very large and complicated. In the end, I didn't utilize many of the features I built into the synthesizer during the final performance. This all leads me to believe that I would have benefited from building a smaller and more specialized synth. This would also have allocated more time to the visuals, which is an area of this project that I think has a lot more untapped potential.

I was asked some great questions at the end of my performance, and I want to take this opportunity to answer them here after giving my response some more thought. The first question is, "What are the applications for this project either professionally or for a performance?" There are two concepts that came from this project that I think are applicable. While I don't imagine my synthesizer will become the new industry standard, I do see value in bespoke synthesizers for specific performances. In other words, building a synth will not be the best option in a general scenario but if you need a synth to able to do specific tasks, I think a custom-built synth will perform the best. The other takeaway concept from this project is the power of audio paired with visuals. Bringing up Chion again, “Certain experimental videos and films demonstrate that synchresis can even work out of thin air—that is, with images and sounds that strictly speaking have nothing to do with each other, forming monstrous yet inevitable and irresistible agglomerations in our perception” (Chion et al.). When done correctly, the combination of audio and visuals creates a truly powerful experience. I have only scratched the surface of reactive visuals, but what I have learned I will continue to expand on to create more powerful experiences.

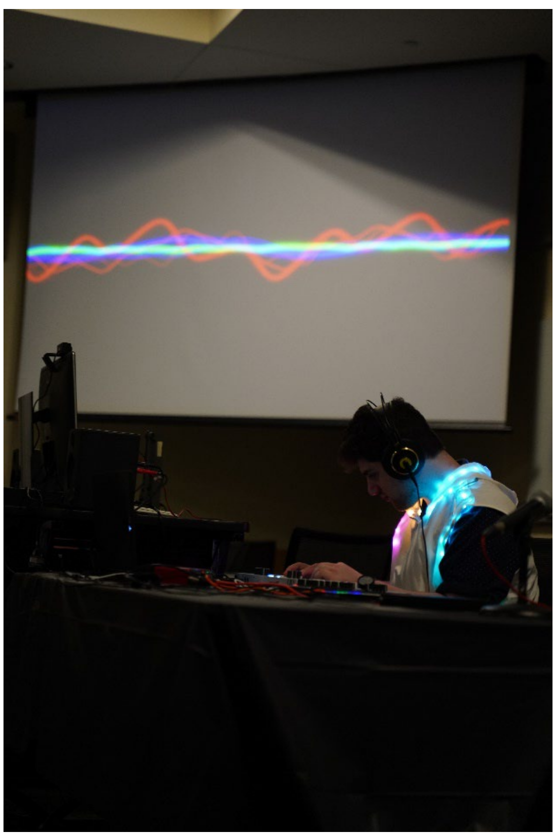
Another question asked was, “What was the hardest part of the project?” Learning, but more importantly internalizing Jitter was very difficult for me. I have spent the last four years learning the ins and outs of audio so the challenge with Max/MSP came from learning how to put everything together. The little 3D knowledge I had going into this project was incompatible with the Jitter workflow. I ran into wall after wall with Jitter. I had ideas in my head for what I wanted the visuals to look like, but I didn’t have the vocabulary to make it into reality. I was very close to scrapping the visuals altogether since I just couldn’t make anything I was happy with, but fortunately on my umpteenth attempt I was able to get two good ideas down. After I narrowed my focus to just the two ideas the work to polish them felt a lot easier.

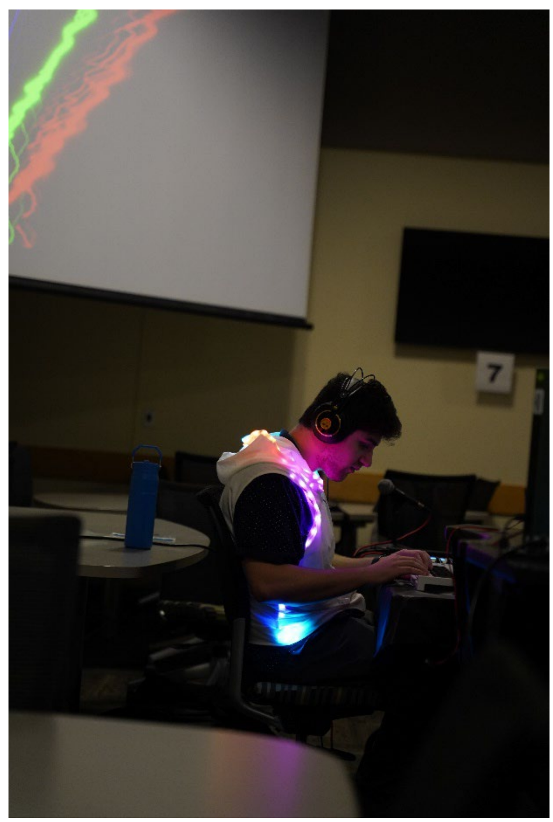
The final question I’ll address here is, “What sort of things would you like to see in the future for audio-visuals? “When I initially answered this question, I tried to think what the most ambitious audio-visual project would be. I quickly realized the answer was something akin to The Las Vegas Sphere. I don’t know what is more ambitious than a 300-foot tall, 500 foot wide, 160,000-square-foot LED panel with the most cutting-edge sound system. So in lieu of the most innovative answer I am going to opt for a different direction. I would love to see AV technology become more accessible. It would be incredible if great AV experiences weren't gatekept behind the high prices and long distances of The Sphere or Disney World. I think the biggest step in this direction would come from more shared knowledge on programs like Jitter or TouchDesigner or the creation of new programs with a lower barrier to entry.

It was refreshing to hear new perspectives on the project that I had not reflected on since I started. I received a lot of positive feedback, and it is encouraging that this work connects with people. I have confidence I will continue to hone the skills developed during this project and make more audio-visual pieces in the future.

This synthesizer, in the end, is not the reward from this project. It is the bounty of new knowledge on the topics of synthesizers, computer graphics, and a new software. It is the problem-solving skills gained after everything breaks even though it was working just fine a second ago. It is the passion to pursue the new creative ventures that this project inspired. But... the synthesizer is pretty kick ass too.

Pictures taken by Kyle Schwieger of the Blending Modes performance



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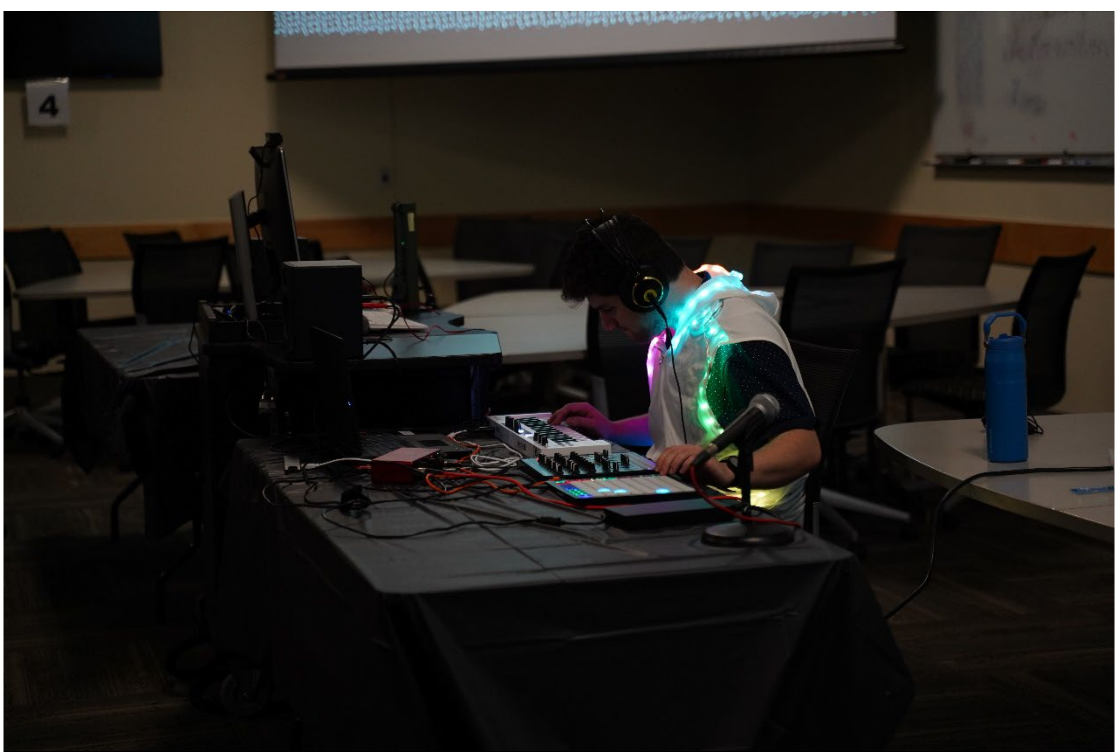
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