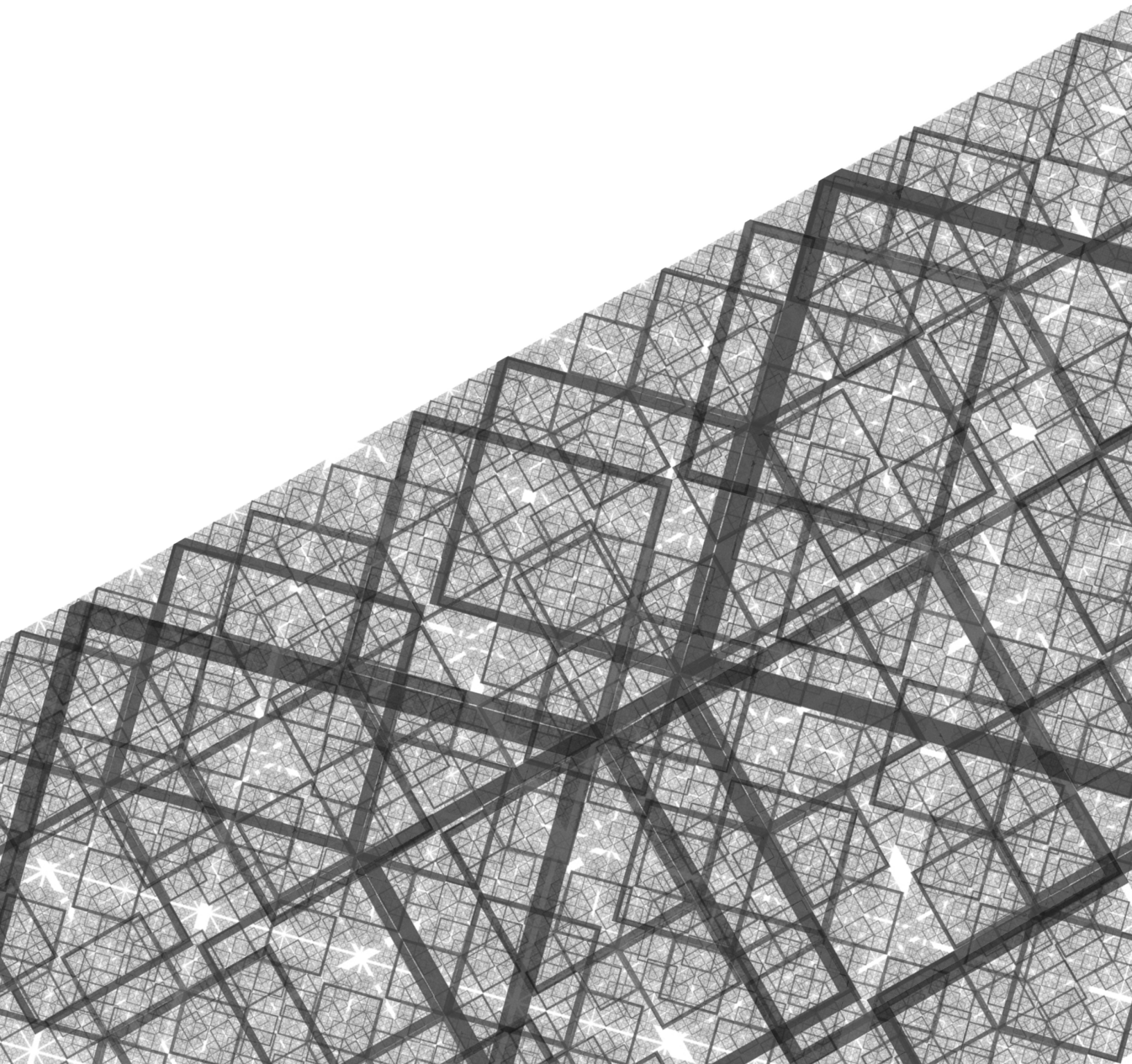
AlgoRhythm

A MFA Sound Design Thesis of
Algorithmic Music & Projections
by Matt Otto

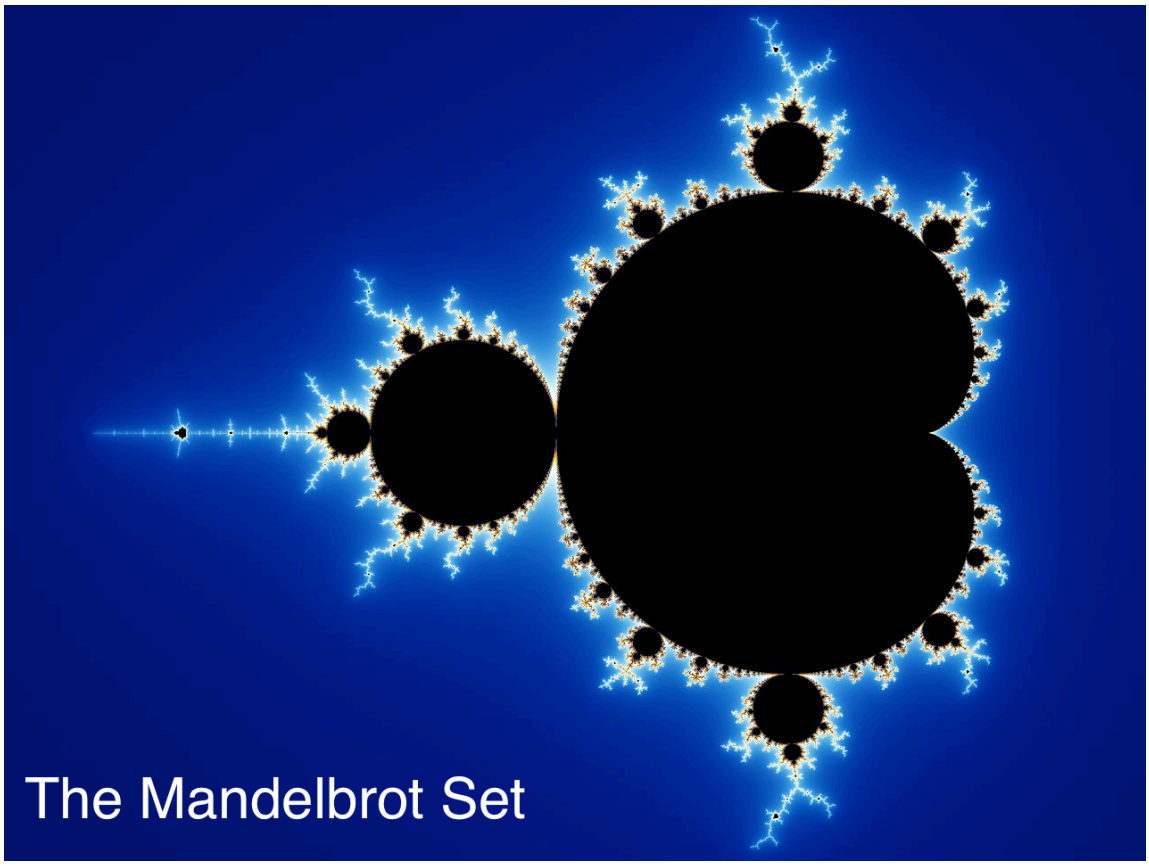


Part 1: Introduction

I originally set out to explore the Golden Mean, the Fibonacci Sequence and Fractal Geometry through music. I ended up exploring and implementing various algorithmic composition techniques, created four pieces with them and presented them to an audience. In this paper I will described my process, my artistic intentions and what I learned from it. The original music I composed was based on the algorithms of Sierpinski's Triangle, Node Counter Sequencing, and waveform to MIDI interpretation found in Ableton Live. The projections were designed by Michael F. Bergmann in response to the pieces of music. Two of the projection pieces were triggered by the notes of the musical pieces.

Part 2: Start of the Process

The impetus for exploring mathematics came from a desire to try to illustrate the power of 3, the golden mean and other visual design elements with sound. I wanted to show that design ideals of the visual world are directly translatable to sound. I started researching the math behind concepts like the golden mean, the Fibonacci sequence and Fractal geometry. I first focused on Benoit Mandelbrot's The Fractal Geometry of Nature and watched the 2008 Nova episode titled *Hunting the Hidden Dimension*, the thesis of both works being that Euclidian Geometry, like squares, rectangles, circles ect. describe the work of man a too simplified version of the universe.



Appendix A

In contrast Fractal Geometry accurately describes the geometry of Nature; mathematically explaining why clouds do not look like spheres, mountains and trees do not look like triangles and lightning does not travel as a straight line to the ground. Simple repetitive mathematic calculations like the Mandelbrot Set: $zn_{+1} = zn^2 + c$ when $C = 0^1$ create natural objects like a cloud, a tree, a mountain or an amoeba.

The idea that the complex natural world is easily described by math is certainly fascinating but what is truly surprising and interesting to me was that the organization of the natural world was also based on fractal geometry. In other words not only is a tree a fractal but the forrest that the tree belongs to is also a fractal and grows at the same ratio that the branches and leaves grown on the tree. From this realization I quickly shifted my focus from the inward looking comparison between the design tools of visual designers and the design tools of sound designers to a more generalized exploration between two geometries the Euclidian and Fractal geometries. I wanted to show people fractals and how they are apart of our every day lives.

It is at this point that I started bringing in Michael Bergmann a 2nd year Projection design MFA candidate into the discussion. I showed him the Nova special and developed a “story arc” for the piece shown below:

Appendix B:

1. Euclidean Geometric Composition
    a. Instrumentation - Tribal Drums, Pan pipe

2. Computerized Synth Fractal Music
    b. With digital visualizations like the Sierpinski triangle
        ii. Start with classic geometric fractals to more abstract fractals

3. 1960s Minimalism piece of fractal composition
    c. Instrumentation: Marimba and glockenspiel
    d. This is to show you can make non computer music with it.
        iii. Start with Mandelbrot end with snow flake

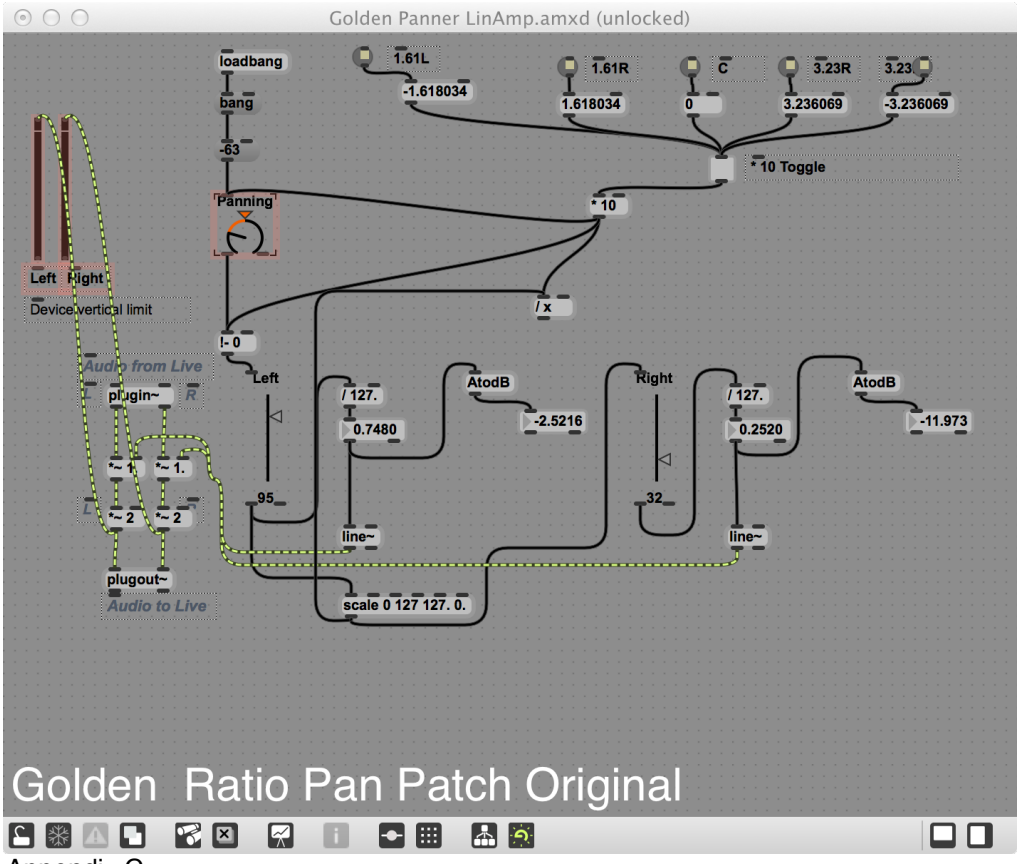
4. Fractal rain piece
    d. Instrumentation: Rain drops and other naturalistic sampled sounds
    e. This is to demonstrate you can create natural worlds and the natural world is a fractal.
        iv. Start with snowflake then go to rain actual images or video of rain to living things like forrest to trees.

5. Heart beat Fractal piece
    e. Ties back to the 1st piece where the drums were an approximation of the human heart and this is actually the human heart. Compare and contrast between the two.

v. From trees to living things like the forrest to the human circulatory system to the human heart.
vi. Human walks in at the end project on them

The arc describes a journey through man made geometry, to weird digital things abstract ideas, to music that sounds natural and describes the natural world, to the point that human beings/all of us in the audience are fractal beings through the demonstration that a human heart beat actually beats in a fractal pattern and our veins grow in a fractal pattern.

Once I nailed down the story arc I set about turning the math of Euclid and fractals into music. I knew that MaxMSP was going to be the key to unlocking this problem. To get my feet wet in the MaxMSP programming environment. I set about creating a stereo panner that would follow the “Golden Ratio” 1.61803398875. After exploring some basic panner patches. I came up with the Golden Panner v0.5.

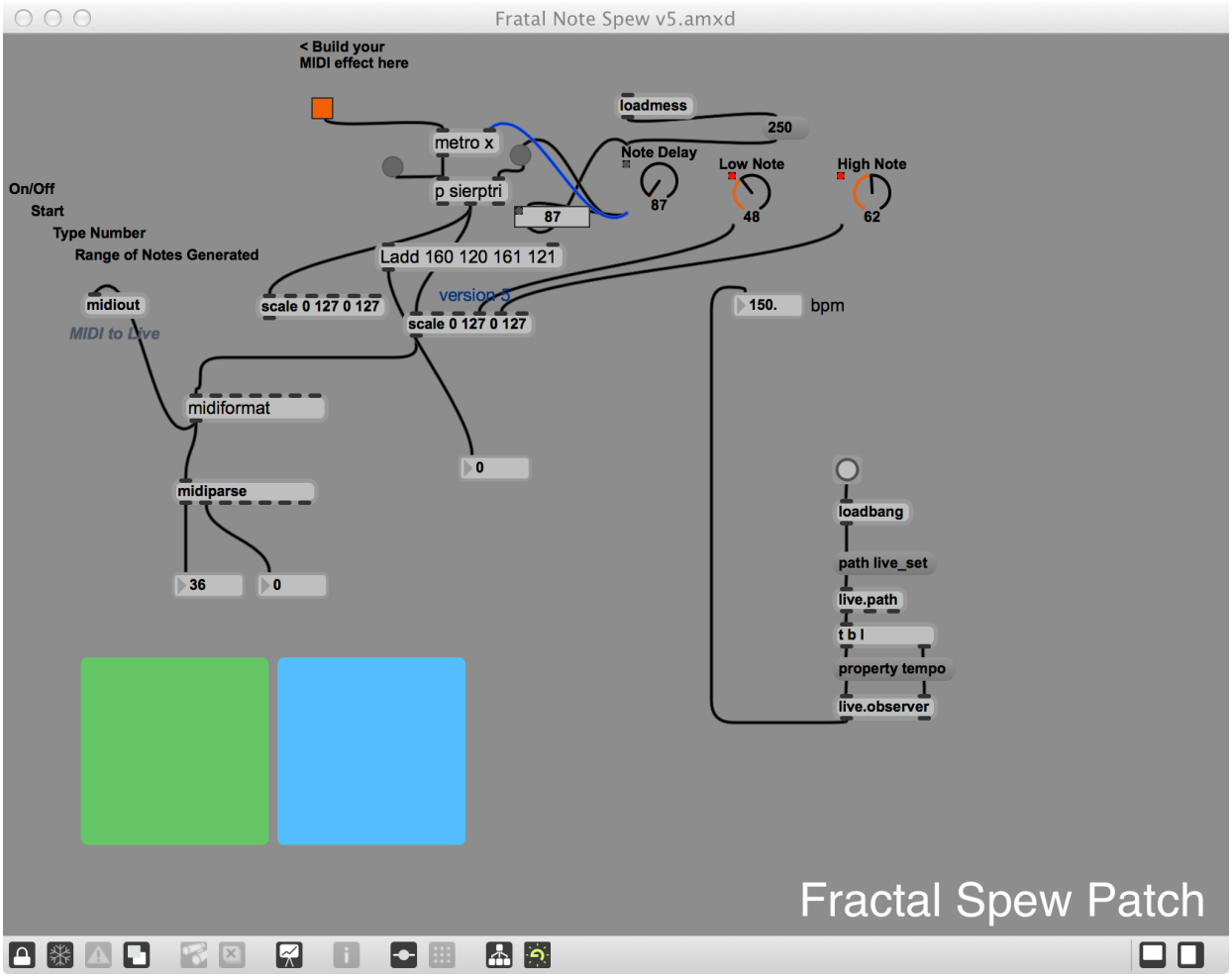


Appendix C

The idea being that the knob labeled panning would raise one channel’s gain and lower the other channel’s gain by the same amount. The knob could be panned Left 1.618034 dB or right 1.618034 dB through two presets. However 1.618034 dB is not enough of a change to be noticeable or interesting so I made it 16.18034 dB instead. The Max patch

is actually a Stereo balancer instead of a stereo panner.. Because it does not take any pan law into effect. I redesigned the patch and come up with a new one that does take into account a -3dB pan law via the `M4L.Pan2` object, which replaces the gain control present in the original patch.

Now that I had a decent grasp of the MaxMSP programming language I started looking for patches I could manipulate and change that contained algorithms I was interested in. I found a Euclidean Beat Generator [2] and a Jitter patch, Jitter being the visual patching language that is part of MaxMSP, that generated Sierpinski's Triangle.[3] I then proceeded to experiment with various ways to generate MIDI notes from the Sierpinski's Triangle Patch and with different ways to control its output. I ended up using the `scale` and `midiformat` objects to generate MIDI notes from the patch and attached three dials to control the output of the patch. The first dial labeled "Note Delay" controls the amount of time in milliseconds the patch waits to generate a note. The second and third dials control the lowest note and highest note the patch will generate on a scale of 0-127 That is then fed to the `midiformat` object which generates a note on and a velocity number and formats it as a MIDI Note and then sends that note to Ableton Live. I titled the patch *Fractal Spew*, because the notes were generated by a Fractal and would



Appendix D

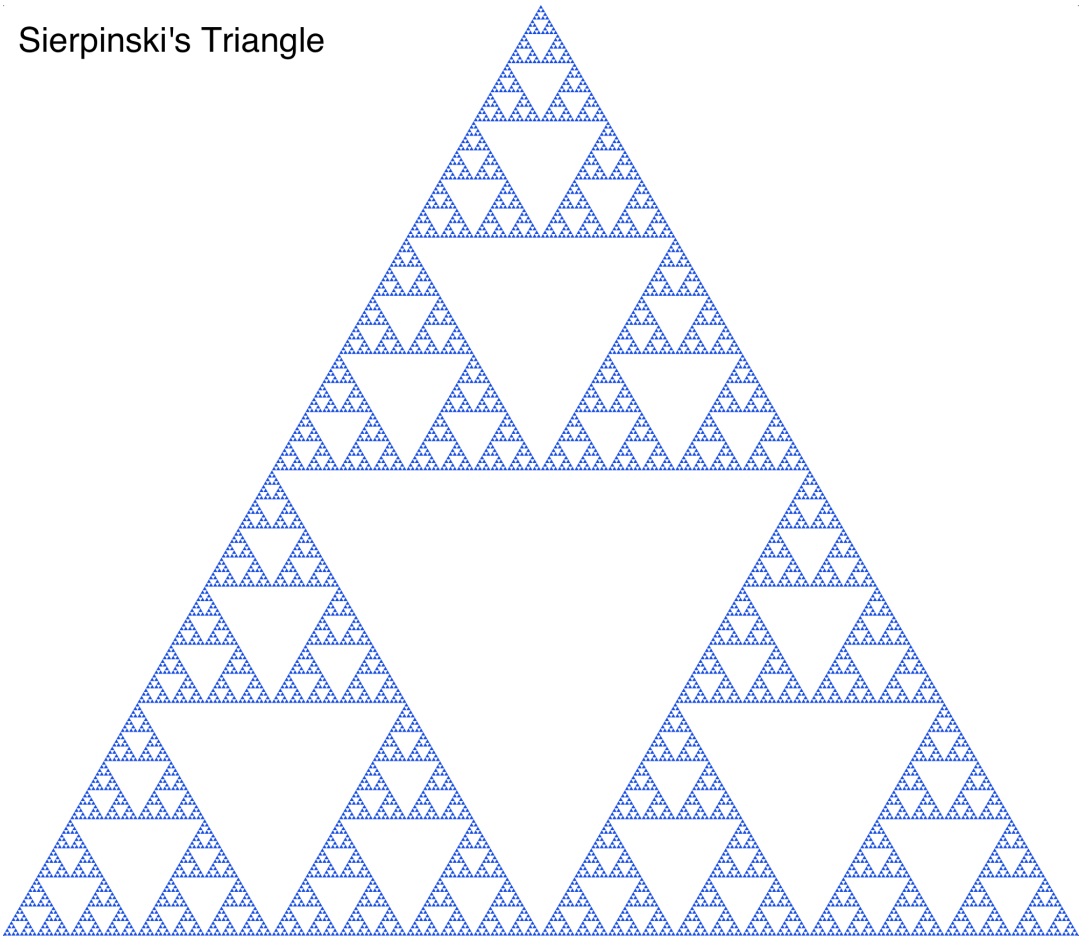
spew out like a firehose. The result are these incredibly dense MIDI files with notes that last forever, because the Max Patch only generates notes on and does not send note offs. How long the note is played depends on the Instrument that is sent the MIDI.

The math of Sierpinski's Triangle works very well for music applications because of rules of picking the points. The formula for his triangle states:

1. Start with a triangle in a xy plane and pick a single point inside that triangle.
2. Pick another point.
3. Pick a third point half way between the other two points.
4. Repeat ad infinitum.

When translating that directly to notes it can sound entirely random, but adding the controls mentioned above, two for the range of the notes generated and one to control the speed at which the notes are generated, creates a melody that can sound both wonderfully human or completely electronic, depending on the settings, which I fully explored in the first piece I wrote titled *Transformations & Translations of Similitudes.*

Sierpinski's Triangle



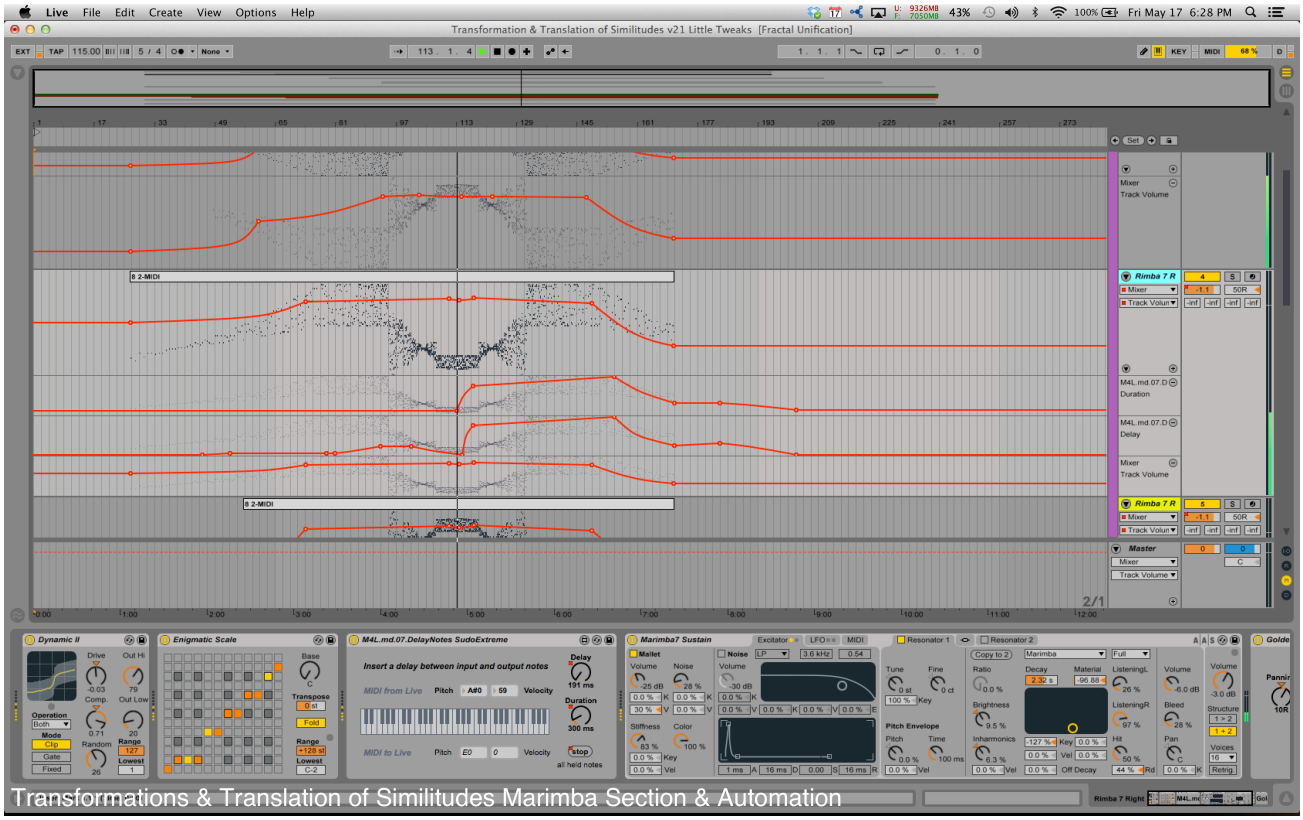
Appendix E

Part 3: Creating the Pieces

1st Piece: T*ransformations & Translation of Similitudes*

Once I developed the Max Patch Fractal Spew. I started playing with it inside of Ableton Live and recording the output into a MIDI track. Fractal Spew does not generate a note off or say when the velocity turns to 0. This results in these progressively dense MIDI files that get so layered with note on messages that its hard to distinguish where one note begins and the previous ends. But it does demonstrate the repetitive and self similar nature of fractals. To get a handle on which notes I was actually outputting when I added a pre-made Max Patch called Delay Notes. This allows you to delay the output of the note in milliseconds and set the duration of the note. I changed the upper limits of the patch to be 100s for delay and 10s for duration. Adding this final control to my Fractal Spew device chain really opened up a lot more musical possibilities and evolution. I now could create notes that last 1/6 of a minute or incredibly short impulses that last a fraction of a millisecond and see the results clearly in my MIDI files.

I then started playing with various instruments and synthesizer patches that would generate long evolving beds like the ones found in the beginning of my piece *Transformations & Translation of Similitudes* and very short attacks like the marimba part from the middle section of the same piece.



Transformations & Translation of Similitudes Marimba Section & Automation

Appendix F

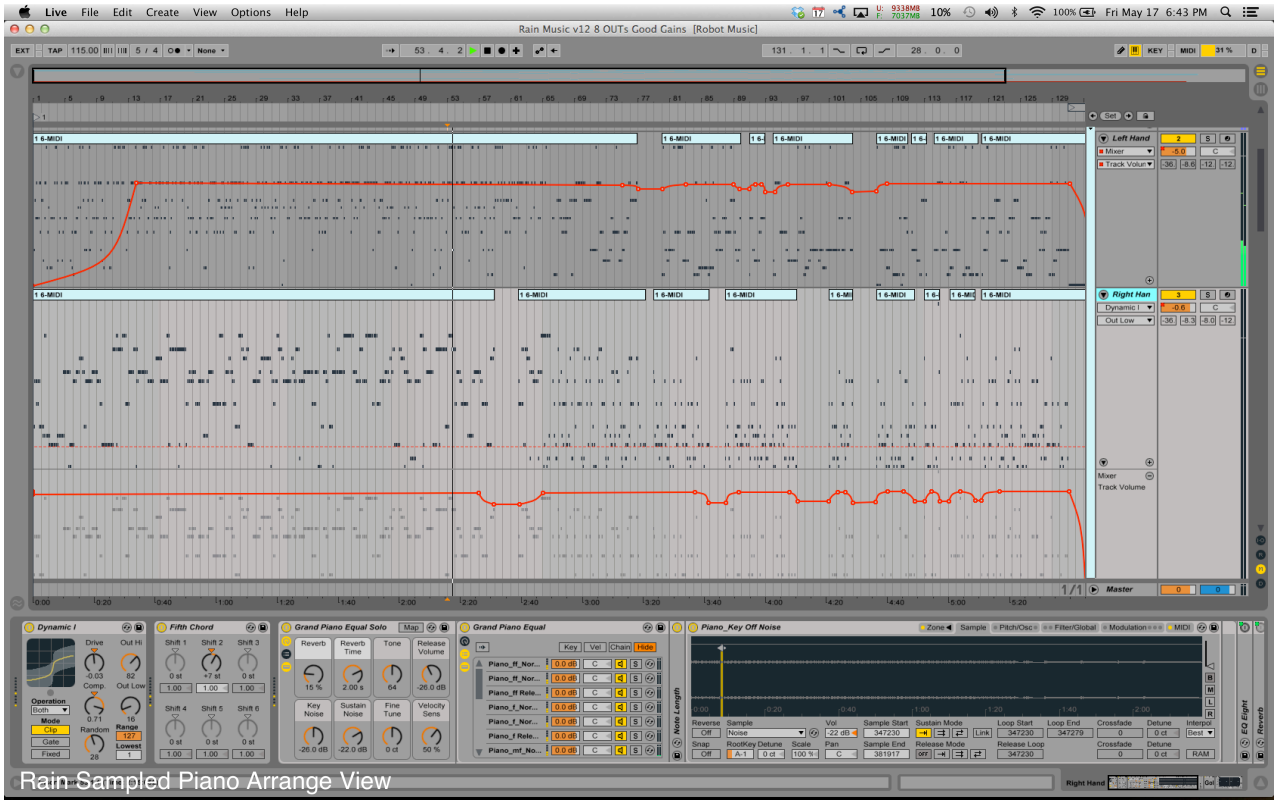
I was inspired by the piece *Come Out* by Steven Reich where Reich uses two tracks that contain the same audio edit of an interview and over the piece delays one track more and more while leaving the other the same. I set out to do a similar effect with six marimba sequences; one for each speaker in the space, using Fractal Spew as my note generator. The House Left Main stays constant while the other five channels, Main House Right, Surround House Left, Surround House Right, Rear House Left and Rear House right are delayed by varying amounts over the course of the piece. On top of that specific outputs notes are inverted. For example when HL Main is ascending Surround HR is descending.

Developing the projections was a straight forward affair. In our earliest discussions we felt that the music should be the focus and the visuals we add to only enhance and heighten what the music is doing. Thus we focused on making the music trigger and manipulate the projections.

To start Michael brought in a wonderful looped video of a set of squares that randomly grew and shrank. We then started exploring various effects and filters that changed the geometry of the squares and the playback speed and blurring of the video. We also played a bit with rotation and XY movement of the video. Once we found a way to change the video into a triangular shape we started building the arc, which follows very closely to the arc of the piece; as the notes get faster the rising and falling squares squares change faster and faster and then settle back down to almost stillness. This gave the audience something interesting to watch, but also allowed the listener to be more aware of the music and what is happening with the delay speakers and the undulation that created.

Because we had MIDI notes triggering the changes in projections we were able to achieve the arc of the piece without much extra work or syncing. The more the notes the projection software received the faster the squares shrank and grew the more it jumped around and the screen enchaining the sense of chaos found in the music. For the top and end of the piece the evolving beds did not send any MIDI notes instead we slowed down the video.

In the final composition with visuals and music the audience is eased into a a calm meditative place that the projections enhance with the slow pulsing triangle. As the marimbas start playing the audience is quickly shifted to escalating chaos that can either wash over the listener or if one zeroes in on a particular speaker creates a sense of control in a world of chaos around you. The projections in the chaos enhance that feeling moving significantly quicker than where they started and shift wildly on the XY planes. The inverted notes I mentioned above allow for greater variation in tonality and a wonderful rumble which felt and sounded like the evolving beds from my first experiments with the Fractal Spew patch. I added the beds to the beginning and end of creating a sense of journey from clam to chaos back to a new different calm, which the projections also followed by returning to a slow almost still place but in a new XY position on the projection surface completing the ABA style.



Appendix G

2nd Piece: Rain

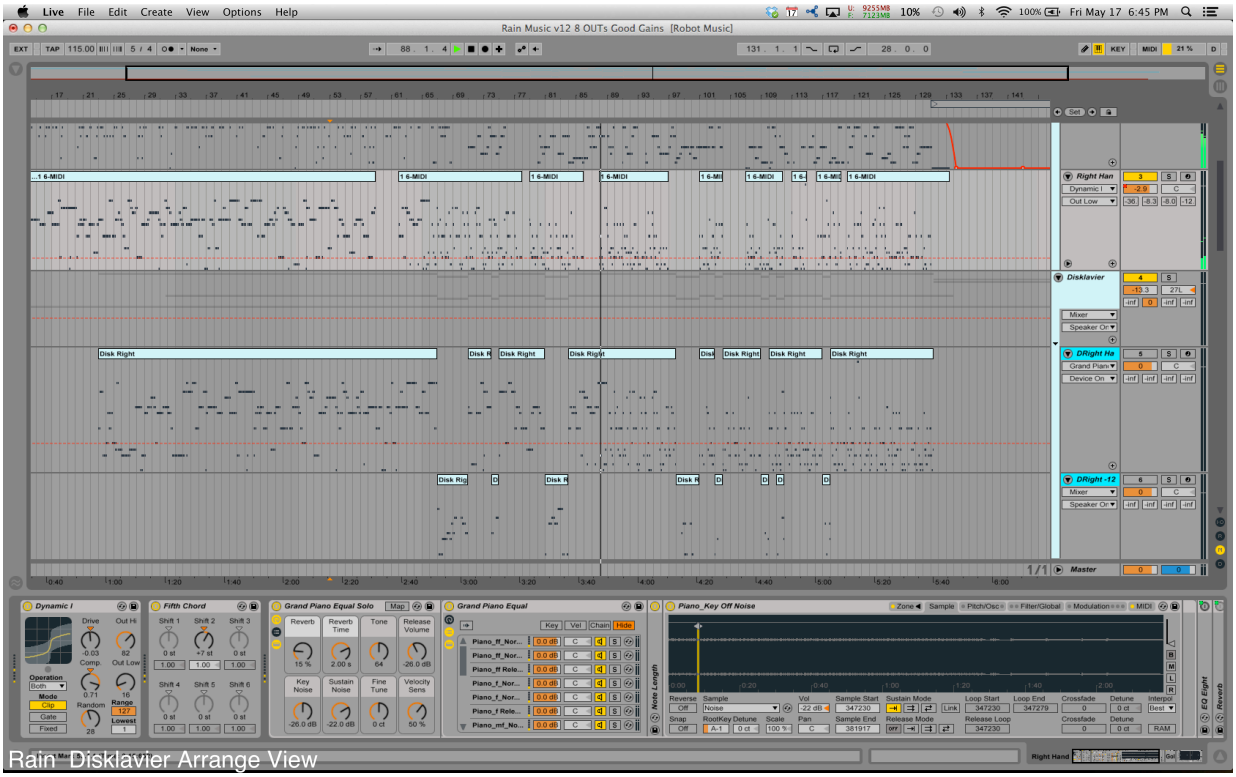
The next piece I created was *Rain.* When I experimenting with various composition techniques for this project I revisited older parts of older pieces. One such part was an old recording of me playing make shift chimes made out of cut metal pipe rubber bands and plastic PVC piping. Listing to it again reminded me how much I enjoyed the melody I created in the recording, and decided to try out a new feature in Ableton Live 9 that translates recordings into MIDI melodies and harmonies. For another project I was working with a new kind of player piano called a Disklavier; a modern MIDI controlled version of a player piano. I grew up with a traditional player piano in my house and was fascinated by how it worked and the music you could play just by pumping your feet on the actuators. Inspired by my previous experience of player pianos and the work of the player piano composer Conlon Nancarrow. I set out to create a duet between the sound system and the disklavier.

I applied the two algorithms, one for melody and one for harmony, to my recording and came up with something that my wife described as “Robot Music,” meaning something that sounded like music but was played by robots. I applied some various MIDI and audio effects like the Arpeggiator, and Scale effects found in Live and created the base of what was to become *Rain*. I then placed a sample Piano at the end of the signal chain and created a wonderful twinkly higher pitched phrase of music, which sounded like a musical interoperation of actual rain. I edited and rearranged the resulting MIDI and came up with the notes for *Rain*. There are many pieces written for tape and piano

or tape and violin or tape and trumpet and even pieces written specifically for player pianos but I was unaware of a piece that used “tape” and a player piano. So I set about taking the show control one step further not only using MIDI notes to trigger projections, but also using MIDI notes to trigger a physical piano. The disklavier allows for a single piano to play as many notes simultaneously as there are keys on the piano so one can create three handed pieces or more, which I took heavy advantage of in the piece, I did not use super fast playing techniques as I did in the previous piece, but I did use complex chords and wide differences in octaves to create it. One could play the piece with four pianos but it would not achieve the same sense of electronic or computerized music.

For the projections Michael took a cue from the name and the twinkly timbre of the early incarnation to develop the projection. The visuals are simply a video of ink in water some rain and some light clouds to keep us in the world of the concert, while letting the very compelling visual of image of the keys being pressed down to be the visual focus.

The end result is a duet between two playback devices that has an intriguing human element: having a live, physical instrument playing grounds the particular piece and the concert as a whole in a very human way. The tonality, timbre and call and response nature of the piece evokes the natural world, but the way it was created still resembles the mathematical underpinnings the other pieces make the listener aware of. Creating it second but placing it as the final piece allowed me to understand what the bigger journey was in the concert as a whole while tying up everything explored previously in a satisfying and understandable way.

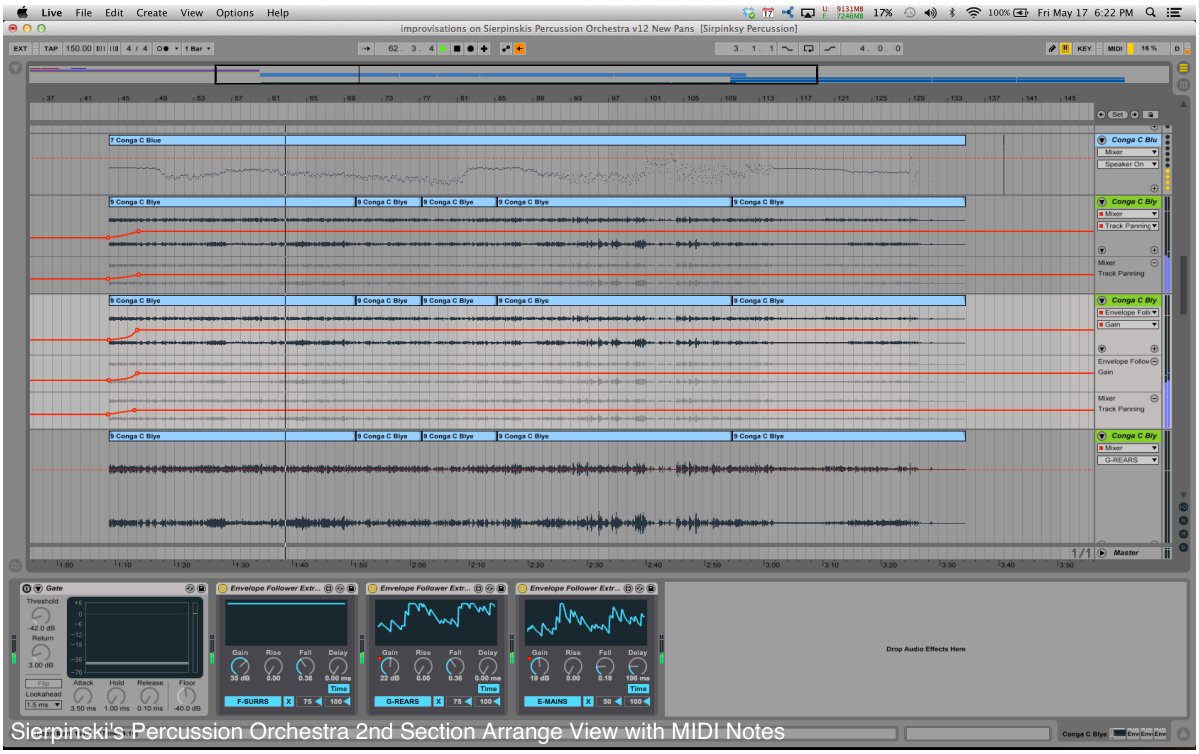


Rain – Disklavier Arrange View
Appendix H

3rd Piece: Improvisations on Sierpinski's Percussion Orchestra

I felt the difference between *Rain* and *Transformations & Translation of Similitudes* allowed me to go back and explore what else I could do with my Max patch; Fractal Spew. Since I found I was able to get both long evolving pads and short percussive sounds from the patch. I decided to explore what a purely percussion piece would sound like could it sound human or would it be too much like a computer.

I threw an instance of Spew on to a track with an instance of the Ableton Live instrument Drum Rack and some conga samples. Then I started adjusting the Lowest Note and Highest Note controls. I quickly found I could keep the range of notes the patch selected very tight, I could even have the patch play the same note forever if the settings where with in 1 note of each other. But if I made the range too big the notes played by Spew would be outside the range of the samples and nothing would play at all. With this realization I found I could skip or drop notes creating more interesting rhythms, which in turn created a sense of “rests” that were still bound by tempo but gave the impression of a person pausing for effect rather than a misfired MIDI note. After a little bit more experimenting I discovered that a delay between notes of 250 seconds felt or sounded like a natural amount of time that a human player would take to hit one conga to the next. Taking into account the rests it started to sound very human and natural. So I started improvising on my patch raising and lowering one setting or another to create a sense of expansion and contraction like a human would playing a true conga set. Through these experimentations I quickly came up with two good and musically interesting sections. I just needed a third one to round out the piece. That is when I decided the next section I create would reveal that it is not a human playing the conga; it is a computer.



Sierpinski's Percussion Orchestra 2nd Section Arrange View with MIDI Notes

Appendix I

I pushed the patch almost to the breaking point. I set the Note Delay to 72 milliseconds which was just enough time for the notes that were generated to sound very very fast, faster than a human could do but not a jumbled mess. Then I improvised on the Highest note and lowest note settings and came up with a section that sounds almost chaotic but still controlled this final section ties it what is otherwise a very natural sounding piece to the rest of the algorithmic and electronic music compositions.

The projections in the piece were the hardest to achieve. Due to its percussive nature Michael and I wanted each note to trigger a change in the projections. But we needed to first develop the images that could be triggered. Michael first found a large amount of short videos from Bell Labs developed in the 1980s depicting how to render images on a computer screen, geosynchronous orbit, and the math and rendering of Sierpinski's Triangle. He then arranged them and looped them into one long movie file. Then he told Isadora, the playback software for the projections, to move the playhead to a random part of the movie when it received a MIDI Note. For example Isadora received the first note it would move the playhead to to 1:02 into the movie the very next note would move it to 2:57. The randomness also ensured that every run of the piece became unique to that particular performance.

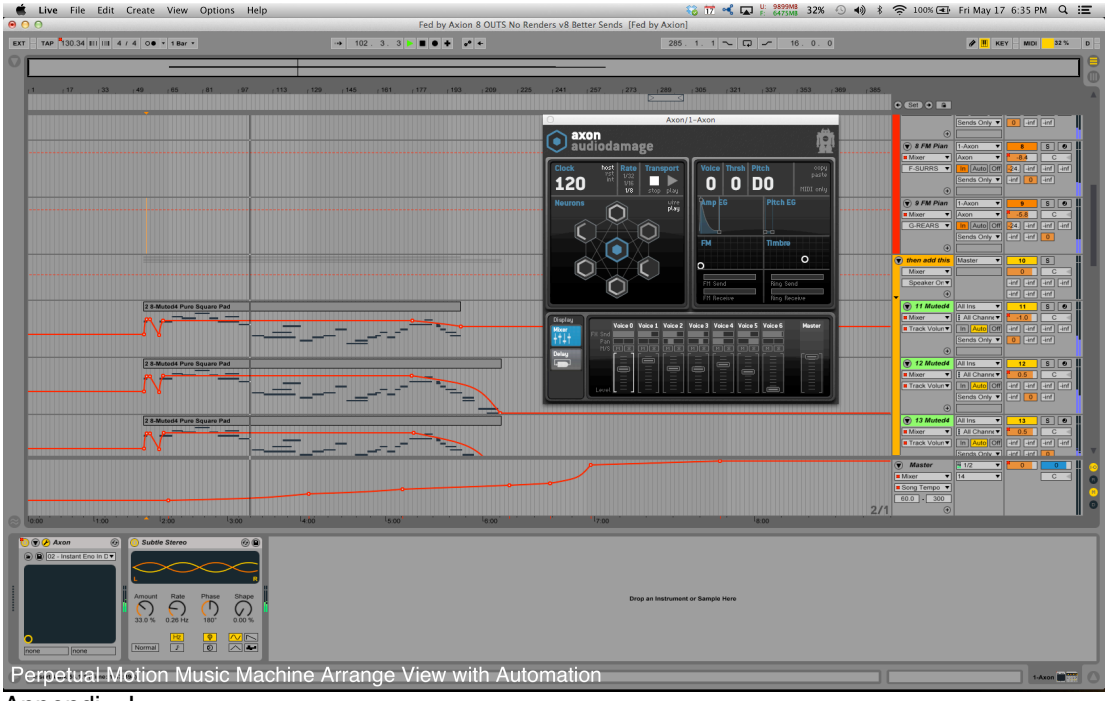
The natural sounding rhythms the audience hears in the first section is a good contrast from the relatively pop ambient sound of the first piece in the concert, but the final piece created, Perpetual Motion Music Machine, and the the very abstract, *Transformations & Translation of Similitudes.* But the unnatural middle section of the ultra fast percussion hint at what is to come in the next piece. The projections juxtaposition of the natural sounding congas contrasted with the unnatural visual of very early computer rendered images allows this piece to feel like it stays with in the world of the concert while also showing of the amount of control Michael and I have and wield through the MIDI firing.

4th Piece: Perpetual Motion Music Machine

The final piece I created was Perpetual Motion Music Machine. It started as an experiment in using a single instrument to power other instruments. A few years ago I purchased the Axion synthesizer from Audio Damage. I always wanted to figure it out and play with it but was never able to find a fitting use for its unique sound. It uses a Neurological Sequencer made up of 7 hexagons to create and control it’s sound. The best feature of this plugin is its ability to power other instruments through the MIDI output of its Neurological sequencer.

Axion’s sequencer is based 7 hexagons that act as 7 individual nodes One node in the center and 6 nodes on the top and bottom. Each node has a threshold, which is how long a node will wait to be trigged; depicted via the sides of the hexagon and a pitch. Once a node is trigged it will sound a pitch and start the timer on the other nodes. The threshold time is measured in BPM, Axion can take the host BPM or set its own BPM. Muting individual nodes allows you to keep their timing but not hear them. This allows for more unique rhythmic combinations. The true power behind Axion is the MIDI out

implementation of the instrument every time a node is triggered a note is sent out this keeps them in sync with Axion and allows you to build upon the sounds axion already provides. Enabling very strong and rhythmically interesting beats.



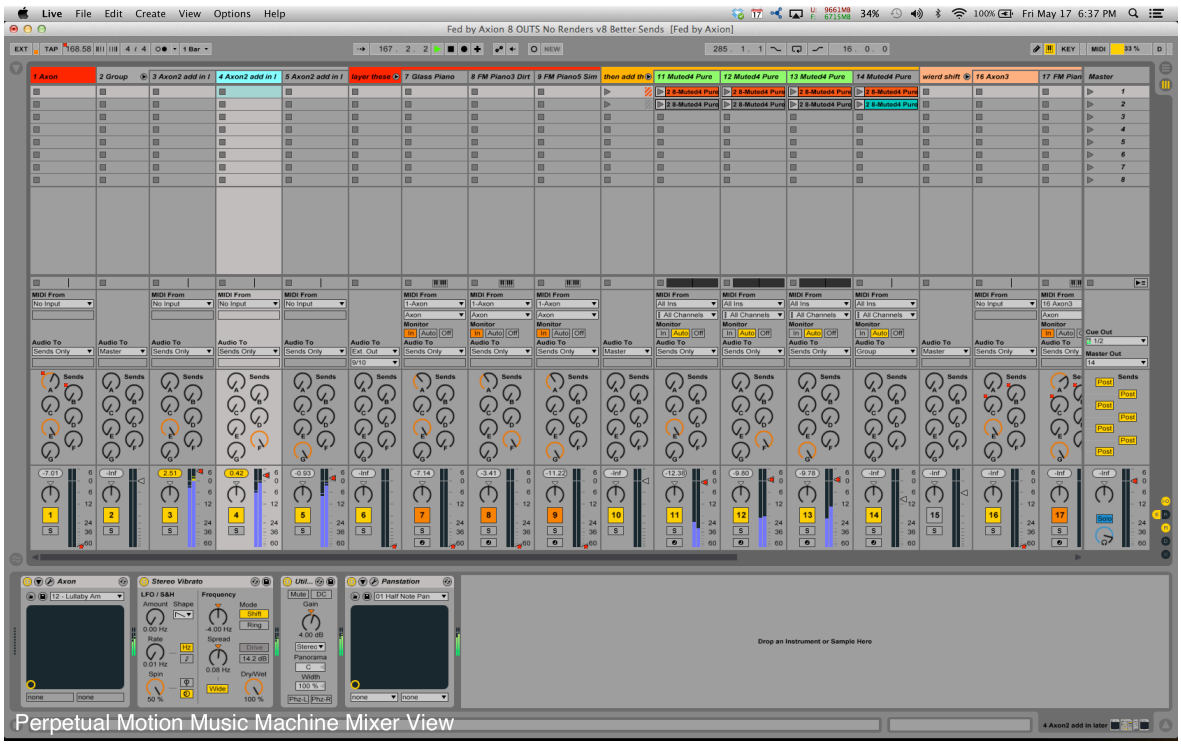
Perpetual Motion Music Machine Arrange View with Automation
Appendix J

I first added the an instance of Axion into Ableton Live and started experimenting with it. Once I established a few interesting beats I sent the MIDI to a few Ableton instruments and added a few effects. This created various sections that I then layered on top of each other and moved around to create a seamless slow and build from one section to another. This was a good start but did not feel like it went anywhere and was just a series of beats. So I added some long held notes to create a ostinato melody. To give the piece a sense of journey I incrementally sped up the tempo until it gets so fast in the piece that it feels we are about to reach escape velocity and arrive at a new location.

The projections developed by discussing the piece and the ideas or feelings it provoked. I gave Michael some long exposure photography that I felt evoked the sense of travel that the piece has. He took those as inspiration and came up with a wonderful projection that is from the front of a car perspective traveling down a road we shift from various places and significant points in the music to heighten the sense of travel and transition from day to night in very tight sync with the changes in the music.

The final piece is a great way to alert the audience to the fact they are about to go on a journey and should trust the authors and further their willing suspension of disbelief. The sound inspired by Brian Eno's *1/1* from *Music for Airports* eases the audience in via a semi-familiar understanding of Electronic Music and sets the stage for the rest of the

concert. The realistic projections of the piece helps the audience the same way visuall with a grounded start of a familiar sense of driving and then evolving to more abstraction as the pieces speeds heading in the end where we push through abstract field of light and reverb. It signals to the audience they have entered a new place that is much more abstract then where we started, and it allows the audience to understand and accept the abstractness that is to follow.



Appendix K

Part 4: Conclusion

When I started my thesis project I wanted to explore the differences of Classical Geometry and Fractal Geometry through music. My initial research led me to then examine what a fractal would sound like. Once I discovered that a fractal can sound natural, like playing the congas, or completely abstract like playing the marimba in 512th notes. I had something that completely gripped me. From those initial successes I set out to explore the compositional benefits of other algorithms. Using Sierpinski's Triangle, Neurological Sequences and audio to MIDI conversion I created four pieces that take the listener on a journey through a world that is natural but also strange and wondrous. A sense of music and mathematics pervade and give the audience the sense of something larger than its individual parts. Adding projections to the music allows the audience to further understand what the music is doing and hints at what one should be listening for but is also expressive and interesting in its own right.

The experience creating *AlgoRhythym* has given me a great set tools to carry into the future; like learning MaxMSP, experimenting with MIDI as show control, a set compositional tools; like the Max Patches I created for this project as well as a repertoire of music from Ligeti, Eno, and Reich, and Nancarrow to draw from.

But the most significant thing I will take away from this project is a keen interest in Sound Art. Making original music for my own goals combined with exploring, experimenting and pushing the programming and technical abilities of the software and then presenting it to an audience was extremely fulfilling. It was something I had not experienced in the same way I had with my sound designs for theatre. It is something deeper that I didn't know was there and now I want to do so much more of it. When I started this project, I did not know I would discover this and now that it is over there is very little else I want to do.

Footnotes:

[1] Wikipedia http://en.wikipedia.org/wiki/Mandelbrot_set and http://en.wikipedia.org/wiki/File:Mandel_zoom_00_mandelbrot_set.jpg

[2] *The Euclidean Algorithm Generates Traditional Musical Rhythms* by Godfried Toussaint*: http://cgm.cs.mcgill.ca/~godfried/publications/banff.pdf*

[3] LObjects Documentation by Peter Elsea: ftp://arts.ucsc.edu/pub/ems/Lobjects/

The Isadora programming for AlgoRhythm had each piece broken down into a separate scene. The triggering of one scene to the next, and fades in between, was done by MIDI control. In fact, a very large part of the effects were controlled by MIDI.

The first piece was the most basic (Fig 1). It was a simple playback cue of a video that was designed and edited to the music.

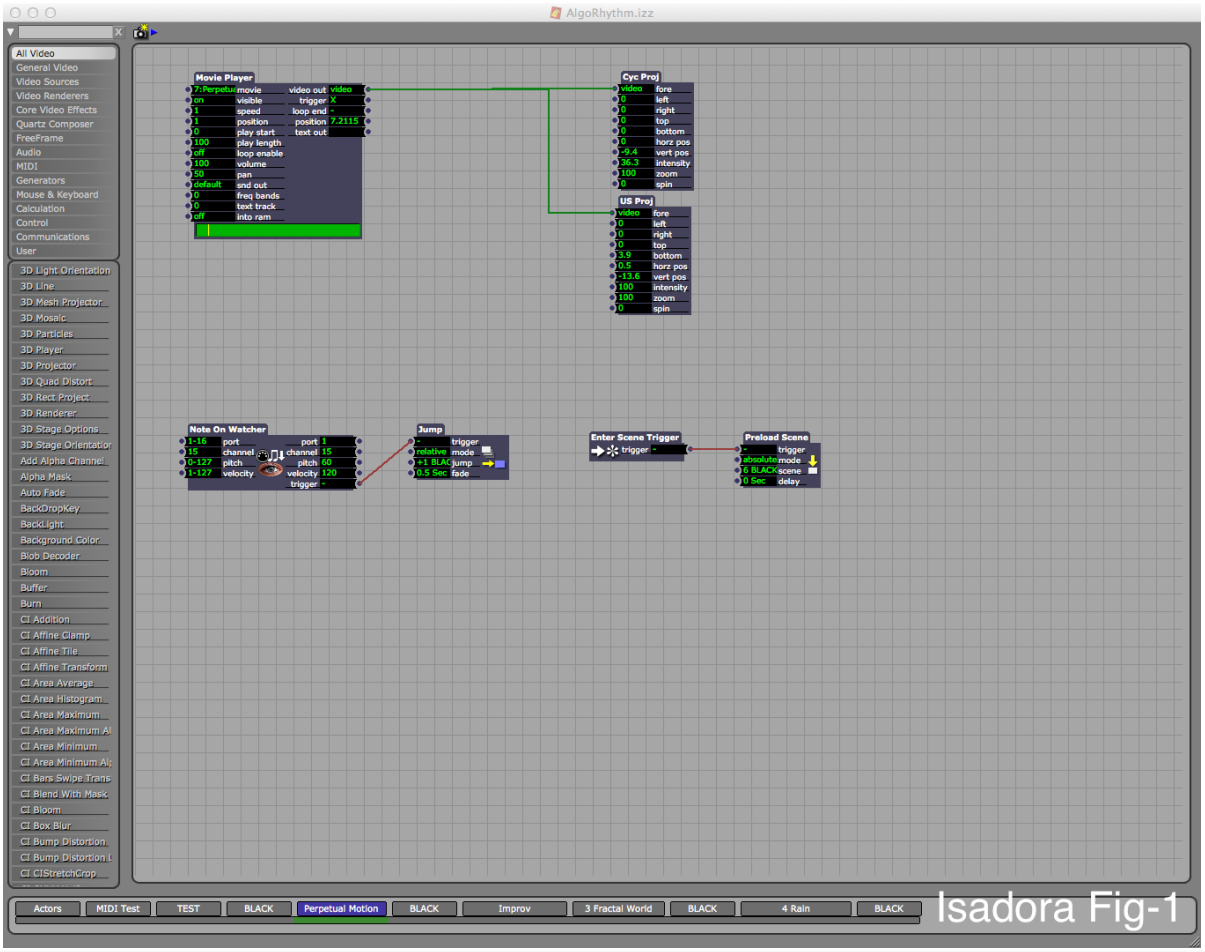
The second piece was the most complicated program-wise, being comprised of a main scene, with two subsections. The main scene (Fig 2a) controlled the opening sequence of fades, as well as the triggering of the further sections. The first subsection, labeled *Part 1* sets the tone for the style of the video design for this piece (Fig 2b). It takes one file, comprised of many clips of old computer generated graphics, and randomly chooses a play position in the clip. This is updated every time there is a new note played over MIDI, and is occurring three times; one channel on the cyc surface, and two layers on the US scrim.

At the next part of the music, *Part 2* activates and crossfades in (Fig 2c). This section run the second and third parts of the piece. In the second part, a continuation of the random jumping of play position is happening, although to an altered clip which includes rotation and zoom changes. Throughout the second part, there are three pauses in the music where we wanted a specific image to be shown. Since the position of the video is random, this is achieved with three specific actors (*Specific Position A, B, C*) to force a play position, triggered by a specific MIDI note.

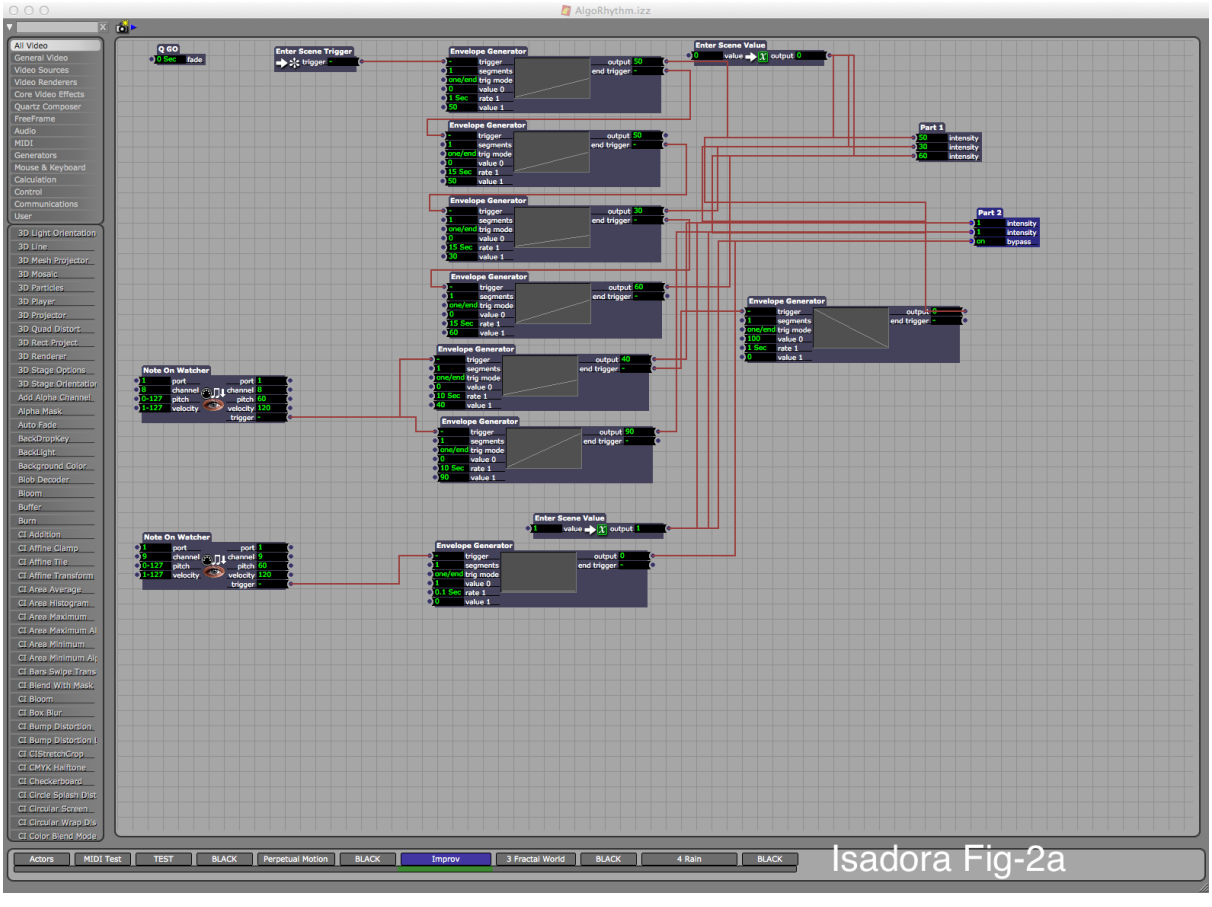
At the third part, the Colorizer is activated, and random RGB values (again based on MIDI note hits) are assigned to the channels of video.

The third piece is controlled by one scene with a variety of Envelope Generators controlling the fade and activation times of various values (Figs 3a and 3b). Again, everything is triggered by MIDI notes. The video transitions from one base geometric clip to another, and back again, all while having a Kaleidoscope effect applied to create the triangular shape. The X and Y positions of the video, as well as the variables of the Kaleidoscope effect, are controlled by MIDI notes on various channels, run through a custom value smoother. A Time Blur effect is also applied at some points.

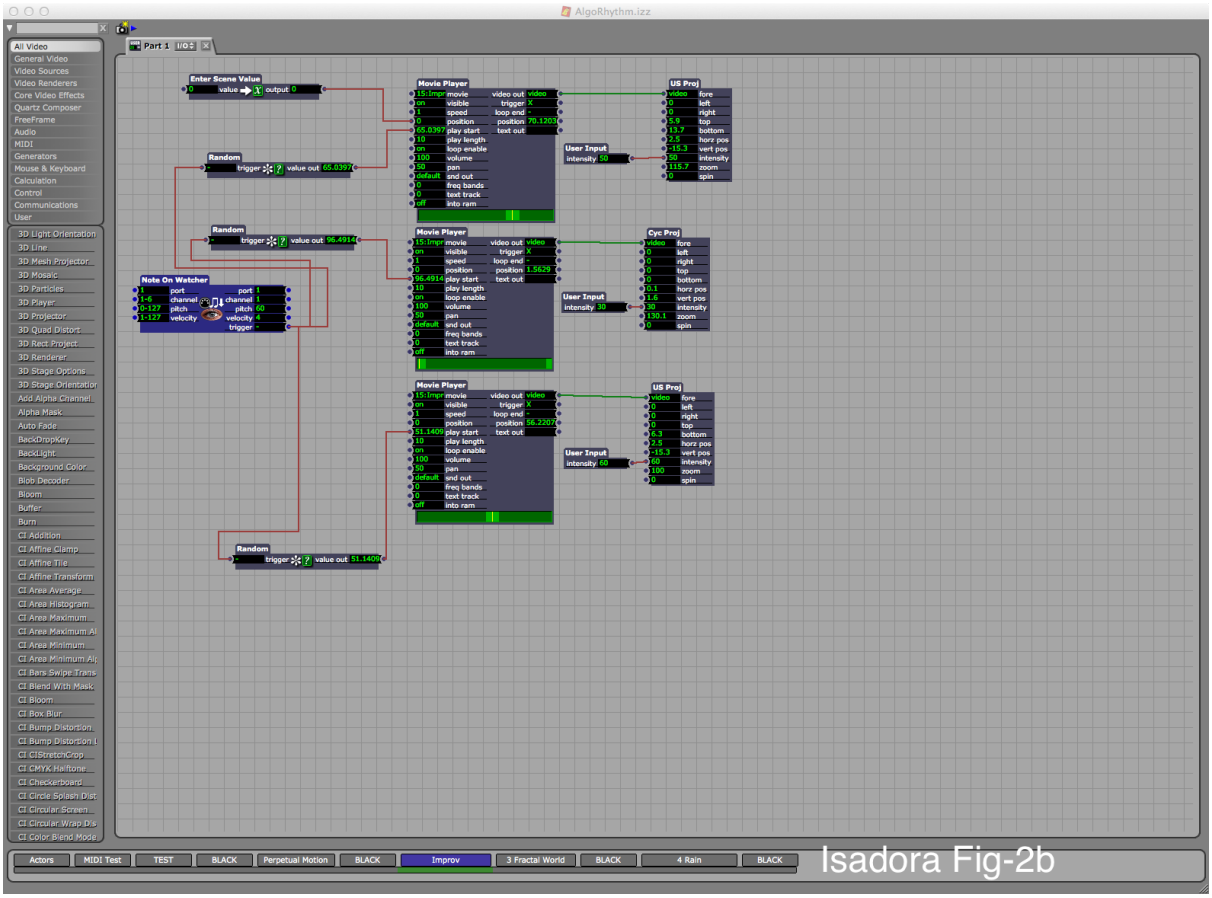
The final piece is similar to the first, insofar as it is mostly playback of pre-rendered content (Fig 4). However, the mixing, crossfading and play control is all timed out by Envelope Generators. As well, a small counter was added to list the current lighting cue (*Lx Cue*), as the last cues were timed based on the music and video position.



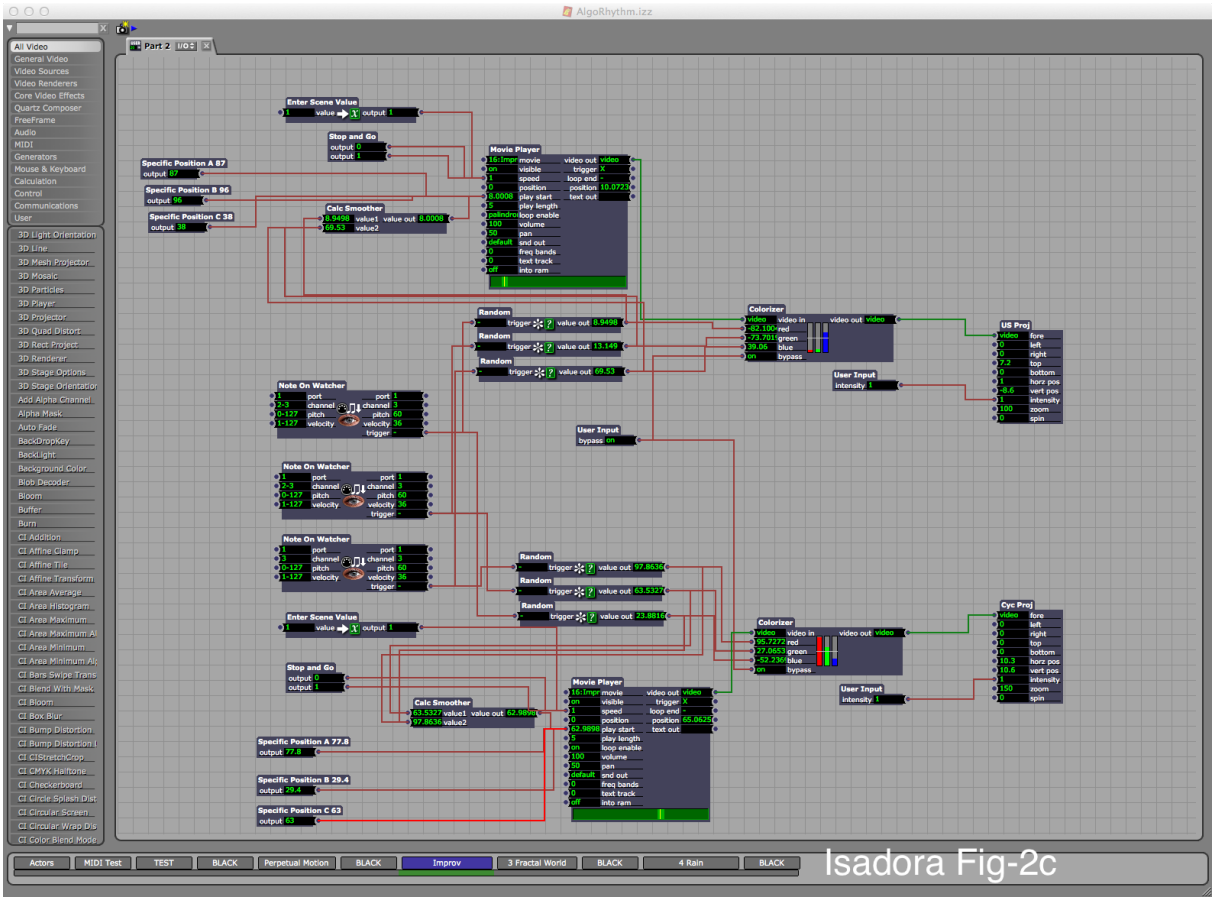
Isadora Fig-1



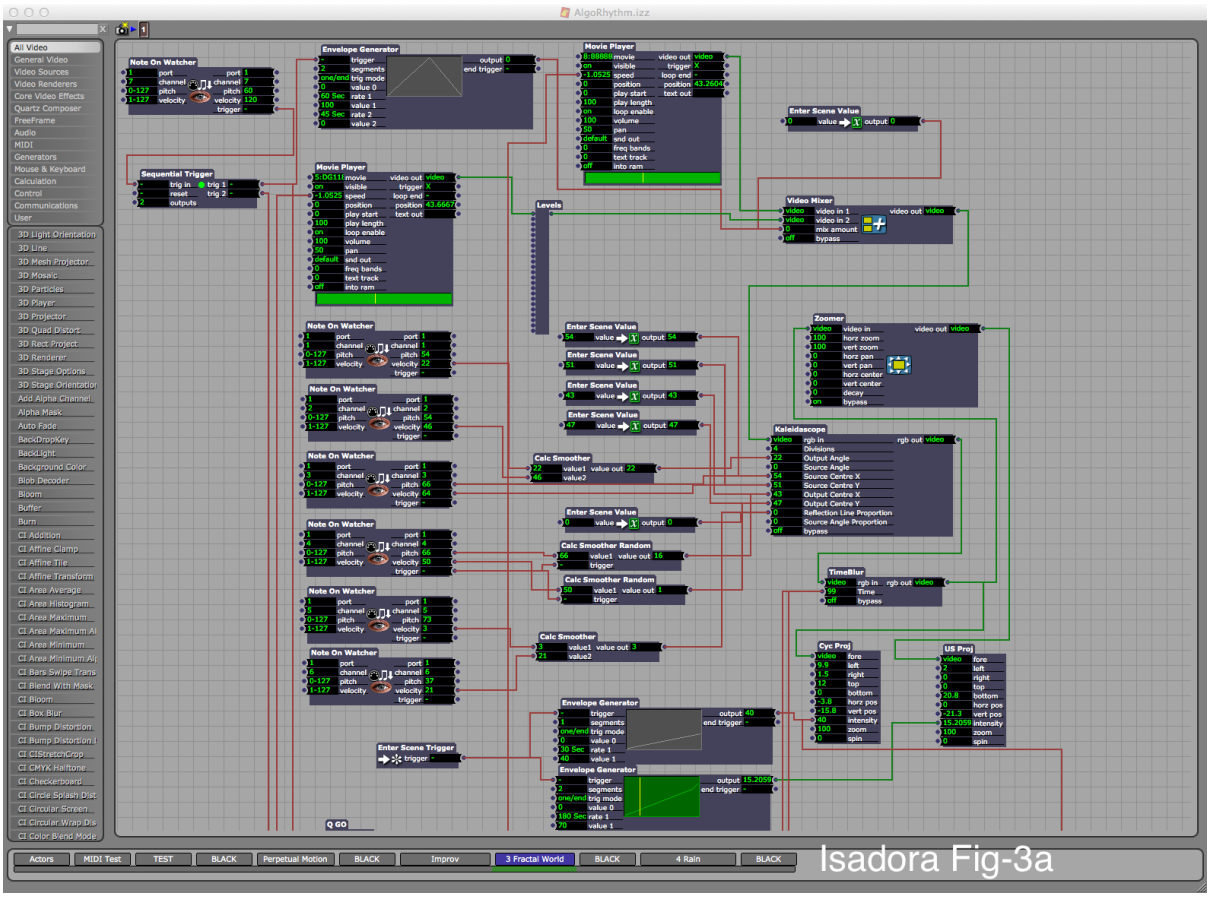
Isadora Fig-2a



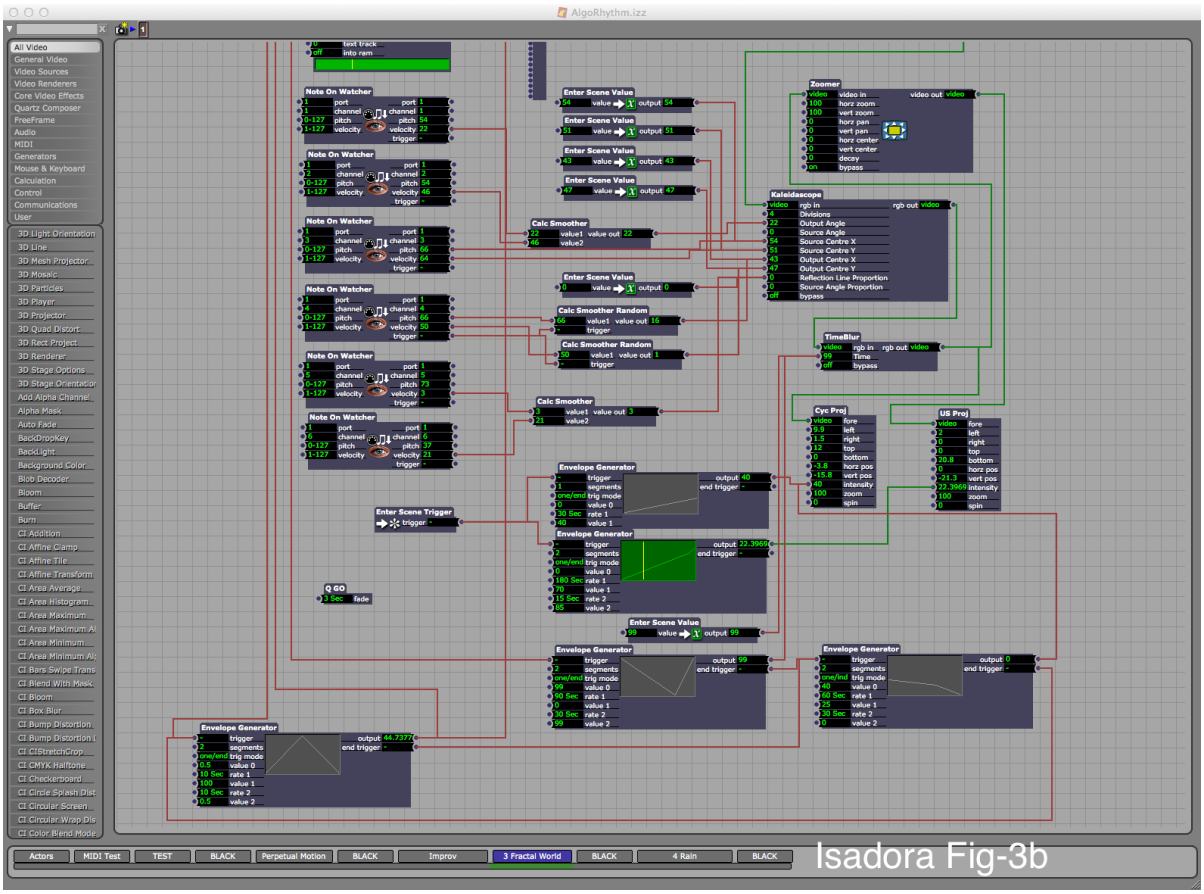
Isadora Fig-2b



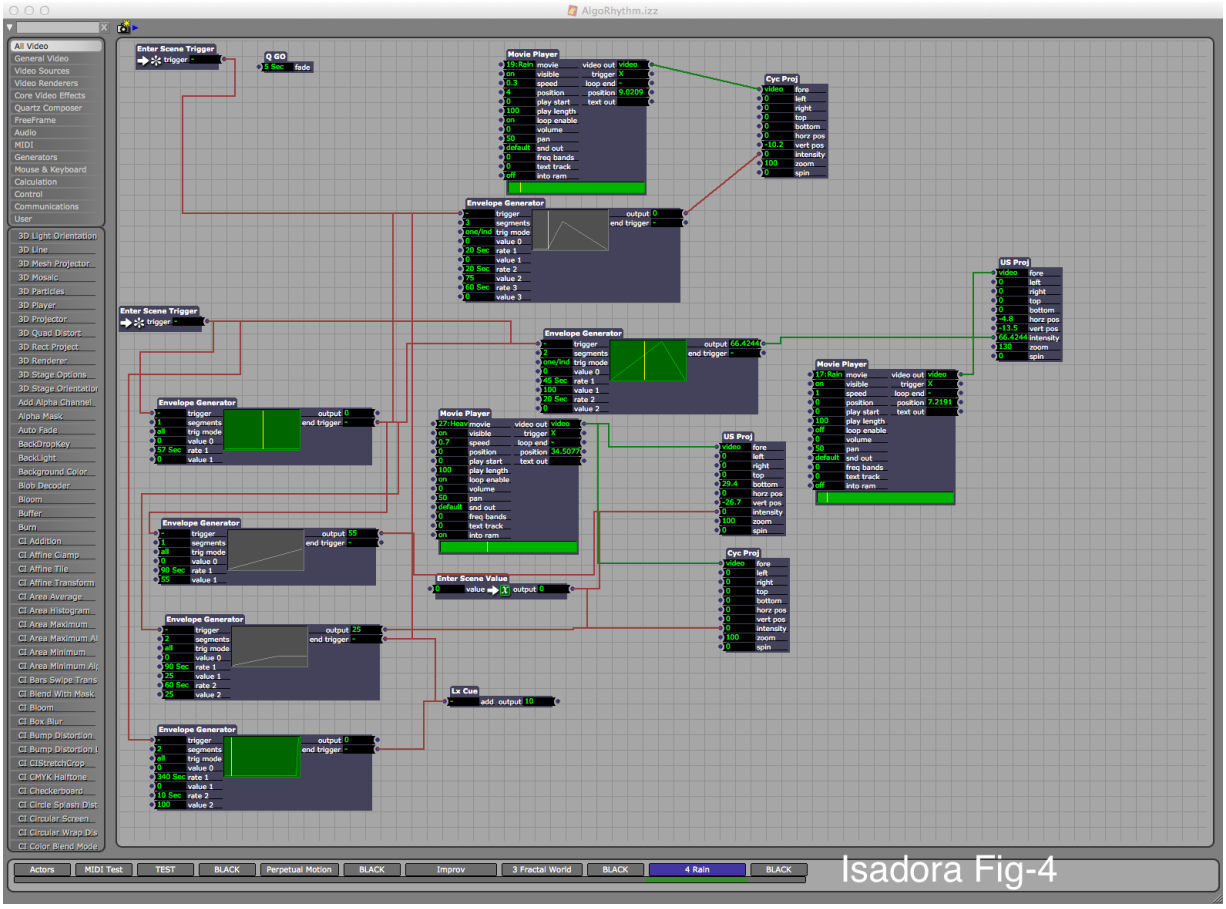
Isadora Fig-2c



Isadora Fig-3a



Isadora Fig-3b



Isadora Fig-4