

REAL TIME MUSIC VISUALIZATION:
A STUDY IN THE VISUAL EXTENSION OF MUSIC

A Thesis Presented in Partial Fulfillment of the Requirements for the Degree Master of
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ABSTRACT

This work documents a design-led process of discovery for artistic development of real time 3D animations functioning as a visual extension to a live music performance. Musical dynamics, patterns, and themes are transposed into a visual form that develops over time through a carefully orchestrated process driven by the artist and the computer. Historical animations by Fischinger, Whitney, and “light organ” projections by Wilfred inform the work’s conceptual development. Various systems automate camera controls, audio analysis, and layers of motion in addition to providing the artist with a unique set of controls that demonstrate the effectiveness of the computer as a visual instrument for the artist. The complete system balances artistic responses, live multi-channel audio input, and computer control systems to orchestrate a real time visualization of a live music performance. The artist’s sensibilities and the computer’s generative capabilities combine to create a visually-focused member in the performing music ensemble.

Dedicated to my Grandad

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FIELDS OF STUDY

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CHAPTER 1

INTRODUCTION

Music is a unique artistic form of expression. It has incredible power to inspire emotion, whisk one away to imaginary worlds, and envelop an audience in a temporal and sonic experience that is unlike any other art form. Music constantly changes, grows, and recedes in intensity as it develops over time. As a temporal medium, music is restricted to the continuous passing of time, or as Horton Presley eloquently noted, “music is by nature a momentary experience. The note sounds and is gone.” (Presley 9). Music requires the advancement of time whereas a painting or sculpture can be enjoyed or analyzed for any period of time. Visualizing music provides an alternate medium that can capture a brief snapshot or history of a music performance.

Now imagine if this visual medium could capture and display this essence of time, sonic decay, or a snapshot of the ever-changing intensity that exists in a music performance. Visualizing music could illustrate the initial attack of a note and its entire decay into silence within a single visual form. How might this visual form take shape? How could an artist use compositional space and time in an animation to illustrate this auditory experience? How would one design a visual language system that could effectively interpret and display this performance in a visual manner? The work documented in this paper explores some of these possibilities by incorporating 3D computer animation as a visual extension to a live music performance. These visual investigations stress the importance of the music as the predominant and controlling

factor throughout the development phases of the animation.

Dynamics are an integral part of a live performance and they create a unique and constantly changing variable during the performance. Just as music permeates a performance space, corresponding changes in positive and negative space within a visual composition create a powerful unity between the two different mediums. The use of visual space and how it conveys the dynamics in a performance is an important factor in the creation of these visualizations. Understanding and exploring this relationship is one of the aspirations for my work in music visualizations.

As a classically trained musician, themes in music define the composer's concept for the piece. These elements can illustrate how a composer developed his or her ideas in a piece of music, and they are important elements that I consider when listening to music. I understand how integral these thematic elements are to a music composition, but how could they influence my visual design process? Can themes in music successfully transfer to the visual animation? Can the structure and development process associated with composing a piece of music inform and embellish the structure of a visual animation? These explorations in music visualizations seek to demonstrate the effective use of relating music themes to specific visual forms in the animation. The guiding influence of themes and patterns in music as they relate to visual forms in the animation is another critical component to my work.

The system that enables these relationships to take place between music and visuals is another critical component to the music visualizations. Providing the artist with a unique tool set, this system contains a hierarchy of controls that allows the artist to visually manipulate incoming audio data and visually construct an animation. This system presents the artist with an open canvas for drawing relationships between musical elements and visual forms. These musical and visual explorations expand the boundaries of a computer as a content creation tool to elevate the computer to a companion role

with the artist in the execution of the real-time animations. The computer's function as a visual instrument for the artist is enhanced through the elaborate system of controls. This system balances the efficient data management and analysis capabilities of the computer with the artist's adaptive sensibilities. The hierarchy of control systems is designed to accommodate both entities' strengths. During the live performance, the system unites the computer and the artist. The computer becomes a visual instrument for the artist to play and the artist works in tandem with the performing musicians to create a 3D visualization that reacts to the live music performance. The artist and the computer can respond to each other and the music performance to create an animation that is a unique collaboration of all three entities involved.

This thesis documents this development process and discusses some of the conceptual ramifications of such a system. How much control should be allotted to the computer? How can the artist maintain a strong conceptual voice in the execution of the animation when timing becomes a critical factor? Can a system be created that caters to each of the strengths of the artist and computer? What controls would be most intuitive for the artist, and what control systems should the computer manage? These questions are addressed and discussed throughout the development of my work.

1.1 Methodology

This work documents and executes the process of designing real-time animations that function as visual extensions to music. The three areas of interest include music dynamics, interpretation of musical themes, and computer and artistic control, each of which is addressed in documentation of the design and development process. A historical account of previous explorations in music visualizations presents a conceptual and inspirational framework for precedents in the artistic and design decisions used to construct the music-driven animations. The works studied include abstract paintings,

abstract films, and performance-based installations that exemplify the use of color, motion, space, and time to represent relationships between visual forms and music. My explorations into the field of music visualizations spans from theory-based animations that depict complex patterns in music, to abstract, dynamic animations that strive to emulate the enveloping qualities of a live music performance. A chronological and conceptual accounting describes my processes, trials, and tribulations. Reflection, introspection, and critical analysis of my work are provided as I continue to develop new methods and build on successes from prior music animations. My work is constantly evolving and my methods continue to change. These changes are documented to reflect my growth as an artist in pursuit of creating a significant visual artwork that can accompany a great music performance. The documentation of these chronological investigations addresses three principle topics that are the guiding force for the music visualizations:

- The use of compositional space and its relationship to music dynamics
- The influence and guidance of themes, patterns, and motifs in music
- The transforming of the computer from a tool for media production to a real-time instrument in which the creation process occurs as part of the live music animation performance.

1.2 Design Challenges

The design challenges this project faces range from artistic and conceptual problem-solving to complex technical hurdles that must be overcome to create real-time music visualizations. Conceptual solutions include the choice of forms best suited to represent a musical theme or the use of visuals that effectively convey the range of dynamics in a music performance. Music performances contain an extensive range of dynamics. Performers can play so quietly that an audience may struggle to hear the

music or they can blast their instruments with tremendous weight and piercing qualities to the sound. The visual component needs to support this potential dynamic range. The selection of visual forms and appropriate use of compositional space needs to exhibit these dynamic qualities in music. If a piece of music is reaching its climactic moment, the animation needs to visually support this. Color choices and the use of space need to be considered and judged on their relationship to prior moments in the music and the animation. In addition to the influence of music dynamics, musical themes are informative to the artistic decision-making process because a musical theme represents the core concept for the piece of music. Composers will state, develop, and use variations on a theme throughout the entire piece of music. Choosing appropriate visual imagery or motion to represent a musical theme presents a unique challenge. This choice needs to support the growth and recession of dynamics in the music, and it must relate and develop in tandem with the musical theme. This will help facilitate the ultimate goal of the work which is to visually support the music.

The technical challenges involve creating a system that is capable of responding to a live music performance. This system needs to provide an accurate audio analysis, manage large amounts of data, manipulate this data according to an artist's definitions, and generate 3D animation on a screen within a real time environment. Response time is a critical factor for creating the perception that the visualization is responding to the live audio inputs. This real-time animation system will also need to balance the controllable parameters between the artist and the computer. The novel approach of this system permits the computer to make decisions during the creation and execution of the animation. This programmed ability needs to be balanced with the artist's control so that both entities work together to create an animation that is responsive to the music performance. All of these challenges are addressed throughout the development of my work and they are continually improved as my work evolves.

The experience of this work in a live performance setting and how it visually conveys the music to the audience is another important challenge. The delivery of the animation needs to be seamless and integrated with the overall performance environment. I do not want to expose the audience to technical limitations that exist in a real-time animation environment. Therefore, the visualizations need to maintain a fluidic motion and acceptable frame rate in the 3D animation, orchestrate camera motions that do not make viewers feel sea sick or severely disoriented, and appropriate high contrast imagery so the projected animation is clearly visible to the audience. The projected animation will compete with stage lighting on the musicians and ambient light that is present in any performance hall environment, so choosing high contrast imagery and colors is a factor that needs to be considered in the design phase of the animation. The logistics of screen positioning relative to the performers and installation of necessary equipment needs to be considered so that the visualization will blend with the performance space. The consideration of all these elements helps to create a unified and immersive environment that connects the visual experience to the music performance. It allows the audience to become enveloped in the visual component of the performance in much the same way the music envelops the space and the auditory senses. The synchronization between the animation and the music performance, combined with a seamless environment between the visual and auditory components creates an experience that reinforces the conceptual challenge of creating a music visualization that supports, enhances, and illustrates a live music performance through the use of 3D computer animation.

CHAPTER 2

ARTISTIC EXPLORATION AND MUSIC DISCUSSION WITHIN MUSIC VISUALIZATIONS

Music exemplifies expressive, structural, and emotive qualities that artists have sought to imbue in their works. Artists like Wassily Kandinsky believed that music had a direct emotional connection to the human soul and by creating visual art that emulated music, one could create a sensual experience that would yield a spiritual awakening (Brougher 31). Kandinsky wrote a treatise *On the Spiritual in Art* in 1911 that discussed the creation of synaesthetic works.

Color is the keyboard. The eye is the hammer. The soul is the piano, with its many strings. The artist is the hand that purposefully sets the soul vibrating by means of this or that key. Thus it is clear that the harmony of colors can only be based upon the principle of purposefully touching the human soul. (Brougher 31)

Kandinsky's paintings used a rhythmic interplay of geometric forms and color in an attempt to create a truly synaesthetic painting (Brougher 24). His work and the treatise he wrote inspired the works of other painters like Frantisek Kupka, Paul Klee, and Georgia O'Keeffe. Kupka's *Disks of Newton (Study for "Fugue in Two Colors")* (1912) was inspired by Sir Isaac Newton's color wheel and many of his works were titled after musical terminology (Brougher 38). Paul Klee considered polyphony, or multiple voices in music, a unique model for color gradations and compositional arrangements in his paintings (Brougher 57). O'Keeffe listened to music while drawing and painting, and she was a proponent of the idea that music could be translated into something for the

eye (Brougher 59). One of her works, *Blue and Green Music* (1921) represents her own ethereal visualization of music. All of these artists used visual forms and specific color choices to illustrate music in their own unique way. Their work has influenced my study and conceptual direction for associating music dynamics with the size and space of visual forms. The works of these painters strive to create a heightened emotional response in the viewer by linking musical inspiration to their creation process. My music visualizations attempt to create a similar heightened response from the audience by using music as the foundation for my project development.

2.1 The use of visual form and space in relationship to music dynamics

The music is the primary source for my inspiration and its constantly evolving nature creates a unique opportunity for exploration in visualization. A music performance is a one-of-a-kind event that cannot be perfectly replicated. The musicians cannot perform exactly as they did the night before, and a recording cannot perfectly replicate the experience of the live performance. All of these variables and variations that are inherent in a music performance present exciting opportunities for visualization. My work consistently refers and relates back to the music, providing the foundation for my visual work. The systems I develop and the visual forms I create are inspired and derived from subtle nuances, structural patterns, and stylistic interpretations that exist in a music performance. The works created for this thesis are not just artistic interpretations of music, but are visual extensions that strive to capture the dynamic interplay between musicians and structural patterns for the music being performed. As a musician and artist, I have a unique perspective on how visual form may take shape as informed by the complexities of a music performance.

My choice to associate the size of visual forms with the dynamic qualities of music is heavily influenced by previous works in music visualization and from an

instinctual perception that larger objects tend to emit louder sounds. Kandinsky writes in his 1911 treatise *On the Spiritual in Art*:

“Finally, our hearing of colors is so precise that it would perhaps be impossible to find anyone who would try to represent his impression of bright yellow by means of the bottom register of the piano.” (Brougher 32)

Kandinsky suggests that it would not be successful to associate bright, happy colors with lower notes or use dark, bold, and heavy colors to represent the higher pitches of a musical instrument. In the same gesture, it would seem contrary to represent a loud sound with a very small visual form or a very quiet sound with a large visual form. The correlation between visual size and loudness relates to an instinctual and survival nature in humans. Humans instinctively associate louder sounds with something that is closer, bigger, or more powerful. This relationship originates from theories of perception for survival and it is a critical factor in the evolution of humans (Proctor).

Dynamics play a critical role in music and their constant variability holds incredible opportunities for artistic exploration. Dynamics are often relative, and their role in a music performance is subject to the performer’s interpretation. In order to convey this, it is important to understand how dynamics are portrayed from a musician’s viewpoint. It is also important to my process when considering appropriate visual forms and their relative sizes. Certain styles and instrumentations of music such as Classical music or jazz ensembles exemplify a different kind of dynamic range when compared to Rock ‘n Roll music or a heavy metal band. My understanding of how dynamics relate to musicians allows me to better articulate this element in my visualizations.

Music dynamics are typically notated in written music by symbols that represent the dynamic changes in the piece. Composers will often use the terms *piano* and *forte* to denote soft or loud dynamics. There are graded variations between these terms which are listed as follows from softest to loudest: *pianissimo*, *piano*, *mezzopiano*, *mezzoforte*, *forte*, and *fortissimo* (Presley 19). In addition to these terms, *crescendos* and

decrescendos can also be used to indicate progressive changes in the volume over time (Figure 2.1). All of these symbols and terms help to guide a musician in performing a piece according to the desires of the composer. These symbols primarily serve as guides for the performing musician and their interpretations are often subjective depending on the musician and the style of the

piece. A *forte* in Barber's *Adagio for Strings* may be interpreted differently from a *forte* in Holst's *The Planets: Mars, the Bringer of War*. The *Adagio for Strings* has many smooth, lyrical melodic and harmonic lines that gently build in



Figure 2.1: An example of the symbols used in music to denote a *crescendo* or *decrescendo*

intensity and recede throughout the piece whereas *Mars* exhibits a thunderous march that builds to an incredible intensity by the end of the piece. Both pieces may call for *forte* at specific times, but the actual intensity of the sound will need to be relative to the style of the piece and the other dynamics that are in the music. Holst's piece would most likely result in a louder more forceful *forte*, whereas Barber's piece may be a more lyrical or stylistically different *forte*. In addition to stylistic differences in dynamic notations, music dynamics can also be altered by combining or omitting individual players within an ensemble. Dynamic intensity can be progressively built by adding musicians to the ensemble. Benjamin Britten's *Young Person's Guide to the Orchestra* adds instruments to progressively build the dynamic intensity of the piece which is exemplified by the staggered entrances in the figure (Figure 2.2).

One of the most prevalent visual elements an artist has at their disposal is the use of space. Visual space can be used to portray size and volume in a work, and it is often derived from a viewer's comparison of space within a composition. On a large



Figure 2.2: Section taken from Britten’s “Young Persons Guide to the Orchestra.” Each staff represents a different instrument and their entrances are staggered to create a crescendo effect

white canvas with a black square in the center, the area within the square can be considered positive, and negative space can be considered the white area around the square (Figure 2.3). The positive space constitutes the space within the object while the negative space encompasses the area that is defined by the frame and the outer edge of positive space. Artists are trained in drawing to be cognizant of the positive and

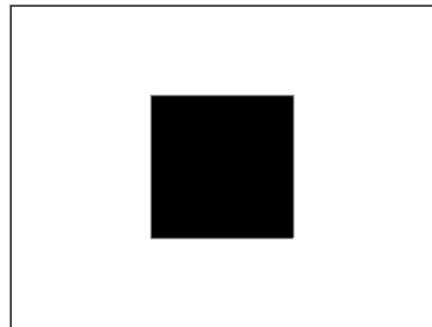


Figure 2.3: A black square constituting the positive space in the frame with the surrounding white space representing the negative space in the frame

negative space in their work. The use of space and its frame defines the composition. The goal is to create a work that is visually engaging to the viewer: A work that provides a roadmap for the eye and allows the viewer to discover subtleties in the composition (Fulks). This consideration in the use of space is an important aspect for my music visualizations. I try to create a work that is visually engaging because of its dynamic response to music and its use of positive and negative space within the composition. The system that is responsible for controlling camera motions is one of the most important

aspects in my visualizations, and it is a system I continue to refine. The camera defines the compositional frame in 3D computer animation, and its motion needs to support the music dynamics. During quiet moments in the music, the camera needs to be close to its subject and focused on the minute details. At louder moments, the camera can pan outward to provide a larger perspective on the developing visual forms (Figure 2.4).

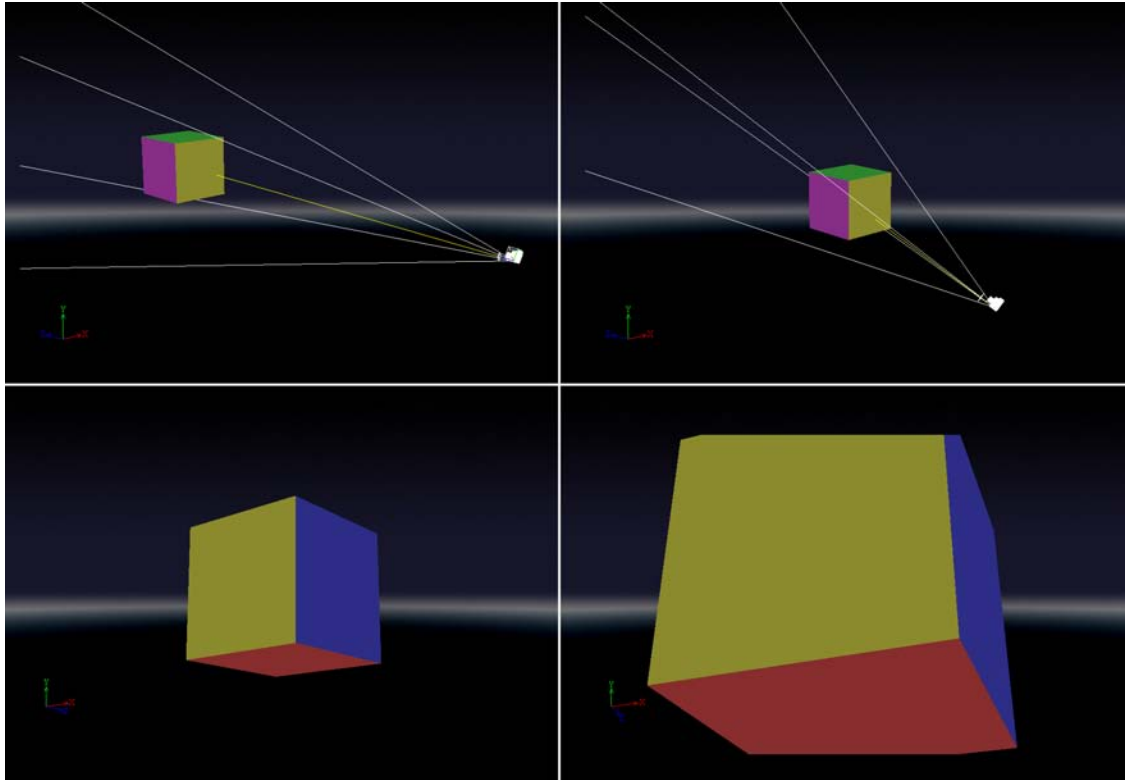


Figure 2.4: Representation of the camera altering its position which results in the cube increasing or decreasing in size relative to the compositional frame. This is a manipulation of size based on the camera only. The cube's actual size in the 3D world remains the same at all times.

In my process, the camera represents the definition of negative space and the adjustments in size for the visual forms that inhabit the composition are considered positive space. My goal is to develop a camera system that automatically adjusts to subtle dynamic variations in the music while still providing some flexibility for me to explore new viewpoints within the visualization. The developing visual forms within the

frame vary in size according to the dynamics of the music (Figure 2.5). These forms may expand to fill the composition or contract to the point where they are barely visible. These visual forms in combination with the camera's position and motion represent my use of positive and negative space. My animations attempt to create an effective representation of a live music performance that considers camera placement and the negative space associated with that placement and the size of the subject or visual form and its effective use of positive space.

The use of visual form and space in relationship to music dynamics is illustrated throughout all the works produced here. One notable example of this relationship is from the Drums Downtown IV work. A suspended cymbal is struck and a corresponding white ring of particles grows to encompass most of the composition (Figure 2.6).

As the ringing sound dissipates into the background, the white ring continues to expand outward and dissipate until it no longer exists. Another example, *Dreams*, associates ascending colored bubbles with the striking of piano chords (Figure 2.7). The bubble's size is related to the velocity of the piano key being struck. The velocity information is derived from MIDI data, and it is used to adjust the scaling of each bubble. Another example of spatial relationships and music dynamics is used in the construction of the real-time animation system for Drums Downtown V, *Arctic Fracture* (Figure 2.8).

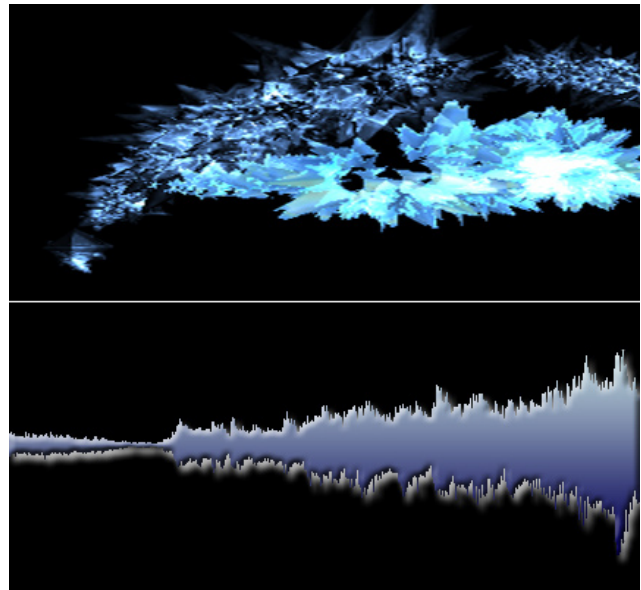


Figure 2.5: A visual representation of a sound wave increasing in volume and a developing visual formation that correlates in size to the sound wave increase

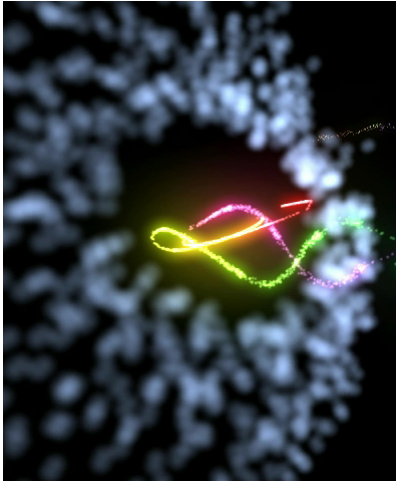


Figure 2.6: Cymbal attack represented by the white ring or shockwave in Drums Downtown IV

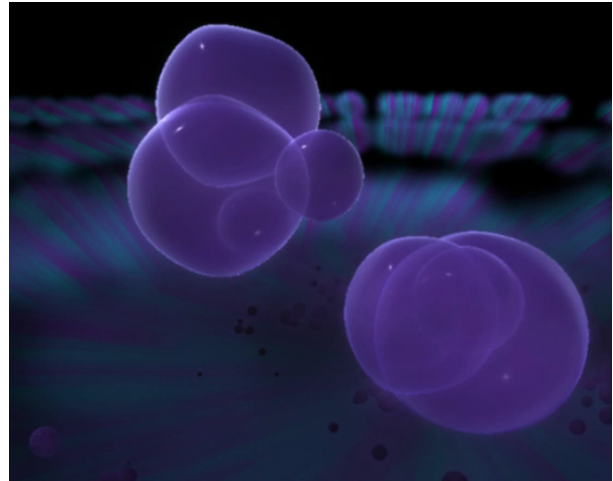


Figure 2.7: *Dreams* animation where the purple bubbles represent piano chords. Variations in size equate to different velocities at which the piano keys are struck.



Figure 2.8: *Arctic Fracture*'s ground plane that would adjust in surface color from light to dark according to differences in the incoming audio amplitude

This animation uses a programmable texture to control the surface color for the ground plane. At low dynamic intensities, the ground plane is completely black or invisible to the audience therefore creating significant negative space in the composition. As the dynamics increase, the ground plane becomes visible with blue hues and at climatic

moments, the ground plane becomes completely white. All of these animation clips exemplify some of the artistic approaches I take to associating visual space to dynamics in music.

2.2 The function of themes, and patterns in music as they relate to visual form and time within animation

My training in music has helped to elucidate structures and patterns that exist in music, and it has helped provide a framework for my understanding of the compositional process used in music. This understanding of music is important to me and my process for developing visualizations because musical structures can potentially influence my design choices and help provide a similar structure for my animations.

A theme in music is the principle concept that is addressed throughout the piece, and it is typically integral to the overall form of the music. Themes can vary widely from long lyrical lines like Beethoven's "Ode to Joy" from his 9th Symphony to small, short phrases. An example of a shorter theme is the famous theme in Beethoven's 5th Symphony, often referred to as "destiny or fate knocks at the door." (Schenker 165) (Figure 2.9) This theme functions as a unifying structure, both rhythmically and melodically, throughout the entire symphony (Schenker 165). Beethoven would layer and iterate this theme throughout for added texture, transpose it for further development, and restate it through different instrumentation in his fifth symphony. Themes function as an



Figure 2.9: Beethoven's 5th Symphony rhythmic theme, "Fate knocks at the door."

overall concept for a piece of music and as Beethoven demonstrates, they can be used in melodic, harmonic, and rhythmic capacities to unify the entire piece. Relating visual forms to themes in music can help unify the animation just as musical themes help unify

a complete musical work.

I often create a visual form that will function in a similar manner as a musical theme. This visual form is stated frequently throughout the animation and typically in correspondence with the statement of the theme in the music. The visual form may iterate and develop into other forms during contrasting sections in the music and return to the original visual form to represent a restatement of the musical theme at the end of the music. The visual form might be a short animation or a unique symbol or shape with the goal of using the structural influence of a theme in music to provide a structural influence in the animation.

An exploration of this visual concept is exemplified in a video installation I constructed in Max/MSP/Jitter. This example uses the theme from Beethoven's 5th symphony as the basis for a short animation. Each time the theme is stated in the piece, the program plays a short fragment that represents the theme in the music. As the musical theme becomes layered, more and more animation fragments become visible in the composition (Figure 2.10).

The animation is an interesting visualization of themes within music because it demonstrates the immense overlaying texture of themes, and their integral function in the overall form of the music.

It illustrates how frequently and how connected the "fate knocks at the door" theme is to Beethoven's Fifth Symphony. My other investigations do not illustrate

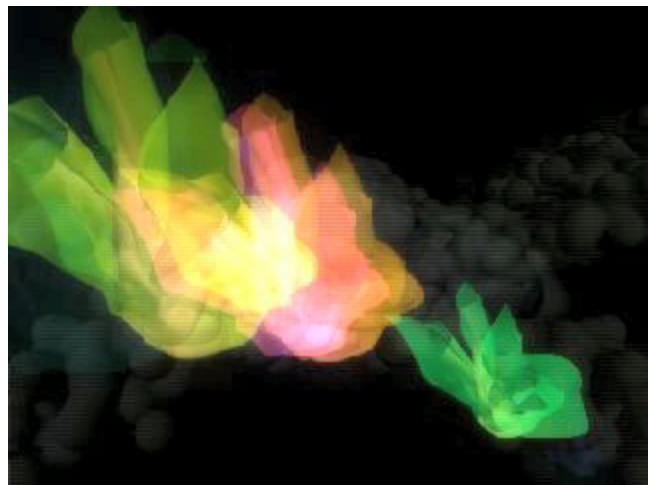
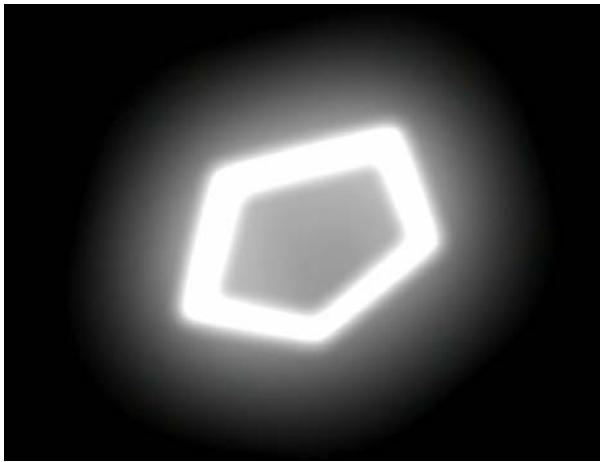


Figure 2.10: The different colored forms each represent one fragment of Beethoven's 5th symphony theme. The repetition and layering of the theme between different instruments is visually constructed in this animation.

a precise one-to-one mapping relationship between a specific visual form and a music theme, but some of my works do create a visual form that functions in the same way as a theme in music functions. The visual repetition, iteration, development, and consistency solidify the overall concept and structure of the visual work.

Another good example of this visual thematic relationship is in the Drums Downtown IV work. A hollow pentagon-shaped symbol is used throughout the piece to



denote a particular rhythmic pattern in the music (Figure 2.11). This pattern re-surfaces multiples times throughout the piece because it is the most audible pattern during two large sections of the piece. During these two sections, the pentagon shape forms in time with each hit of the higher-pitched drum beats. In

Figure 2.11: Drums Downtown IV's pentagon theme which was used to denote particular drum patterns in the music.

the middle section or development section, I allude to the pentagon by outlining a star shape of particle trails (Figure 2.12).

In the final section of the piece, I create five different particle trail systems that ultimately join together at a single point. A large pentagon shape expands outward from this



Figure 2.12: Drums Downtown IV five-pointed star shape that functions as a subtle reference to the five-sided pentagon shape

central point filling the composition at the end of the performance (Figure 2.13). This example demonstrates how an important pattern or theme throughout the music can be transposed into a visual form that provides a unifying symbol throughout the animation. The pentagon shape is presented in two large sections of the animation, and it is subtly suggested in other sections of the animation. These characteristics are similar to how a theme or motif would be presented in a music composition. The importance of a theme in music influences my choice of shapes and forms, and I try to play off the musical theme and use it to strengthen the visual composition. The combination of both visual and musical themes creates a tightly integrated work that reflects the goals of creating an animation that functions as a visual extension of music.

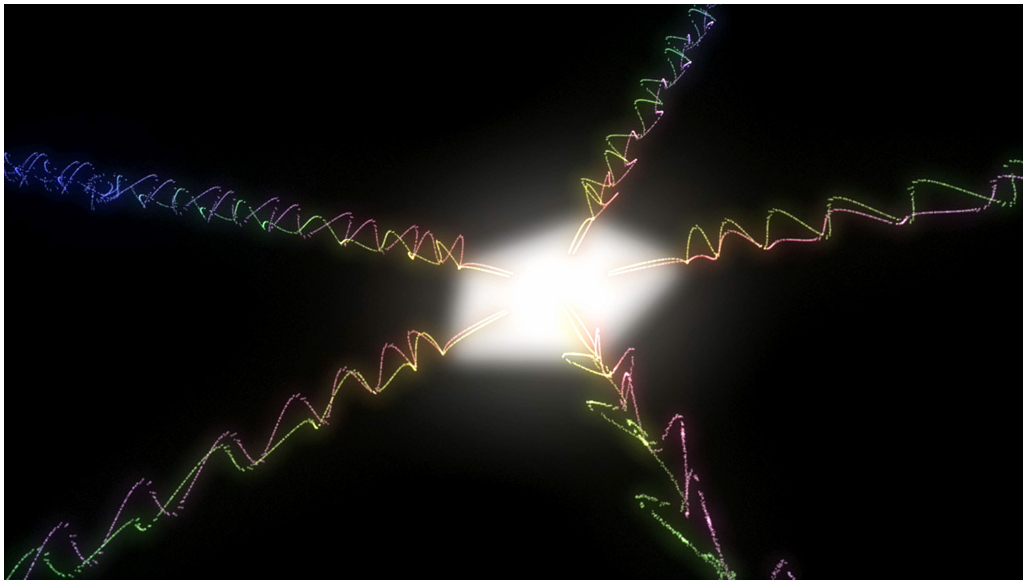


Figure 2.13: The pentagon shape at the end of the performance right before it completely engulfs the entire frame.

CHAPTER 3

HISTORICAL ACCOUNT OF MUSIC VISUALIZATIONS

A historical account of music visualizations serves as an inspirational and conceptual point of departure for my work. Many of these works have influenced conceptual development and design choices exercised in my music visualizations. Some of these influences in my work range from Fischinger's use of abstract shapes and motions to Wilfred's organic and ethereal "Lumia" works. This documentation provides a brief chronological synopsis of some important works that relate to my music visualizations and some of the concepts I gained insight from the works.

The marriage of visual and music forms has challenged and inspired artists, composers, and philosophers in our culture for centuries. Artists and musicians have combined the two forms to create new works ranging from abstract paintings to color organs to immersive multimedia environments. Many artists have attempted to create synaesthetic works that unite the senses of sight and sound (Brougher). The theory of synaesthesia breaks down sense perception into discrete units, whereby one sensation finds its equivalent in another; music, with its notes and phrases, harmony, and compositional structures, lends itself most readily to visual form, color, space, and motion (Brougher). The idea of uniting visuals with music is to create a synaesthetic experience that allows a viewer/listener to feel a transcendence or poetic response from the work (Brougher 213). Some, like the Whitney brothers (1940's – 1980's), went so far as to define themselves as a new kind of composer: One that could create ideas musically and

visually (Whitney 17). The advent of computers further facilitated the interdisciplinary drive to create works that combined visual and auditory mediums. John Whitney considered the computer as the ultimate tool for constructing a work that included visual and auditory mediums (Whitney 17). In the digital realm of the computer, all data is treated equally. Audio and visual data share the same framework of binary information so both mediums can be combined, manipulated, and juxtaposed in a programming environment.

3.1 Color Mappings to Pitches

The drive to create this synaesthetic experience in a work began with paintings in the 18th century by associating specific colors with specific pitches in music. The goal was to unite two different mediums, painting and music, in an attempt to elicit a poetic experience for the viewer. In 1704, Sir Isaac Newton's original concept was to create a one-to-one mapping of the seven notes on a piano to seven colors in the rainbow (Collopy). Other artists and inventors like Castel, Bainbridge, and Rimington each had their own perspective on the appropriate color to sound mapping scheme (Brougher) (Figure 3.1).

The figure illustrates a brief historical account of various different pitch-to-color mapping schemes with most sharing a similar color scheme and some differing radically (Collopy). Scriabin had a unique color mapping scheme (c. 1911) that was based on the circle of fifths instead of a chromatic association like Newton's concept (McDonnell, Collopy). The circle of fifths iterates through all the available notes on the piano, A through G#, by progressing in intervals of five rather than chromatically by intervals of one on a piano keyboard. Though many of these mapping schemes like Newton's were theoretical in their application, the invention of the color organ and the desire to "paint with sound" drove many inventors, artists, and musicians to

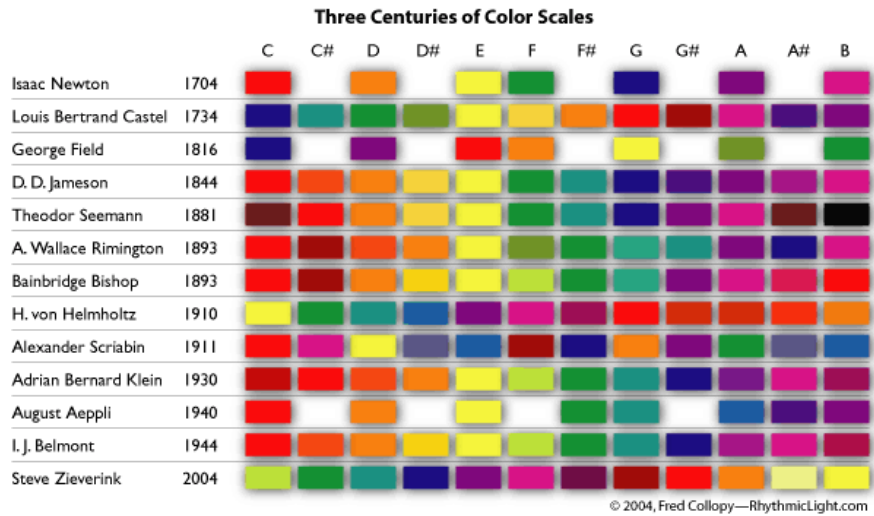


Figure 3.1: A chart of various color-to-pitch mapping schemes throughout history

construct their own ideal color-to-pitch mapping schemes. The color organ became a physical realization of these various mappings.

The choice to map colors to specific pitches is also evident in my music visualization works. The animation, *Dreams*, uses colors to denote changes in the chords (Figure 3.2). The first chord is represented in green and successive chords are illustrated

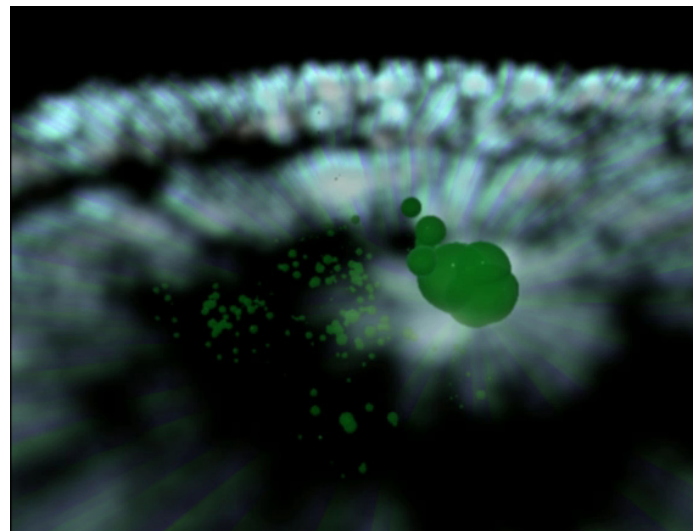


Figure 3.2: *Dreams* animation showing the beginning chords in green



Figure 3.3: Color to pitch scheme where red equals lower frequencies while greens and blues represent higher pitch frequencies

with blues, purples, and whites. The demonstration I created for ACCAD's (Advanced Computing Center for the Arts and Design) open house in 2007 shares the closest relationship to Newton's mapping scheme. The colors for the orbiting trail effect use a direct mapping of the visible spectrum to the audible range of audio frequencies. Lower frequencies are represented in red while higher frequencies are colored green to blue (Figure 3.3).

Aside from these examples, the role of specific color mapping schemes in my work is more of an aesthetic choice that varies between the works. I do not try to conform to one specific mapping strategy or restrict my choice of color based on musical pitch. My color choice is related to visual themes and the choice of music. For example, in the

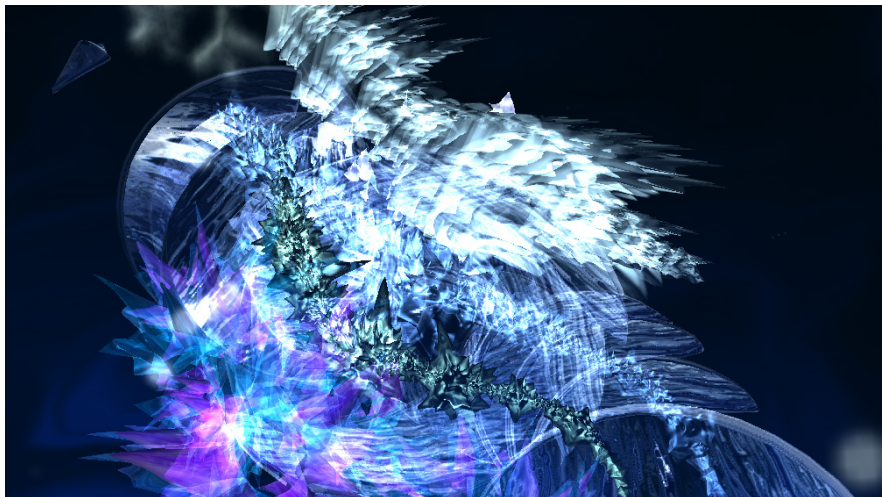


Figure 3.4: *Arctic Fracture* with varying shades and hues of blue which were used to create an arctic landscape or frozen theme

Arctic Fracture animation, my inspiration for the piece was frozen water droplets and crystallizing ice formations. Variations in the color blue were used to illustrate this theme and its frozen environment (Figure 3.4).

3.2 Color Organs

One of the first major inventions that merged sound and colored light was the “light organ” (also known as a “color organ”). A light organ is essentially an organ or clavichord that would emit a colored light based on which piano key was pressed (McDonnell, Brougher 70). Louis Bertrand Castel created the first light organ in the 1730’s. His invention consisted of a clavichord with a screen placed above and small windows with colored glass. Behind these windows were curtains that were attached to keys on the keyboard. When someone pressed a key, a curtain would open up and allow light to shine through the colored glass (McDonnell, Brougher). Bainbridge Bishop created a similar variation around the end of the 19th century, but A. Wallace Rimington was the first to create a color organ that used electricity in the early 1900’s. This was the instrument that was used for Scriabin’s *Prometheus, the Poem of Fire* (Jon and Moritz). Scriabin’s piece was specifically written for the color organ in 1910, and he even had the conviction to suggest that audience members should wear white so the colors from his piece would reflect off of them and create a unique interactive painting (Moritz). This work is unique in that it challenged the notion that audience members were merely observers of the performance. Scriabin’s piece invited the audience to become participants in work. The resulting effect was an interactive light painting installation that encompassed the entire performance space by including the musicians, light organ, and the audience.

Thomas Wilfred also created a device similar to the color organ that produced light projections for music in 1921. He called this device a Clavilux, and the art form was

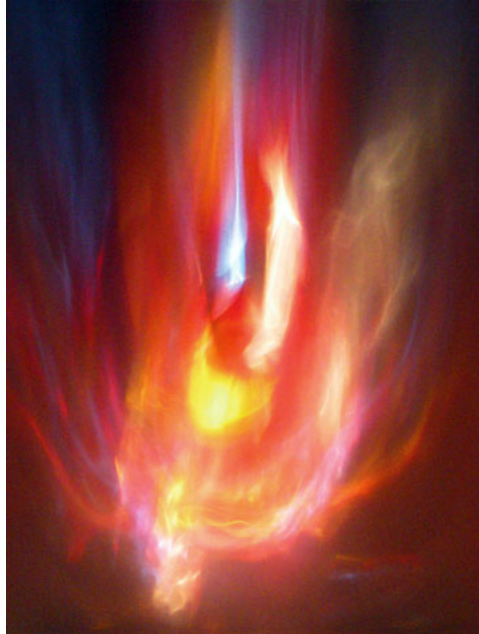


Figure 3.5: An image from Wilfred's Clavilux device that created his art form, "Lumia"

titled "Lumia."(Brougher 76) Wilfred even made small Lumia boxes that could be placed inside people's homes. These devices looked very similar to small televisions (Lovstrom). His Clavilux devices created some incredibly ethereal-looking projections of music (Figure 3.5). Wilfred's instrument created these effects according to this description provided by the Hirshhorn Museum:

"Incandescent light passes through a moving stained-glass color wheel and a moving reflecting cone aimed at rotating shaped-aluminum reflectors to form constantly changing images on a translucent screen." (Brougher 82)

These light projections are a driving inspiration for my works. The ability to "paint with light" or construct ethereal, fluidic forms have captivated and pushed me to recreate this concept using 3D computer animation. The ethereal, gas-like quality of Wilfred's Lumias represents this unique spatial quality in music, and its inherent ability to immerse an auditorium in sound. Music is a very expressive medium and this is often apparent in the physical motions and passion exemplified by a musician

performing live. Capturing the vigor of a violinist's down bow stroke during a driving musical passage, the sway of a trumpeter's bell as they rise above the orchestra's musical texture, or the intricate and subtle motions of a flutist as they fly up and down along a cascading musical line are all examples of expressive motions musicians may use during a performance. These energetic motions inspire and drive some of the concepts in my music visualizations. An amorphous form that can solidify or gently float throughout the compositional space is a quality I try to develop in my work. Another quality of these forms is their ability to linger in visual space, in the same way a musical note decays over time. These qualities are exemplified in my work through the consistent use of transparency and somewhat organic construction of my visual forms. The organic bubbles in *Dreams* that represent piano notes, the sine-wave DNA motion of particles in *Drums Downtown IV* representing the two performers, or the water-like surface quality in *Arctic Fracture* that represents the bass drum all illustrate this organic visual form that is appropriate to a visualization of music. John Whitney described the computer as a tool that allows an artist to paint with light; a perspective that I find to be inspiring because light shares many qualities of music. Similar qualities of light and music include being intangible in form and capable of adding dimensionality to a space. 3D computer animation allows me to manipulate light in a virtual world, and it is an excellent medium for constructing ethereal and organic visual forms.

3.3 Abstract and Story-based Cinema

Oskar Fischinger was one of the most prominent filmmakers in creating synaesthesia between music and visual motion. Some of his more famous works include *Motion Painting No. 1*, *Composition in Blue*, and *An Optical Poem* that were produced for MGM and distributed to theaters nationwide in 1937 (Zone). Fischinger essentially created the first music videos almost 60 years before the creation of MTV. He constantly

strived to find visual harmony in his artwork through the use of color, space, and motion (McDonnell, Brougher). In the 1940's Fischinger worked with Disney to help create the film *Fantasia*. He left due to artistic differences, but examples of his work can clearly be seen in the first Bach section of the film (Zone).

Fischinger's film work illustrates the powerful nature of music and visual synchronization. His works demonstrate the importance of timing between music and the visuals. This perception is vital to music visualizations because it can visually emphasize the performance qualities of music which may include dynamics, pattern, and form. Fischinger's Motion Paintings are a significant contribution to the visualization of music. White lines, arcs, and other abstract shapes dance across the compositional frame in response to the music. These motion paintings almost resemble a carefully orchestrated ballet of abstract shapes. Their entrances and exits from the frame are perfectly synchronized to important beats in the music. Fischinger's work strives to "create a synthesis of visual art and music that could be consumed by large numbers of people" (Brougher 91). His approach to music visualizations is a particular concern for my work. In a similar manner, I want my music visualizations to pervade throughout the concert-going public. The music animations in this thesis attempt to envelop the audience in the performance space and connect them to the dynamics and thematic development of a music performance.

Disney's *Fantasia* was conceived by Walt Disney and it was originally called "The Concert Feature." Disney wanted to "develop the concept of using animation not just as a potent story-telling device but as a kind of new art form by conceptualizing serious music on a screen (Walt's Masterworks). *Fantasia* was a significant financial undertaking for Disney and an unconventional experiment to combine story-driven animation with classical music. It did not become successful for Disney until its re-release in 1969 (Brougher). Disney would continue to capitalize on re-releases of

Fantasia and eventually release *Fantasia 2000* to continue Walt Disney's original vision. That concept was to make *Fantasia* an ongoing work that would constantly evolve over time and introduce new animations while still retaining some of the original ones (*Fantasia 2000*). *Fantasia* shares a similar goal with Fischinger's works: To combine visuals with music to create a new kind of work that can be presented to the mass public. *Fantasia* demonstrated that music and animation could be linked successfully and distributed to the general public through the film medium.

In *Fantasia 2000*, Disney animators created short animations that varied from abstract colored butterfly swarms in the first movement of Beethoven's 5th Symphony to toy soldiers and ballerinas falling in love in Shostakovich's Piano Concerto No. 2 Allegro Opus 102. The animation sequence that accompanies *Carnival of the Animals* by Camille Saint-Saëns contrasts the orchestral accompaniment with the piano soloist by juxtaposing the instrumentations with a goofy yo-yo wielding flamingo as the pianist and an orderly, no-nonsense flock of flamingos as the orchestra. The contrasting nature of the characters relates to contrasting dynamics and interplay that exists between the piano soloist and the orchestral accompaniment. These carefully orchestrated animations use the characters to represent thematic and instrumentation differences in the piece. This technique of associating specific visual forms or characters to a particular musical element is an important technique I explore in my music visualizations. In my work, *Arctic Fracture*, I represent each musician in the ensemble with a different ice formation. The final result illustrates a unique dynamic interplay that exists between the musicians during the performance. As the musicians respond to each other by varying their dynamics, different ice formations expand and contract in size.

CHAPTER 4

COMPUTER DEVELOPMENT IN MUSIC VISUALIZATIONS

The advent of computer technology facilitated a new development platform for music visualizations which enabled audio and visual information to be combined and manipulated. Both mediums could be controlled and adjusted with one universal tool; the computer. Max Mathews is considered the grandfather of computer sound synthesis and his work began around 1961. Beginning in 1970, Max Mathews developed a new synthesis system at Bell Labs called GROOVE (Generating Realtime Operations On Voltage-controlled Equipment) (Spiegel). This computer had numerous inputs ranging from knobs, sliders, joysticks, to even a small organ keyboard. People could create programs using the computer's FORTRAN IV and DAP 24 bit assembly language. By specifying various connections, users essentially created "patches". The system allowed a user to control and interact with many different physical interfaces in real time. A video component was added to the system in 1974 and thus VAMPIRE (the Video And Music Playing Interactive Realtime Experiment) was born. Unfortunately, due to hardware constraints at the time most of the work could not be recorded. The entire system was operational from the late 1974 until 1979 when it was dismantled (Spiegel). The contributions from this system include a flexible, user-patchable sound generating system. Contemporary software such as Cycling '74's Max/MSP program is based on the contributions of this system, including the name, "Max," and the ability to control multiple inputs, outputs, and modify their contents as they move from one "patch" to

another. Max/MSP program has led to the proliferation of many real time video and audio projects because of its unified development platform. Audio signals, MIDI data, and video processing can all be integrated and developed in the Max/MSP program environment. The invention of MIDI (Musical Instrument Digital Interface) provided a common framework and specification for computers to interact with many different mediums including music, and stage lighting systems. In addition to allowing precise recordings of digital instruments like drum machines and electronic keyboards, MIDI can be used to control live video feeds, synchronize recording equipment, or even drive 3D computer animation. The Max/MSP program provides a unified graphical environment for the combination of MIDI, music, audio, and other multimedia.

4.1.0 Current Approaches to Music Visualization: from theory-based to expressive/interpretative

4.1.1 Stephen Malinowski's *Music Animation Machine*

Stephen Malinowski's *Music Animation Machine* is one example of a contemporary approach to music-driven animation. The goal of Malinowski's *Music Animation Machine* is to illustrate a musical score that can be understood intuitively by anyone without needing years of conventional music training and to bridge the gap between a static page of music notation and the time-based movement of music. His animations display a moving score without any measures, clefs or traditional music notation (Malinowski). Malinowski's first animation machine used hand coded values for each measure in the music, and his later revisions incorporated MIDI as a way to automate this process of synchronizing visuals to the music. His music animation machine resembles a scrolling bar graph with different blocks lighting up as the

corresponding musical note is played (Figure 4.1). The length of the bar is associated with the length of the note, and its position on the Y-axis corresponds to frequency of

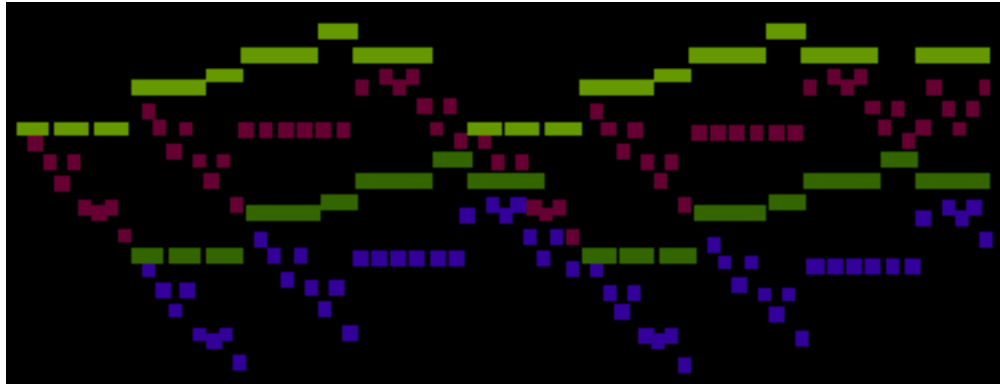


Figure 4.1: Malinowski's *Music Animation Machine*

the note. This bar scrolling visualization allows viewers to see how pitches and timing in music relate to each other. His use of color denotes different instruments, thematic material, or tonality (Malinowski). As the music progresses, different bars are highlighted as their corresponding notes are played. The graph continuously scrolls to the right so that currently playing notes are always kept in the center of the frame. This concept has also inspired other works that expand on this visualization like *Moonlight* by Jared Tarbell, Lola Brine, Corey Barton, and Wesley Venable. Their installation was exhibited at the Texas Fine Arts Association gallery in downtown Austin, TX as part of the 'Digital Face of Interactive Art' exhibition organized by the Austin Museum of Digital Art (Tarbell). Malinowski's work has also explored many other facets of music such as instrumentation, tonality, timbre, interval relationships, overtone interactions, and chord relationships. Each of these different music components have their own unique visualization that does not necessarily adhere to his original scrolling bar graph. These visualizations vary tremendously with some incorporating multiple colors, shapes, connecting lines, and unique forms that represent different aspects of music (Malinowski). Malinowski even

created a series of works entitled *Oskarettes* which resembled the motion and flow of Oskar Fischinger's early motion studies (Malinowski).

Malinowski demonstrates a methodical approach to visualizing specific elements of music that has driven the analytical approach I use to create the animation based on the Bach Fugue analysis by David Lewin. Some of Malinowski's animations are highly analytical in nature and focused on specific elements in music with a targeted approach that seeks to visually illustrate that precise element in music. Some of the concepts visualized in his experiments are frequently discussed in music theory coursework, for example the study of interval relationships. The goal of these analytical animations is to inform the viewer about a complex process or structure that is inherent to music. This process could be chord progressions and relationships between note intervals in these chords or interval relationships between different melodic passages in the music. Artistic expression is often reserved in these demonstrations because the animations are primarily designed to educate the audience, and their design is targeted towards the concept that is illustrated. The *Music Animation Machine* has far more applications in an educational context or to further the development of a specific concept in music analysis. Stephen Malinowski's *Music Animation Machine* is designed to illustrate a simplified variation of traditional music notation that is easy to understand without significant musical training. I, on the other hand, want to capture the essence of music as an audience member who sits and listens to a musical performance. The music analysis plays an important role in my early decisions for an animation but the final product is not designed to educate or illustrate some of the complex intricacies in music. I want to illustrate the expressive dynamics of a music performance, so my music visualization demonstrations focus on the performance-based aspects of the music and the expressive qualities that are inherent to a performance. My goal is not to educate the audience but to build on and accentuate the emotive and dynamic qualities of a music performance.

4.1.2 Wayne Lytle's *Animusic*

Another artist that has incorporated the use of MIDI in music animations is Wayne Lytle and his *Animusic* animation series. “The things that differentiate us from most other animation studios such as Pixar is that our animation is driven by music rather than a story, and that most of the animation here is generated procedurally rather than through keyframing.” (Alberts) Lytle uses MIDI data to generate key frames for 3D computer animation. One of his famous animations, “More Bells and Whistles,” was shown at SIGGRAPH in 1990 (Lytle). All his animations incorporate the use of visually complex computer models of instruments with unique apparatus that play these instruments. Some examples include multi-head guitar platforms with several robot fingers that launch outwards to pluck the strings or laser light shows that fire beams of light in time with melodic lines. One of his popular works, “Pipe Dream,” launches small balls in perfect trajectories that hit sprawling arrays of drums and xylophone contraptions. Lytle’s animations demonstrate the potential and capabilities of using MIDI to control an animation. A MIDI file contains the exact timing and pitches for all the notes in a piece of music. This information allows Lytle to create animations that perfectly anticipate the specific note they represent. If a note event occurs at a specific time in the music, Lytle can create an animation with a trajectory that preempts the starting time of that note. An example of this concept is illustrated in “Pipe Dream.” Balls are launched from a central emitter long before the note they represent is sounded. Because of this effect, the animations exemplify a tight integration of sound and visuals with unique designs for the construction of the virtual instruments. Another unique musical trait Lytle’s *Animusic* visually demonstrates is the pitch bending of a single note. Some of his songs have brief moments where a single note quickly bends up and down in pitch. This effect would be similar to a trumpet player using vibrato to enhance a long note that would otherwise seem stagnant. This modulation of the pitch is clearly demonstrated with osculating

beams of light.

An important distinction in Lytle's work is that his animations create the association that the visuals are causing the music. His animations clearly depict unique instrument designs that are being played by robots, floating guitar picks, or bouncing balls. *Animusic* clearly uses music as its foundation for the entire animation and this structure is precisely what my visualization works use. His animations visually support the music through the unique perspective of autonomous virtual instruments. His animations are also procedurally generated in accordance to MIDI data. Both of these concepts are represented in my music visualization demonstrations. My work visually supports and enhances the music, and my method for creating the animations is also a procedural technique. The Drums Downtown IV animation is an excellent example that shares concepts with Lytle's work. Both animations use MIDI to synchronize the visuals to the audio and both animations are pre-rendered. One of the differentiating factors between Lytle's *Animusic* and my animations is the use of a real-time performance-based environment. My recent works deviate from pre-rendered animations and use real-time authoring environments like Virtools. Music analysis is performed in real-time by Max/MSP. One of the major goals in my work is to design a music visualization that can accommodate and adapt to the variability that exists in a live music performance.

4.1.3 E. Chew, A. Francois MuS.ART System

Research by Elaine Chew and Alexandre R. J. François focuses on the real-time adaptability and musical analysis of a live performance. Their work MuSA.RT (Music on the Spiral Array, Real-Time) depicts a spiral array as a geometric model to align musical pitches and tonality in a live music performance (Chew). This spiral model is very similar to the tonal model mentioned in Carol L. Krumhansl's research overview entitled "The Geometry of Musical Structure: A Brief Introduction and History." (Krumhansl) This

model chromatically aligns pitches in ascending frequency along a spiral, which functions as a representation of pitch classes. The model in the MuS.ART system demonstrates the relativity of pitches and the relationships between tonal centers that develop throughout a piece of music (Chew). Chew and François' music visualization system tracks the progression of chords, pitches, and tonality throughout a piece of music and translates this progression into spatial points or *centers of effect* (CEs) in their visualization model (Chew). The system is an excellent visualization of a real-time music analysis that tracks the perceived change in a tonal center of a piece. This work and Carol Krumhansl's research were invaluable tools for the visualizations I created with Jacob Reed. Their research provided a framework for our animations that depict interval relationships in the first six measures of Bach's Fugue #14 in F minor. The MuSA.RT system and our theory animations serve the distinct purpose of illustrating or educating an audience about a specific function or relationship in music. The MuSA.RT system uses a real-time environment and 3D animation to track tonality in Classical music. The animations of Bach's Fugue visually convey interval patterns that exist in the introductory measures of the music. Both animations focus on a particular music theory principle and visualize this concept to aid in understanding. Another commonality between this animation and my later music animations is the use of a real-time environment. A critical goal of the MuSA.RT system is to track tonality in a real-time performance setting. My animations also seek to visualize music in a real-time environment, but my animations focus on the expressive qualities of the performance instead of on the analytical approach taken by Chew and François' visualization system.

4.1.4 *Cirque du Soleil*: DELIRIUM

A live concert I had the pleasure of seeing twice has influenced a significant portion of my work as a visual artist for music performances. *Cirque du Soleil* is typically known for their incredible multimedia driven performances that focus on human acrobatics, flexibility stunts, and complex choreography. Their live concert, DELIRIUM, took a different approach. “For the first time *Cirque du Soleil* puts musicians and singers center-stage with their music as the driving force of this gigantic event.” (Delirium) The show highlights the musicians and their music with minimal acrobatics. The show was created by Michel Lemieux and Victor Pilon, and they collaborated together to create a show that is based around the music of previous *Cirque du Soleil* shows. The theme of the show was “driven by an urban tribal beat” that incorporates awe-inspiring visuals, musicians, singers and dancers (Delirium). The touring show takes place on a stage in the shape of a Roman numeral one or “I” with the audience facing the long central beam of the “I” figure. Projections cover the entire length of the stage so animations cover about 270 square feet of projection space or the equivalent of almost 2 IMAX screens (Delirium). The resulting performance is an amazing, immersive, multimedia experience. The visuals are carefully synchronized critical events in the live music performance. I was disappointed when I discovered that some of the most impressive visuals appeared to be pre-rendered sequences. It would have been more interesting if the visuals responded in real-time to the performance. Since live musical performances are never exactly the same from one performance to the next, it would have been interesting to see a visualization that was capable of illustrating those variations. Despite this observation, it did not detract from the overall experience, and I was still awestruck at the visuals that were integrated into the show. There was one particular moment in the show that really stood out in visualizing the music. A singer was introduced on stage by projecting massive sound waves that spread across the entire screen as she began to sing. This

was one of the most direct correlations I saw between the music and the visuals. Her projected sound waves dissipated a large bubble in the middle of the screen on stage which eventually broke down into a single line that stretched the entire width of the stage. As the drum beat in the song started, spikes that resembled an EKG monitor pulse began racing across the stage (Figure 4.2). The imagery looked pre-rendered to but its synchronization and execution with the music was flawless. To see a music performance



Figure 4.2: *Cirque du Soleil DELIRIUM* concert with the EKG pulsing line across the stage

visualized on such a large scale was a breath-taking experience for me. The large scale visualization was definitely a contributing factor to the immersive effect and my experience of the concert.

The Drums Downtown IV and V performances best represent the influence this show has on my development process. Both of these performances incorporate a projected image behind the musicians. The Drums Downtown IV event uses a pre-rendered animation that the performers have to conform to in order for their music to synchronize with the visuals. The Drums Downtown V performance uses a real-time

animation system that responds to the musicians. Both of these performances attempt to visually capture this dynamism that exists in music by visually engaging the audience. This level of excitement is something I try to incorporate in my work by visually capturing the grandeur, passion, and dynamics of a live music performance. When a music ensemble builds in intensity to a climactic moment in the music, I attempt to visually emphasize this moment in my real-time animations. DELIRIUM is an excellent example of this effect, and I think it merely scratches the surface of what is possible with live music visualizations.

Cirque du Soleil's DELIRIUM concert also opened my eyes to the possibilities of a greater influence the computer could have on my work and how the computer could be better integrated into a live music performance. This was a conceptual junction in my work where I realized the computer's real time analysis and rendering capabilities could be used to enhance and respond to a performance. This started my development process towards using the computer as a visual instrument and the appropriate relationship that would exist between the artist and the computer.

CHAPTER 5

THE ROLE OF THE COMPUTER TO THE ARTIST

The use of the computer in my process of creating real-time music visualizations involves a complex balancing act of control between my artistic concepts and the computer's ability to manipulate vast amounts of data at a speed measured in milliseconds. The music visualization system allows the artist to function as a mediator between the incoming music data streams and the computer's pre-programmed capabilities. The system provides unique control sets for the artist to manipulate the visualization in ways that are not necessarily possible by audio analysis alone. Development of the system is divided into three different phases; initial creation of assets, programming the automated functions in the system and designing artist controls, and the final execution of the system during a live music performance. Due to the generative nature of the second phase and its potential outcomes for the third phase of development, these two design phases may iterate between each other multiple times before a satisfactory visual form is created.

In the preliminary design and construction phase of the animation system, the computer functions as a content creation tool. The initial design, concept, and construction of the music visualizations use the computer to digitally create visual forms and animate these forms for the animation. This asset creation process is similar to the methods used to create a computer generated film. Artists use 3D animation programs like Autodesk's Maya to model an object. The modeled object is then surfaced or

textured. Images are mapped onto its surface giving it a more detailed appearance. The textured object is then animated and placed into a scene. The creation of assets is heavily dependent on the artist for decision-making. The computer primarily functions as a complex tool providing no creative input of its own in the process. After the construction of all assets for the animation, I begin to design a system that will incorporate these assets into a real-time virtual environment that responds to audio input.

The computer has the capacity to manipulate and analyze large amounts of data in milliseconds. These data streams can drive various functions within an animation, for example the scaling, translation, or rotation of an object. One of the key design challenges is to decide which animation functions would be best suited for this type of manipulation and which functions should be controlled by the artist. An audio spectrum analysis moves too quickly for an artist to meaningfully react to what has been processed, and the computer is far more capable of managing this data and visually reacting to it in a real-time system. This is where I choose to relinquish some control over the development of the animation and allow the computer to interact with the music data. The decision to balance control between the computer and the artist arises frequently during this phase of development. As an artist and a programmer, it can be tempting to push the system to one extreme or another. For example, the animation system could be completely driven by the computer with minimal input from the artist except during the conceptual and asset creation phase. An example of this system would be the music visualization effect in Apple iTunes. An artist or programmer designed all the parameters for the system and a user is typically limited to changing between a select number of visualization presets. At the other extreme is a pre-rendered animation similar to Disney's *Fantasia 2000*. The artists are responsible for all aspects of this animation. They have complete control over the entire process associated with animation including the story's development and outcome. The artists create the concept for the story, illustrate all the characters, animate

them in synchronization with the music, control lighting, camera viewpoints, and control the finishing touches for the animation. The computer merely serves as a content creation tool with no creative input in any facet of the process.

To balance the control between computer and artist, I designed my music visualization system with multiple hierarchical levels of control. Lower levels in the system are completely automated with the computer driving rotation, scaling, or translation values of an object based on a live audio data stream. Higher levels in the system might incorporate other audio data streams to control the same object's color, or the camera's distance from the object. An example of this system might use the amplitude from an audio data stream to adjust the scaling or size of a cube. A level above this one might use the pitch information from the same data stream to alter the rotational values of the cube. A third level above this might use a different audio data stream to control the translation values of the cube on the X and Z-axis. The final level above all of these may use a keyboard input, or some other input dependent on the artist, to direct the camera's viewpoint or the cube's translation value on the Y-axis. Creating structured levels of control allows the artist to react to each control in the music visualization and respond accordingly. Driving translation values for the cube may prove to be too erratic in movement during the first iteration of this specific system due to subtle fluctuations in the data that dictates those translation values. A second level of control could smooth this erratic behavior. Building a hierarchy of control levels provides the artist an opportunity to correct, change, or build on the visual results of these different levels. My strengths as an artist and musician are the ability to see or hear patterns and themes in the music that span greater periods of time. Using my knowledge of forms in music, I can envision and predict overarching structures in the music. The influence of musical forms allows me to distinguish transition periods and higher level structures or concepts in the music. This unique ability to conceptualize and calculate trajectories in musical forms is a key

distinguishing factor between the artist's decision-making process and the computer's capacity for high-speed data analysis. As the artist, I can react to the music in a more meaningful way than can the computer because of my artistic sensibilities and my knowledge of music which includes the ability to distinguish structures, patterns, and themes in music.

The artist is ultimately responsible for the visuals in the animation and the programming that defines the computer's boundaries; however, there are periods when the computer provides inspiration based on its unanticipated output of the data. For example, the cube might use audio amplitude values to drive its translation values on the X and Z-axis. The system might prove to be too erratic in motion at first, so the artist adjusts the values to smooth out the translational movement. The resulting movement might create swooping motions, elegant arcs, and dynamic curves which may not have been previously considered by the artist. After being captivated by the new motion, the artist might create another system above this one that traces the outline of these curves and this motion may become the foundation for future developments in the animation system. This is a unique trait in which the interplay between the computer and the artist becomes more of a shared experience as each entity responds to another in the continuing development of the animation system. The artist is ultimately in control, but the final animation may be taken in an entirely different direction than originally intended.

The third phase of development continues this interplay between the artist and the computer into the execution of the animation during a live music performance. The artist uses pre-programmed controls to manipulate the animation in order to accommodate his or her interpretation of larger structural themes that may be present in the music. The computer generates visual forms that quickly react to multiple incoming audio data streams. Both the computer and the artist capitalize on their strengths and react to each other in tandem to create a unique visualization of a live music performance. The

computer is responsible for the more intricate and repetitive motions in the animation yet within the framework of the audio analysis, there is room to generate the unknown and unexpected. The artist in turn responds to these unknowns and intricate nuances that are generated by the computer. The artist can also adjust the entire visualization by using the higher level of controls in the hierarchy to the different musical patterns and themes as they develop. The potential interplay between these two entities during a live music performance is immense.

During the live performance, the computer and the artist react to the musicians through this shared hierarchy of control levels. The computer micro-manages all incoming audio data streams and manipulates the size of visual forms in the animation, adjusts camera motions, and controls other parameters like color saturation. The artist shares the same control system with the computer, but the various levels of control allow the artist to override some decisions made by the computer and influence developments on a larger scale in the animation. The artist and the computer essentially function as a visual musician in the performance. The relationship between the computer and the artist represents many similar qualities that a musician exemplifies in the performing ensemble. Musicians are bound to each other through the framework of the written notation. All are responsible for their own parts, and they are responsible for interpreting those parts in connection with their fellow musicians. The computer/artist relationship is also bound to the musicians by responding to the sounds they play. The computer and artist are responsible for accurately visualizing performance qualities such as dynamics and thematic structures. The unpredictable potential in a performance for musicians and the computer/artist performer is in their interpretations of the music and their connection to each other. Musicians in an ensemble must faithfully interpret the music and blend with their partners so that the ensemble functions as one in its interpretation of the music. The artist and computer also need to function as one entity that can effectively visualize the

performance and become a performing member of the ensemble. Allowing the computer to react to the music through programmed means to create visuals in the animation that are different than the expectations of the artist adds a humanistic and instrumental quality to its presence in the ensemble. Musicians performances will always vary slightly in tempo, dynamics, technique in their instruments, and in their interpretation of the music. The computer's construction of visuals that differ from the artist's original concepts for the animation mimics this interpretive variation of a musician in the performance and creates a variable element for the artist to master.

In effect, the computer can be considered a visual instrument for the artist. The programming required to create visuals is similar to musicians practicing their instruments in preparation for the concert. The programmed environment for the computer exemplifies subtle nuances that the artist must learn to control just as the trumpet's sounding of the low D (D4) note has a strong tendency to be sharp in pitch and must be adjusted. Some subtleties that exist in a programming environment include how data is stored and retrieved, the appropriate syntax for writing a function, or a specific network protocol that can interface with multiple different software programs. All of these elements have their own unique behaviors and getting them to communicate with each other shares a similar relationship to how a musician would practice his or her instrument. Musicians learn to adapt to these nuances in their efforts to master the ability to play the instrument. As a visual artist and programmer, I need to adapt to slight variations in programs, protocols, and scripting languages in order for them to all work in harmony and generate functioning music visualizations. The resulting animations signify a mastery and practice session with the computer as a visual instrument of light which is a similar concept to one John Whitney refers to in his book, *Digital Harmony: On the Complimentarity of Music and Visual Art*. The computer can be used as a visual instrument by the artist and connect with the musicians in the performing ensemble to

generate a real-time visualization of the live music performance.

The implications for this type of authoring system are valuable to not only this field of study, but in other disciplines as well. Creating a hierarchy of control systems can present visualization systems that are truly adaptable to their content. This type of system could aid in adaptive learning environments where the combination of a computer and human could interact with a child to enhance the child's learning experience. It could also be used to construct advanced artificial intelligence systems. The computer's fast response times and the human's deep analytical perceptions can be combined to create a powerful A.I. system that benefits from the human's and computer's strengths. The system is still dependent on the influence of a human but the human's abilities to manipulate data would be enhanced by the computer's faster response times. The entire system demonstrates the possibilities of a computer functioning as a highly customized tool for a specific user and for a specific application. This work documents the computer's customized function in real-time music visualization capacity.

The computer's role in the development of this music visualization system starts in a traditional role and continues to evolve to become a partner or companion during the final performance. The initial phase of development uses the computer as a tool for content creation and exploration. The second phase is where the computer's ability to construct visual forms that may be unexpected for the artist provides an avenue for artistic inspiration and potential design direction in the creation of a hierarchical control system. This is when the artist may discover unique visual forms and design or program additional sets of control to manipulate these new forms. Creating a hierarchy of control allows the artist to evaluate the computer's interpretations by limiting the complexity and variables that are added to the overall system. The third phase is where both entities work together to react to the live music performance. The computer analyzes multiple audio data streams and uses the data to generate visual forms and motions on a micro-

level. The artist has access to the various different levels of control spanning from some micro-level controls to macro-level controls. The artist can respond to small nuances in the computer's generative forms or make sweeping changes to the overall visual structure of the animation. These changes could be in response to larger musical evolutions like thematic developments and pattern recapitulations. This system is unique because it requires both entities to work in tandem to create the animation. The computer can micromanage multiple data streams and drive the animations while the artist can respond to these animations and adjust them according to the music performance.

Designing a system that allows the computer to produce visuals that differ from the artist's original vision forces the artist to interpret and react to these dynamic elements and creates a compelling animation process that responds to a music performance. The construction of these dynamic elements distinguishes the computer as a visual instrument that the artist uses to create music visualizations. The computer's relationship to the artist is similar to the relationship between a musician and his or her instrument. Music performances can never be perfectly replicated and will vary slightly in their tempos, dynamics, and interplay between the musicians. These factors often contribute to what makes live music events so exciting. Variations in the musicians' interpretations of the music, unexpected visual formations that are constructed by the computer's analysis of the performance, and the artist's reaction to all these live generative elements represents the exciting dynamic interconnected system that exists between all performers in a live music visualization performance.

CHAPTER 6

DESIGNING MUSIC VISUALIZATIONS

6.1 A Tetrahelix Animates Bach: Visualization focusing on Music Theory

A Tetrahelix Animates Bach is an exploration in the use of 3D computer animation as a medium for visualizing complex theoretical structures in music. I collaborated with a music theory student, Jacob Reed, in the design and implementation of a series of 3D animations for Neo-Riemannian Theory. Our work was based on the analysis made by David Lewin on the first six measures of Bach's Fugue 14 in F# Minor. David Lewin brought innovations to music theory in the form of mathematically-based theory and the development of transformational theory. These subjects are discussed in his treatise *Generalized Musical Intervals and Transformations*. The transformational theory concept is succinctly summarized by Lewin's question in his treatise, "If I am at s and wish to get to t, what characteristic gesture should I perform in order to arrive there?" (Lewin 159) His work focuses on relationships between structures and patterns in music and how these relationships might build to illustrate larger patterns.

Our research first consisted of finding an appropriate geometric form that succinctly represents all twelve pitches in addition to showing a chromatic and octave association between the pitches. Carol Krumhansl, a researcher affiliated with Cornell University in Ithaca, New York, has discussed many issues related to our problem including geometric forms that represent music, psychological perceptions, tonal relationships in music, and a concise history of previous visual mappings of pitch classes

(Krumhansl). One visual form we discovered to be ideal for our representations was a three-spine spiral helix. We arrived at this structure on our own accord before validating it with Krumhansl’s research. This helix shares a similarity to Shepard’s geometrical approximation that is outlined in Krumhansl’s historical synopsis (Krumhansl). This geometric form is also incorporated into other music analysis research like Chew’s and François’ MuSA.RT real time visualization system (Chew).

Our spiral form associates distance with pitch relationships which determines the space between points along the spiral (Figure 6.1). The higher one progresses up the spiral, the higher the pitch. Horizontal lines that are projected through the spiral connect

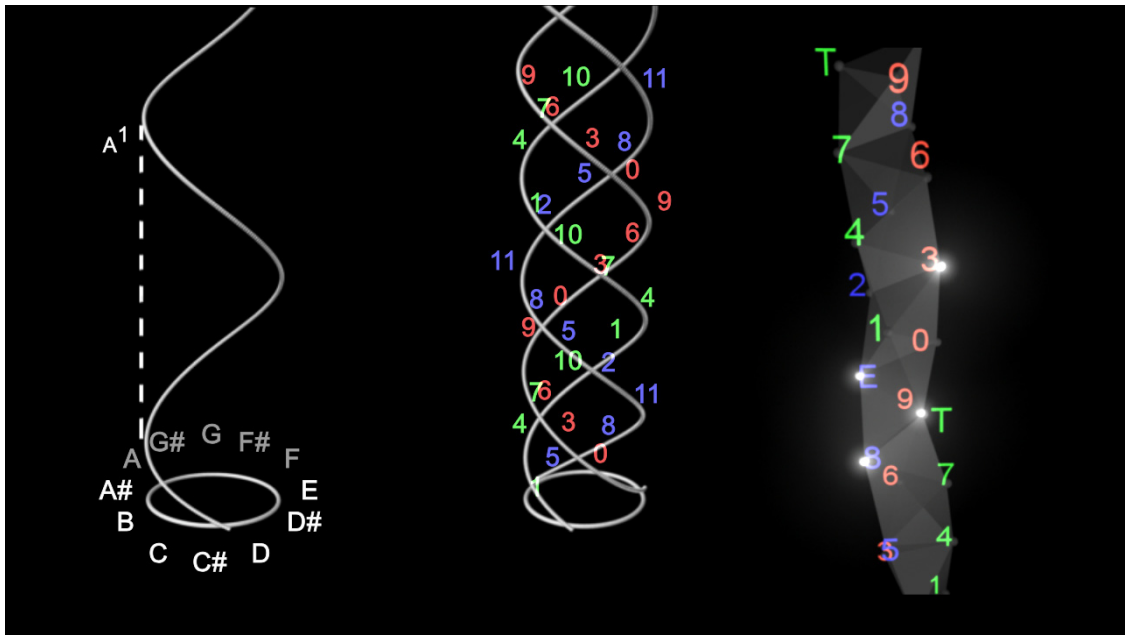


Figure 6.1: The first spiral shows the relationship between the same pitch in two different octaves. The second spiral shows how all the different pitches climbed in a uniform layout along the spiral. The third spiral represents our final shape used in the animations.

to points along the spiral to form vertices for the tetrahedrons. Since we were using computer-generated shapes, we used each point’s position in space to define polygons on the spiral. The polygons form the tetrahedron shapes, and stacking the tetrahedrons

on top of each other represents the basic pitch interval pattern that was explored in Lewin's analysis of the Bach fugue. We used different colors to highlight respective faces on the tetrahedrons, and these colors represented the subject, answer, countersubject, and crosstalk within the first few measures of the fugue. The resulting 3D animations provided an excellent visualization for Lewin's analysis of Bach's fugue. The animations also augment the analysis by demonstrating in real time how Bach "surfs," as Lewin describes, through "Cohn flips," or a graph constructed of relational sets of different note intervals (Reed). These visualizations are analytical in nature, but they demonstrate how 3D computer animation can be used to visualize various forms and structures within music theory. By illustrating patterns and structures on various theoretical levels from note interval relationships to subjects, answers, and countersubjects, computer generated animations can elucidate hierarchical patterns and structures that exist in other musical works.

The analytical function and purpose of this type of music visualization was appealing to me because of its interdisciplinary focus and its potential educational benefits. Creating work with music theorists that visually demonstrates complex problems in their field of study was an exciting avenue of visual exploration. 3D computer animation could elucidate and amplify musical analyses to help educate music theorists and students about the complexities that are inherent to many musical compositions. Unfortunately, the field of music theory felt dry and the artistic interpretive side of me was yearning for more. I did not want to create animations that served only to deconstruct music theory into graphical patterns for closer study. I wanted to explore an alternative interpretation of music that focuses on the emotive, expressive, and dynamic qualities of a live performance. I wanted to create an animation that grows, recedes, and responds to a music performance. This visualization of Bach's Fugue was an important step in my development because it helped to clarify the concept for my work, which is to visually

accentuate the expressive and dynamic qualities of a live performance through animation. These animations also stressed the importance of automation and scripting in my work. The creation of the geometric form and the synchronization of the animation to Bach's Fugue 14 in F# minor was a very time consuming process. The tetrahedron vertices were meticulously animated to the striking sound of a piano key. Thankfully the project only required the animation of the first six measures in the fugue. This process is not suitable for larger scale works or complex animations that require key framing movements for multiple entities. In order to animate and synchronize complete musical works to a computer generated animation, I need to develop a system that is capable of extracting audio data and using it to generate key frames or motions within the animation.

6.2 *Dreams*: Creation of a system for generating synchronous animations to music

In order to create a system that can automate the synchronization between audio and visuals, I explored the use of Maya Embedded Language (MEL) scripting and Music Interface Digital Instrument (MIDI) data. MEL scripting provides the capability to automate any task necessary in Maya while MIDI data provides precise timings for musical notes, note duration, and the pitch or audio frequency of each note.

The first step in my process was to extract the MIDI data into an acceptable form for Maya and MEL scripts. A program that converts MIDI files into an ASCII text format was created by Piet van Oostrum from the Utrecht University in the Netherlands (Oostrum). This tool extracts all MIDI data into a sequential list that includes a timestamp of the note that was hit, the channel the note was played on, the pitch of the note, and the velocity at which it was struck. With this provided, I then developed my own MEL script that opens the appropriate MIDI file and initiates the conversion to a text format. After creating the text file, the script extracts the relevant data and discards unnecessary information such as the midi-specific channel for the note and stores the data in memory as arrays. The

second phase of the MEL script iterates through the arrays and applies key frames for translations, scaling, or any other desired motion on a respective 3D object. Since each note event has a corresponding timestamp, I was able to synchronize the key frames to these timestamps in the animation timeline. One problem I overcame was the translation of MIDI “ticks” into animation frames. Determining the frequency of ticks in relation to seconds allows me to convert the seconds into the 24 frames that correspond to one second of animation. This alignment between visual frames and MIDI ticks is a critical component to creating a clear synchronization between the visuals and the music. This synchronization satisfies the goal of creating key frame information in response to a musical piece. With the process of generating key frames automatically with the MEL script, I explored relationships between the adjusted MIDI data and visual forms in motion.

My initial explorations focused primarily on simple abstract forms such as a sphere or a trail of particles. I discovered how easy it was to synchronize motions to musical events, and it was very easy to get lost in the programming aspects of the project. During this exploratory phase I often struggled with appropriate mapping strategies or visual relationships between form, color, space, and the large amounts of data. Particle systems were of particular interest to me because particles naturally leave behind a trail. Particle life span, color, and position can be manipulated by MIDI data which consists of pitch, note length, and velocity information. Depending on the life span, particles can illustrate the development of a line or similar visual form over a period of time. Their size can be adjusted to convey dynamic swells in the music. I wanted to visually convey a history of developments in the music, so this aspect is particularly important in my early works. Music is constantly evolving in time and by illustrating a short history of development through the use of particle systems, I am able to provide a brief snapshot of the music’s development.

One example of this effect can be seen in the short animation entitled *Dreams*. The animation incorporates most of the MEL scripting techniques I developed thus far. Colored bubbles burst upwards depending on when a piano note is struck. The physical qualities of a bubble's shape best represent the sound quality of a piano note. A piano note does not have a forceful impact at the beginning of its sound and it gently dissipates into silence. The round shape of a bubble depicts this gentle rise and fall of the note through the perfect curves on its surface. The slight imperfections that might exist in a bubble represent the slight tonal variations that exist in a piano note's sound.

The size of the bubble is determined by the velocity of the note hit, so louder notes are larger than softer notes. Multiple bubbles rise up at once when a chord is played. Chords in music consist of two or more notes that are played simultaneously; however, an analysis of the note timings indicates that notes are typically a few milliseconds apart from each other. In order to account for this subtle discrepancy in timing, I created a system that groups notes into one chord if they were played within a certain period of time. (This system essentially accounts for the fact that humans are not able to play three or four notes in a chord on the piano at the exact same time. A threshold or period of time is used to create a window for all notes to be collected and considered as one chord.) The colors of the bubbles change according to the quality of the chord such as major, to minor, to diminished seventh. These color transitions are directly written into the MEL script. .

Multiple rings or dust clouds that expand in size and move in an outward direction from a central point constitute a shockwave pattern that I used every time a chord is played. The shockwaves incorporate a color scheme that is shared with the bubbles, and they are used to denote the average interval distance between all the notes in that chord. For example, two chords played at opposite ends of the keyboard yield a very large and expansive shockwave because of the large interval distance between all the

notes while two chords that are played close together on the keyboard have smaller intervals between the notes so these would yield a smaller and shorter-lived shockwave. The bubbles represent an ideal choice for the stylistic and auditory feel of a piano note, but the composition lacked depth so I chose to create a shockwave or expanding ring of particles. This is one of my first explorations into using space within the composition to illustrate music. The shockwave provides additional dimensionality to the work, but I do not feel the shockwaves clearly depict a relationship between chords with small interval differences and chords with large interval differences. The shockwaves remain within the frame too long for a viewer to see an appreciable difference in the interval distance between chords, but they do help to visually accentuate the point in time when a chord is struck, and they provide a sense of depth to the composition.

This example was a good demonstration of the MEL scripting capabilities I had developed, but it also exemplified some difficulties I had in mapping various musical events to an appropriate visual effect. During the initial design phases of this project I was overwhelmed by the avenues of exploration. Creating relationships between visuals and music could incorporate hundreds of different elements. I attempted to narrow my possibilities by creating a list of elements in the visual and music realms in order to make the task more manageable. The table outlines some of the major elements in visuals and

Music Elements	Visual Elements
Pitch	Colors
Chords	Space
Volume/dynamic	Scaling of an object
Articulation	Shapes
Phrases	Lines and line weight
Theme/motif	Camera/viewpoint and space
Instrumentation	Composition of shapes
Rhythm pattern	Visual Pattern

Figure 6.2: A table showing the relationships I explored between musical elements and visual elements

music that could be correlated through artistic interpretations (Figure 6.2).

This list was helpful in sorting out some possibilities that I could explore. Some of the more interesting possibilities for me were the association of color to pitch, volume/dynamics to object scaling or size, and articulation to shape. Just as Sir Isaac Newton and Scriabin had developed their own color to pitch interpretations, I felt color and pitch relationships could play a vital role in my animations by illustrating different audio frequencies. Volume and size associations could adhere to our instinctual perceptions and expectations of louder sounds being larger and softer sounds being smaller. Articulations as they relate to shapes could help distinguish different sounds or timbres. A loud clap has an entirely different shape in comparison to a plucked string. Both sounds have different characteristics: the clap has a sharp, striking sound that pierces the air while the plucked string has a slight thud in the beginning of its sound as the finger swipes across the string's surface, and the quality of the sound that reverberates afterwards is much softer and longer lasting when compared to the quick dissipation of a clapping sound. As I considered and described these different characteristics of sound, I became more interested in visualizing these sounds and less interested in analyzing structures in music. I enjoyed creating the animation, *Dreams*, and I was anxious to visually explore other sounds and how those sounds could be depicted.

MEL scripts were also becoming too cumbersome in managing and organizing data. It was difficult to integrate complex pattern matching, chord detecting, and pitch analysis into a MEL script. MEL scripts do not allow arrays within arrays or dynamically resized matrices. For example, the size of a matrix in Maya must be specified at the beginning of its creation and it cannot be altered afterwards (Matrices). This is just one example of the hurdles I began to encounter as I attempted to incorporate a theoretical analysis of music into my MEL scripts. Furthermore, there are other programs which are more adept to analyzing MIDI data and providing a musical analysis, so I did not want to

“reinvent the wheel” by using MEL scripting to perform MIDI analyses.

My work also began to deviate from the artistic and visual interpretations of music. I was constantly bogged down by the programming aspects of the work, which diverted my focus from the artistic and visual interpretations of the music. My previous animation work with Jacob Reed was heavily focused on the theoretical patterns and analysis of music, while the Dreams animation represented a departure from this type of work. I explored other aspects of music while still retaining some music theory elements like interval differences and chord classes. My focus for music visualizations was moving towards an artistic and interpretive approach that does not require a conventional music theory analysis of the piece. The intended audience for my animations was expanding beyond music theorists to include the general concert-going public. The goal of my work was to create a visualization that an audience could appreciate as an artistic and visual experience that enhances a live performance, and for the work to reflect the dynamic and inspiring moments of that performance. To satisfy these refined goals, I began to explore the more general use of motion, dynamics, and visual space and how these elements might accentuate and respond to a live music performance. I narrowed the focus of my study on performance qualities and abandoned complex theoretical analyses of music. These experimentations in MEL scripting did provide me with a strong framework for my next project which uses MEL scripting for timing and synchronization within an animation.

6.3 Drums Downtown IV: Live performance to pre-rendered visualization

Drums Downtown IV was a unique opportunity to design a 3D computer generated animation for a live musical performance, entitled *carpe diem* by the Pendulum Duo. This percussion piece “was written in 1996 to further expand on the repertoire for two percussionists in a soloistic setting.” (Drums Downtown IV) The animation is created

using MEL scripts which dynamically build and synchronize visual forms to create a procedurally generated animation. The musicians are paramount to the performance so they are placed down stage towards the audience. The animation is presented on a large screen behind the musicians to visually reinforce their performance.

The pre-recorded audio performance of *carpe diem* was provided in advance for synchronization purposes, and so I could study and formulate a visual interpretation of the piece. I formulated my interpretation of the music by sketching blueprints (Figure 6.3). These sketches represent a rough concept of some contrasting themes, rhythmic

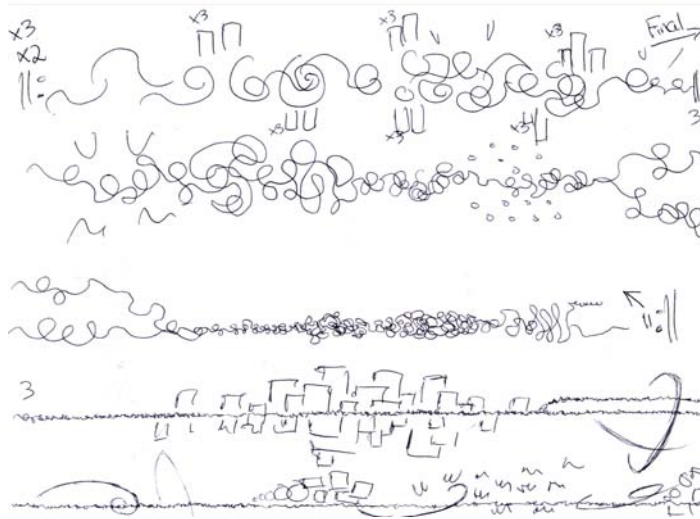


Figure 6.3: This represents one of my sketches for music where different lines and shapes represent different musical elements like contrasting themes or sounds, and rhythmic changes in the music

differences, and similar sounding patterns in the music. The shapes of the lines often denote the progression of the music passage, whether it is moving upwards or downwards in pitch, or perhaps a rhythmic passage builds or recedes in dynamic intensity. These figures may indicate different types of attacks like sudden percussive attacks, or slowly growing string bowings. These sketches in combination with the music influence my artistic choices for visual forms in the animation. The strong percussive attacks are visually represented by angular shapes like squares and triangles whereas soft, mellow,

and resonant sounds were represented by spheres, ellipses, or other curved forms. (My visual choices for form are always influenced by the sounds in the music.) I chose to divide the animation into five contrasting thematic styles or patterns based on my interpretation of *carpe diem*. Dividing the piece into five distinct sections also helped to modularize the MEL scripting development.

Artistic interpretations are often made in a fashion similar to how musicians must interpret music. Musicians usually do not have the luxury of contacting the composer to discuss their thought process and their personal interpretation of the music they wrote. Instead, the interpretation is reliant on the musician's background knowledge of music. However, if one is fortunate enough to meet with the composer, valuable insight can be gained on specific sections of the music. My process mirrors the interpretive challenges a musician often faces when performing a piece of music. Most of my decisions are based on my independent artistic and musical interpretation of the work while some segments are directly informed by a specific concept the composer was trying to convey in their music. I was fortunate enough to have access to the program notes written by the composer herself for *carpe diem*, so I was able to use them to influence my interpretive process. For example, the first section involves an Aaron Copland inspired fanfare (Drums Downtown IV). Aaron Copland's music often expresses majesty through his use of lengthening notes, creating spaces of silence in his music, and tenderly stretching folk song themes (Berger, Copland 61). His work has been visually associated with the vastness of American landscapes so I chose to work with this common interpretation by creating a vast open space in the beginning of the piece (Berger 92, Copland).

The opening section of *carpe diem* shares similar qualities to Copland's music by creating long periods of silence that are interspersed with strong gong hits, rolling cymbal crashes, and triumphant timpani hits. All of these musical sounds in the beginning section were associated with a different visual element based on the qualities of their

sound. (Figure 6.4) Hazy clouds cover the lower field of view in the animation to create a dramatic sense of depth in the composition. The cloud texture is animated to convey some movement and illustrate the extent of the depth in this opening shot. A large glowing ring emanates from the center of the swirling clouds to ground the audience's

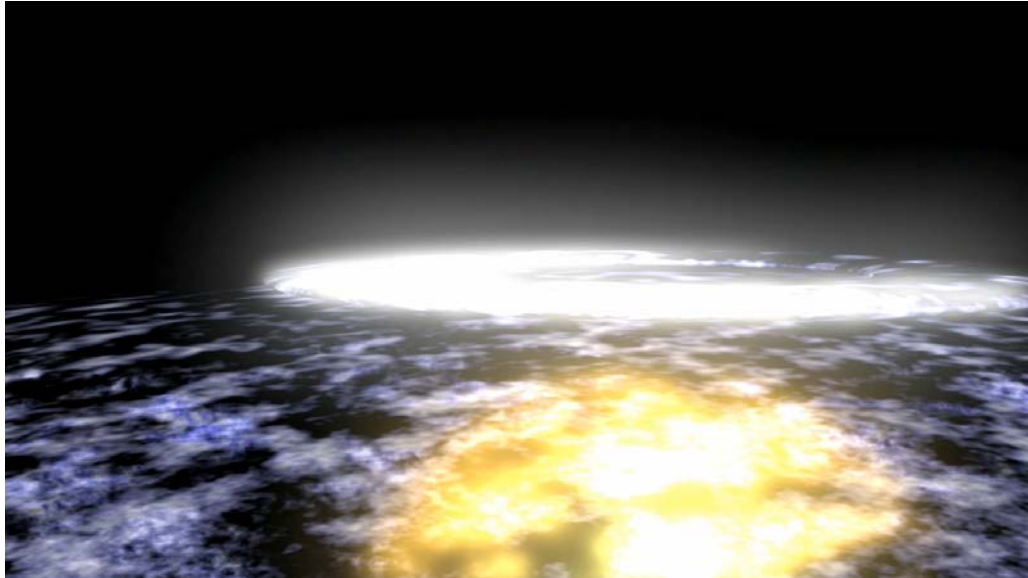


Figure 6.4: An example of the vast space I tried to create. The white ring represents the sound of the gong hit and the yellow circle represents the strike from a timpani.

view and reinforce the distant horizon line. This glowing ring expands and brightens with the dynamic building of the suspended cymbal roll which climaxes with a loud hit from the gong. The expanding and contracting ring is used to emphasize the contrasting dynamics and crescendo during the opening sequence. Colored bursts from beneath the cloud texture resemble the pointed attack of the timpani hits which occur after the climactic build of the suspended cymbal and gong. These colored bursts quickly expand and contract because the timpani do not reverberate as long as the gong hit. The ring and colored bursts resemble the type of sound each percussion instrument creates, and their motions reflect the changing dynamics of the performance. The overall composition depicts an expansive space that shares inspirational characteristics of Copland's

compositions with sparse visual interjections that adjust in size to represent the changing dynamics in the opening of the performance.

The second section of the animation begins the interplay between the two percussionists with one performer playing a consistent pattern which functions as a bass line while the other percussionist begins a pattern on the higher-pitched tom-toms. To illustrate this interplay between the performers, I incorporated a double helix that continually ascends in the frame. The interweaving nature of the double helix represents the communication the two performers exhibit as both of their musical lines connect with perfect rhythmic integrity. A hollow pentagon shape represents the high-pitched tom-tom pattern which audibly stands out above the baseline due to its higher pitch. At one point during this section, the regimented rhythms take a momentary break where the percussionists play an interjection that is completely different. I attempted to accentuate this moment and show the audience that it was a unique break in the consistent rhythms that had been exemplified so far in the second section. I used different camera viewpoints to accentuate contrasting rhythmic passages the music by angling the camera's viewpoint downward so the audience could see the overall pattern that had been created (Figure 6.5). After the interjection, the rhythm resumes and thus the camera returns to its original side-facing view of the animation.

Typically in a large symphony's piece in sonata form, there is a development section where iterations or variations on a theme may be explored or contrasted with previous thematic ideas (Berry 190). In the third section of *carpe diem*, the piece takes a noticeable turn from strong repeatable rhythmic patterns to a more developmental phase where different rhythmic motifs are explored. I labeled this section the exploratory or development section. There are three important visual elements in the third section that relate to different musical passages or instruments. The third section includes cymbal attacks, a "rolling drum" sequence, and snare drums flams, or accents. The first visual

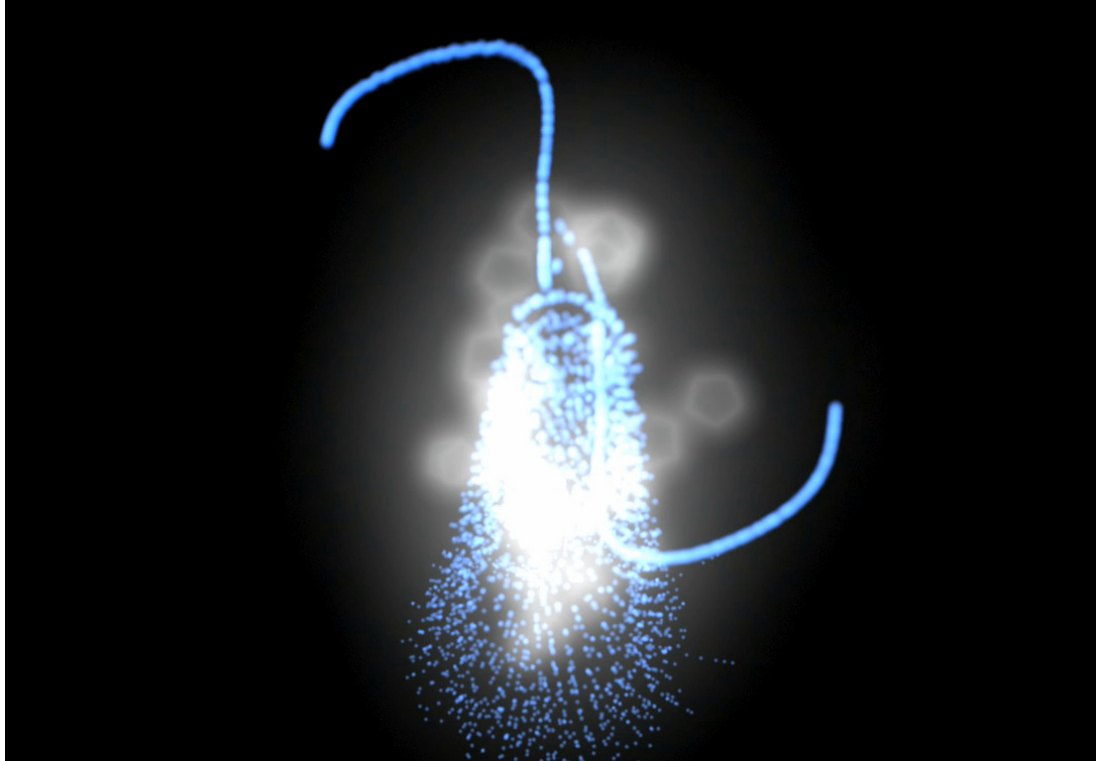


Figure 6.5: This image shows the altered camera view. The differing camera angle corresponds with a brief pause or change in the rhythmic patterns

element is a shockwave-like white ring which represents the cymbal strikes. This ring shape is closely related to the actual shape of a cymbal, and its high white intensity provides a representation of the higher frequencies that are exhibited by a cymbal hit. The high frequencies of the cymbal hit present a very bright and loud dynamic contrast in the music. Associating this instrument with large, white rings that expand outward illustrates the bright timbre or sound of the cymbal. The second visual element that is introduced is the “rolling drum” sequence. This pattern occurs during the beginning of the third section where the glowing line loops around itself in a diagonally-downward moving motion (Figure 6.6). This moment corresponds with a repetitious pattern of drums descending in pitch and their repetitious pattern. The descent in pitch relates to the downward movement; the loops help to iterate the repetitious nature of the pattern. The third element

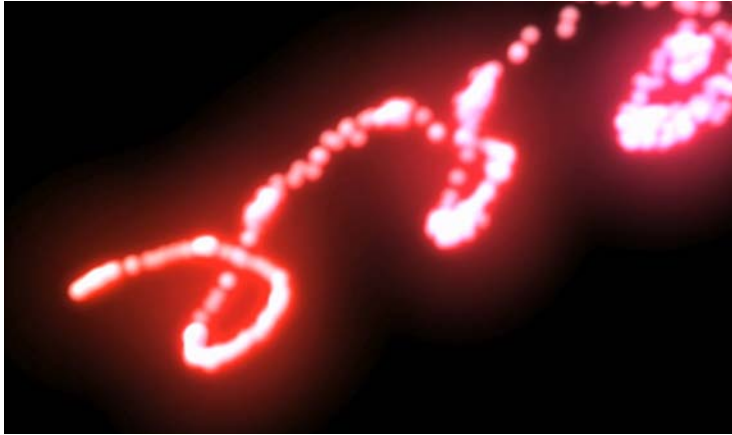


Figure 6.6: The “rolling drum” sequence that based on an audible pattern I discerned in the music.

uses snare drum accents to propel a particle-based line throughout the composition. Each snare drum hit causes the progressive development of the particle line to briefly leap forward creating this visual sense of the line being pushed across the

composition. Most of the visual forms created by the particle line are abstract. However, one formation outlined by the particles resembles a five-pointed star which is a subtle reference to the five-sided pentagon shape that was introduced in the second section of the piece (Figure 6.7).



Figure 6.7: The five point star which references the five sided pentagon shape.

The fourth section of the piece is a slight variation of the second section. The baseline and tom-tom pattern are reintroduced. To link these rhythmic patterns visually, I return to the upward moving helix, but chose to expand the color palette by using red and yellow instead of the blue of the previous iteration. This section also contains two rhythmically different interjections.

The first one is represented by a unique twist in the double helix strands with no deviation from the camera's viewpoint. I attempt to build on the camera interjections principle instead of replicating the format used in section two, so the first rhythmic deviation enhances visual interest by doing something the audience would not expect. The second interjection returns to the alternate camera view from the second section that shows the audience the entire structure created (Figure 6.8).

This interpretation helps exemplify the complexity of section four which has two rhythmic interjections instead of one. The complexity is reinforced by my choice to use two different camera scenarios for each rhythmic deviation.

The final section is a combination of many different elements from the previous four sections. There are driving baselines, cymbal hits from the third section, the “rolling drum” theme, and the rhythmic patterns from sections two and four all thrown into the last moments of the piece. To distinguish this section from previous ones, I drive the motion of the camera view to the left. This also serves the purpose of creating a horizon line that can be used to create another unifying structure in the piece. All the previously mentioned percussive patterns are re-introduced in this section but they adhere to the

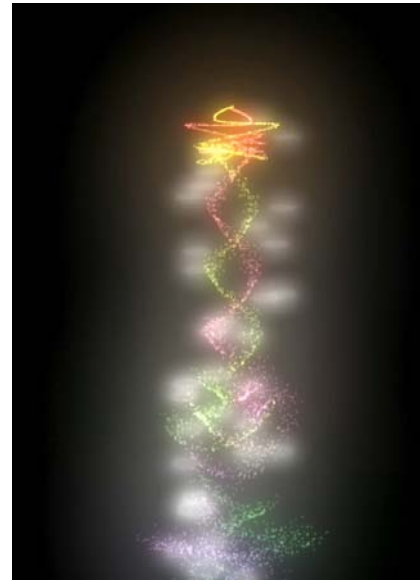


Figure 6.8: This is the second interjection or camera change that is similar to when the camera first altered its viewpoint during the second section of *carpe diem*

leftward motion of the camera's viewpoint rather than the upward motions of the previous sections. Cymbal crashes bring the shockwave rings back and the hollow pentagon shapes represent louder drum hits (Figure 6.9). Before the final percussive hit in the piece, the camera pans out so the audience can see five different particle trails racing towards a single point in the middle of the composition. As the dynamic and rhythmic intensity builds, the five lines merge into one point and a large white pentagon shape materializes and expands to cover the entire composition (Figure 6.10). This white pentagon expansion culminates with the final hit of the piece.

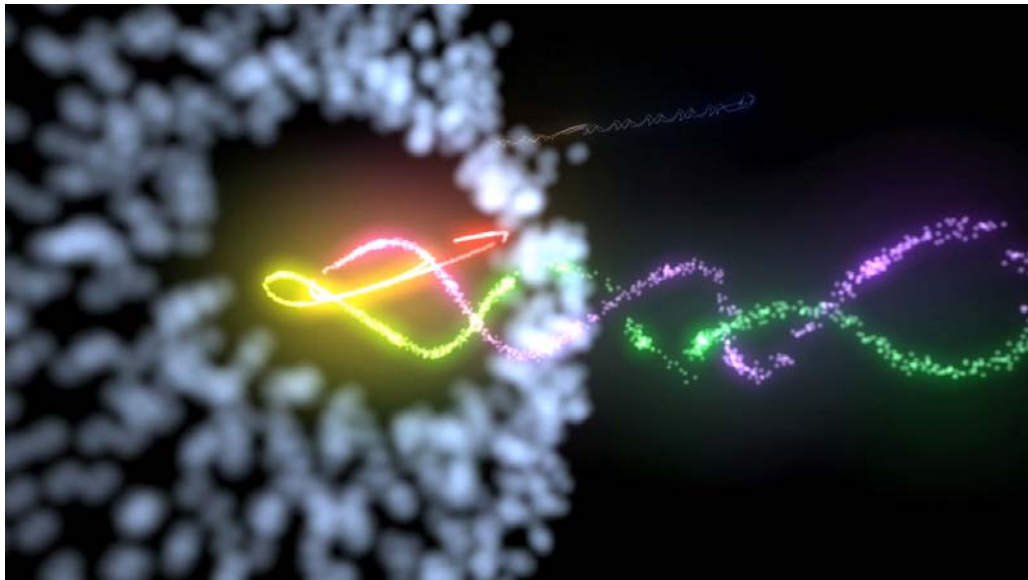


Figure 6.9: The return of the cymbal shockwave in the final section of the piece. This particular instance visualizes the hit from a suspended cymbal.

The Drums Downtown IV animation was an excellent opportunity for me to explore and polish my skills in MEL scripting. I refined my scripting techniques by dividing my programming into smaller segments. My scripts were broken down into two distinct sections. The first section opens the MIDI file and places all of the data into an array. The second section iterates through this data and executes certain animations. I discovered that this process can be layered to incorporate multiple different

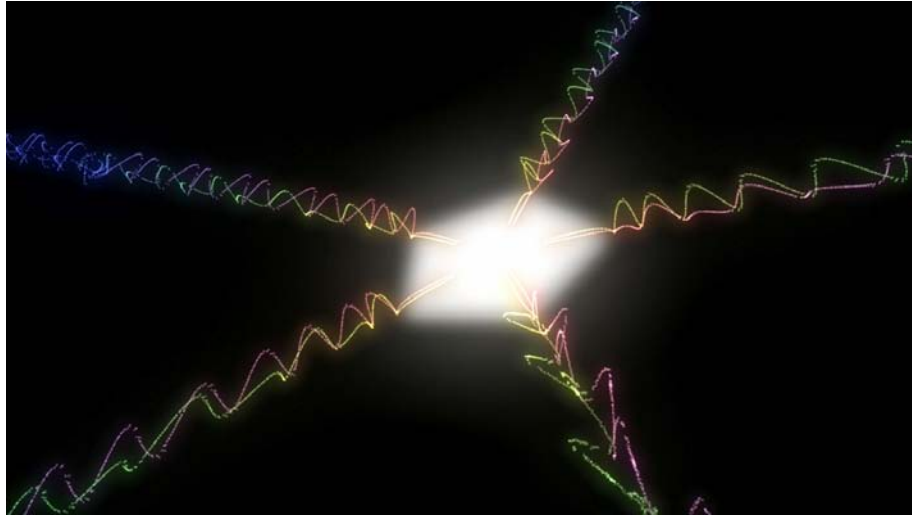


Figure 6.10: The final moment in the Drums Downtown IV animation when all five lines merge to create a pentagon shape that grows to fill the frame.

animation passes over the same section of music. For example, one script can generate the white shockwaves in synchronization to the cymbal hits, and in a separate pass, a script can generate the hollow pentagon animations in synchronization with the higher-pitched drum hits. This concept quickly blossomed during my development. The first animation section uses two scripting passes while the final animation section uses four scripting passes. This fueled my perception of designing animations in a generative and layered process.

The work explored the association of specific visual elements to recurring rhythmic patterns in the music and the use of visual space and compositional framing helped accentuate key moments in music. I attempted to show the audience how rhythmic patterns continually re-surface and develop throughout a piece of music. The pentagon was originally introduced in section two, alluded to in section three with the star pattern, revisited in section four, and used for the various rhythmic pattern reiterations in the final section. Visual forms like the pentagon, rolling drum pattern, double helix strands, and camera viewpoint alterations helped to convey rhythmic contrasts, patterns, and

developments that occurred throughout the performance. Shockwaves representative of cymbal crashes and expanding and contracting rings representative of gong hits helped to visually convey dynamic variations that were prevalent in the performance.

The major benefit to creating a pre-rendered animation is the ability to control all aspects of the design and creation process from the first to the last frame in the animation. As an artist, I can create a visual theme, execute and develop this theme over time, and conclude the theme in the same way a composer would explore a musical theme from exposition, to development, to a concluding restatement. A pre-rendered animation can be perfectly mated in synchronization and thematic development to a pre-recorded piece of music. It can function as a visual recording of the music and because the artist is responsible and in control of all aspects pertaining to the animation's creation, the final result can be a perfect translation of the artist's vision and interpretation of the music. The artist is responsible for all the aspects in the animation including the concept, design, and development. The resulting pre-rendered animation will always be the same.

The biggest drawback to creating a pre-rendered animation for a synchronized music performance is that the musicians must conform to the tempo constraints of the animation. Both percussionists must perform the piece at the exact same speed from start to finish. All accelerandos and ritardandos must also be performed exactly the same each time. If the performers deviate from the original tempo used in the creation of the animation, the entire effect will be ruined by going out of synch. This places a lot of strain on the musicians, and it limits their ability to vary their interpretation of the music from one performance to the next.

In *Drums Downtown IV*, both percussionists agreed to perform to a click track. The click track gave them a solid metronomic pulse for all tempos throughout the piece including accelerations and decelerations and it created a framework so the percussionists could consistently replicate their performance. This click track was piped through a

separate audio channel and into headphones that the performers were wearing during the performance. This click track was derived from a previous performance and used to synchronize the animation. The overall effect was that the visuals were responding to the percussive beats however, the performers were actually limited to the tempo restraints of the pre-rendered animation and the pre-determined click track. I was fortunate enough to be working with two talented percussionists. Their ability and willingness to play along with the pre-rendered animation was paramount for the proper effect. The percussionists exemplified consistency and repeatability in their performance, but this is not an ideal scenario for a music performance. An animation that adapts, adjusts, and responds to the musicians' performance would be preferable because the musicians are then free to adjust, respond, and express their interpretation of the music without being restrained to the synchronization requirements of a pre-rendered animation.

Drums Downtown IV was an excellent intermediate step towards the ultimate goal of creating real-time music visualizations because I was able to experience my work in a live performance-based environment. I was able to explore different visual forms and how they might portray contrasting patterns and rhythmic sequences in a piece of music. My explorations in camera viewpoints helped to establish the concept of using only one camera to convey the complete development of the animation. In Drums Downtown IV, there were no camera cuts, dissolves, or transitions. The music was presented as one piece to the audience, and I designed the animation to reflect that singular concept of presentation. All of the camera work in Drums Downtown IV supported this concept by using one camera that follows the developing visual forms. Alternate camera angles are used to accentuate contrasting themes or developments in the music, but there are no cuts between the various viewpoints. This helped create a sense of one work that continuously develops in the same form as the music. I also became familiar with the limitations of a pre-rendered animation and its restrictive qualities over a musician's interpretations and

flexibility. This furthered my desire to create an animation that would truly respond to a musician's performance.

6.4 Fiddling with Bonk: Building a system to visualize music in a real-time environment

In order to construct a system that responds to a live musical performance, I abandon the MEL scripting techniques that were previously developed. Developing in Maya with MEL scripts require extensive rendering times for animation frames because the rendering systems in Maya are not designed to run in a real-time environment. There are other software programs that are more adept to creating real-time environments and animations such as Dassault Systems' Virtools or Cycling'74 Max/MSP. Instead of relying on MIDI data, this new system would need to analyze audio in a real-time setting. Cycling'74 offers a software solution entitled Max/MSP (Cycling'74). Max/MSP combines the functionality of manipulating MIDI and audio data. Max/MSP uses a visual programming interface that allows a programmer to connect "patches", or specific programming functions, to other patches. An entire network of connected patches can manipulate data in a real-time environment. Max/MSP includes functions to manipulate audio waveforms and MIDI data. Data is seamlessly shared, developed, and passed between audio waveform functions and MIDI functions. Exact pitches, beats, note durations, and chords that are contained within the MIDI specification are juxtaposed with the frequency, amplitude, and phasing of the analogue audio waves in the same programming environment. This software was an excellent launching point for experimentation and development on a real-time audio analysis system. Max/MSP has also served as a suitable software platform for many other researchers who work in real-time audio analysis.

Two objects that are of particular interest for my work are the *~Bonk* and *~Fiddle* objects. These objects were developed by Miller Puckette, Theodore Apel, and David Zicarelli (Puckette). *Fiddle* is a pitch detector and *Bonk* is a beat detector. These two objects contain algorithms that are capable of determining the approximate pitch of a monophonic instrument and detecting an attack from a percussive instrument (Puckette). These objects are one of the foundations for my exploration in real-time audio analysis. Live audio feeds from a microphone source can be input and analyzed by these algorithms and the corresponding pitch and beat detections can be output as numerical data.

The first implementation of my real-time audio analysis system in Max/MSP receives a live audio feed and divides this input source into ten different frequency bins. These frequency bins subdivide the entire audible range of human hearing from 20 hertz to 20,000 hertz into ten different segments and isolate different spectrums of the audio signal. The beat detection object, *Bonk*, is applied to each frequency bin. This method allows *Bonk* to focus on a narrower audio range instead of detecting beats across the entire spectrum. A bass drum attack resonates in the lower frequencies of the audio spectrum while a cymbal crash or high hat cymbal attack registers in a higher frequency. Isolating the various frequencies yields two different attacks, one for the higher pitched instrument and one for the lower pitched instrument. In addition to multiple attack detections, the severity or strength of the attack can be quantified. For example, a snare drum rolls out a standard marching cadence and *Bonk* detects these attacks within the middle-ranged frequency bins. Now, suppose a bass drum hits at the beginning and end of the snare drum cadence to denote a new phrase or drum cadence. The bass drum is detected in the lower frequency bins at the same time the snare drum is detected in the middle frequencies. By segregating the audio spectrum into ten bands, the analysis system quantifies the snare drum as a single attack and the snare drum and bass

drum combo as two attacks. If a high-pitched cymbal crash were added to this cadence moment, the system might register three attacks. The quantification of attack strength is a relatively coarse measurement, but it provides a useful element in determining movement and pacing within the 3D animation.

The use of *Fiddle* provides an approximate value for the current pitch in the audio and this data is often used to drive color values in the visualizations or alter movement in subtle increments. *Fiddle* has difficulty calculating the pitch of multiple instruments that are playing simultaneously. Ideally, each instrumentalist should have his or her own microphone, but this may not be practical in larger ensembles. *Fiddle* also has limitations on pitches it can discern. Lower pitches are more difficult to isolate, and it can take a few seconds for *Fiddle* to zero in on the correct pitch. These limitations are reflected in my design choices for animations. I use *Fiddle* as a rough approximation of pitch with the understanding that it may not always be accurate, so critical visual forms in the animation rely on other analytical functions. I did not want the correlation between visuals and music to appear arbitrary. The use of *Fiddle* is a concern because it can be difficult to establish a clear relationship between *Fiddle*'s output and the actual pitch of the music so I limit its use to less critical developments in the animation.

All of the spectral analysis and pitch information is gathered into the form of a list and sent to a real-time environment authoring software entitled Virtools using the Open Sound Control protocol. The Open Sound Control (OSC) protocol is an open-ended network protocol that provides an interoperable real-time communication system for the control of sound, musical instruments, and other media processing instruments (OpenSoundControl). Virtools and Max/MSP offer OSC objects or building blocks that are compiled for their respective programming languages. Through OSC, the exact timing of attacks, attack strength, approximate pitch, the MIDI note associated to that pitch, and peak amplitudes for the ten frequency bands are

transmitted to Virtools. Virtools provides additional functionality to manipulate this data or use it to drive specific functions in a real-time animation.

My first iterations in the real time music visualization process focused on the synchronization of musical attacks to create motions in the animation. I explored the association of dynamic contrasts in music with dynamic contrasts in visual motions. The first visualizations focused on a central node that acted as a focal point and controlled the location of objects around it. Dynamic fluctuations in the music controlled the movement of this central node, and this scenario was acceptable for visualizing contrasting sections in the music (Figure 6.11). I continued to build on this structure and began to incorporate other data streams such as pitch or amplitude values from different audio frequency segments into the animation. *Fiddle's* ability to decipher pitch frequencies was used to alter the color of objects. The color choice was arbitrary in the first iterations of these animations. I simply mapped the detected frequencies from *Fiddle* (20Hz – 20kHz) to the

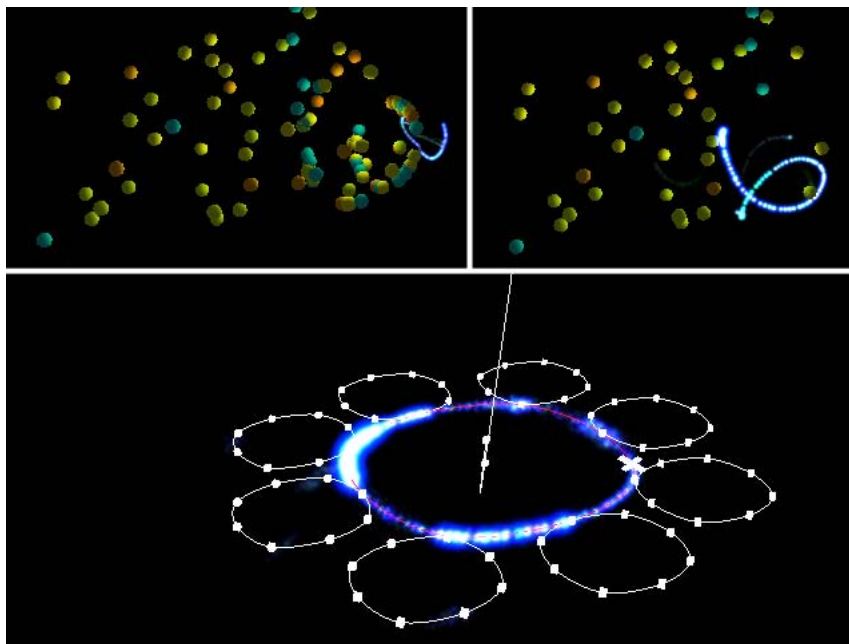


Figure 6.11: The various spheres in the top two images depict the movement of the central node over time. The lower image shows the entire central node with some rings surrounding it.

visible spectrum of light, because of *Fiddle's* limitations with accurate pitch detection.

The first real time visualizations suffered from a lack of focus on specific visual forms and how those forms related to create an overall visual theme. Instead, these early visualizations served as a means for discovering appropriate music to visual mapping strategies. I was able to experiment with pitch to color relationships, amplitude variations to object translations and rotation, and a preliminary camera system that tracked a central node in the animation. These experimentations helped me discover the importance of a central node-based system. The central node provides a clear subject for the camera, and it provides a focal point for the creation of other visual forms. As the central node moves through the 3D environment, objects are generated in response to the audio data and positioned relative to the central node. The resulting effect is a trail of objects that presents a brief snapshot of the audio data as it evolves over time.

A focus that develops in these preliminary visualizations is the illustration of a visual history of music. Audiences were able to witness the generation of an animation in response to musical data streams and with an alteration of the camera's viewpoint, they could see a visual history of what recently occurred in the music. One difficulty in this setup was the immense amount of data that needed to be visualized. As the music progressed in time, more and more data needed to be displayed. A long straight line of objects generated in the animation may be the most obvious choice for a visual history, but this was not a very inspiring concept for me. A straight line is very predictable, and not representative of a music performance's suggestion of curves, jumps, sways, revolves, and most importantly unpredictable directions that constantly leave the audience wanting and listening for more. A long line of visual data is also cumbersome and difficult to navigate. As the line grows longer it becomes increasingly difficult to show the entire line in detail. No matter how I orient or position the camera, the introductory developments of a line will always be difficult to see in the compositional frame. Panning away from

the line comes at the expense of detail, and it does not effectively use the space within the frame. To combat these limitations in a straight line, I experimented with wrapping the visual history around a sphere in the same way yarn is wrapped into a ball. This solved both problems I had with the straight line approach. Having the line contained to the surface area of a sphere allows for a more effective use of the compositional space. Lines remain visible on the backside or the area facing away from the camera in addition to being visible on the front side or the area facing the camera, so I was able to effectively use foreground and background space within the composition. It also added visual interest in the composition. The curves that arc throughout the space more effectively represented the dynamic qualities of music and better utilized the space within the compositional frame. The overall effect is demonstrated in the figure (Figure 6.12).

The visual history of music and wrapping of data around a sphere was a principle concept behind the work which was

demonstrated at the ACCAD open house in 2007. This work consisted of a large blue sphere that served as the central node in the animation. This central node technically orbits a larger sphere which was invisible to the audience. This created a more dynamic

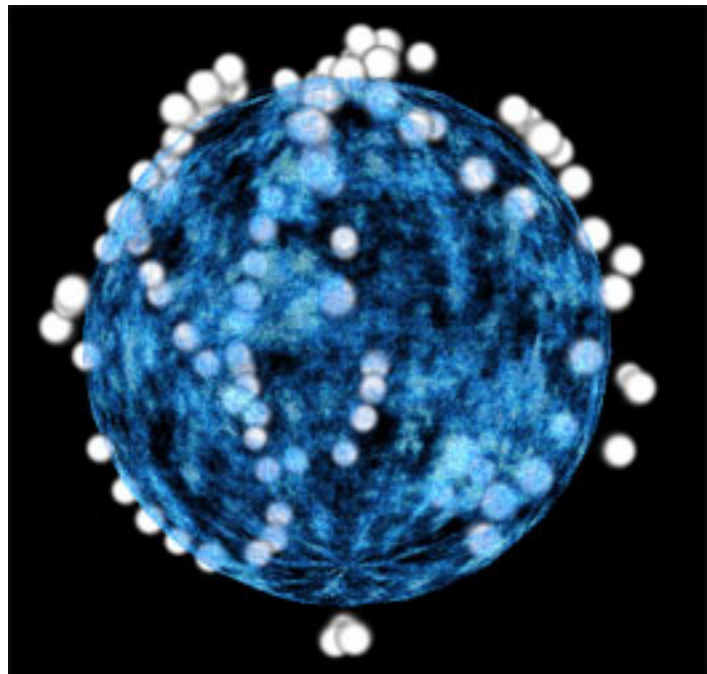


Figure 6.12: This shows the more effective use of space. The smaller white spheres can occupy the foreground and background. This is also the first implementation of wrapping a visual history around a sphere.

and seemingly unpredictable path for the central node, and it represents my first use of hierarchical control structures. A small particle-like system orbits around a larger blue sphere which orbits around a larger invisible sphere. The combination of three different orbits creates some unique twists and turns in the developing visual history of music. The most compelling visuals transpired later in the animation when multi-colored streams that once represented the current amplitude and pitch of the audio curve, twist, and arc



Figure 6.13: This image depicts some of the unique compositional elements and an effective use of the compositional frame to illustrate a visual history.

through the compositional space in a seemingly interconnected web (Figure 6.13).

Unfortunately, the animation exhibited some flaws and one unique problem that actually enhanced the visual history of music. As the animation progressed, the computer was programmed to periodically clear all the visual history. During the demonstration,

the computer failed to clear the visual history and continued far beyond my original intentions for the animation. The animation became progressively slower and slower as the particles constantly increased in number. It was during these moments that some of the most compelling and visually engaging images came about from the hundreds of colored arcs and twists that dotted the compositional space. The orbiting particle trails kept the piece visually intriguing by breaking up the space and creating unique interconnected webs of visual music history. These visual history lines connected the foreground and background of the composition with some lines periodically filling the frame while others appeared as tangled meshes in the distance.

The animation exemplified one other problem where the central node or blue sphere remained in the center of the composition at all times. This lacked a dynamic and variable quality for the composition because the camera was constantly tracking this central node. I did not want a single static object to be the focus of attention for the duration of the music piece. Music is never static or stationary so the unchanging view of this central blue sphere node seemed contrary to the very nature of music.

The creation of the particle trail lines which vary their size in response to the amplitude was a good starting concept for capturing dynamic changes in music. I needed to refine this concept and emphasize the contrasting qualities of the particle's size. I wanted dynamic contrasts to fill the compositional frame. If the music was going to blare with a deafening intensity of volume, then I wanted a bombastic visual form to accentuate this moment. This animation represented a significantly tamer version of those dynamic contrasts. The particle trail does vary in size but it still remained small relative to the other formations in the composition.

The resulting animation may not have visually captured the music in a dramatic and compelling way, but it did demonstrate an effective system for real time audio analysis and the generation of an animation in response to that analysis. This system

illustrated a developing visual history of music. Thanks to a malfunction in the system, the animation created a far more intricate and complex visual history than I originally intended. The system also represented my development process for the construction of a real time animation system that responds to a live audio source. I focused on technical issues involved with creating the animation system and refined my process for future versions. This system increased my desire to create a more dynamic camera system and to create visual forms that more effectively convey the contrasting dynamics of a live music performance.

6.5 *Arctic Fracture*: Real time live performance of Drums Downtown V

Arctic Fracture expands on the previous real time visualization system by addressing my desire to emphasize dynamic contrasts within the compositional frame and by creating a more complex camera system that better responds to changes in the music. This animation departs from my concept of creating a complete visual history of music and focuses more on the immediate reaction the animation has to music. *Arctic Fracture* also builds on the strengths of the computer in the real time execution of the animation, and incorporates multi-channel audio inputs for a more cohesive dynamic visualization of a live music performance. Additional systems are created to control the camera's view and provide support for the artist to manipulate certain aspects of the animation.

Drums Downtown V was my second opportunity to collaborate with the OSU percussion ensemble and their directors Susan Powell and Professor Joseph Krygier. This work attempted to construct a real-time animation that would respond to a small percussion ensemble's performance. This would be a radical departure from last year's work where the performers had to conform to the timing constraints of a pre-rendered animation. The musical piece is entitled *Ursprung/gläntor* or *Origins/Glades* by Henrik Strindberg, and it calls for a small ensemble of six percussionists all performing various

hand drums, wind chimes, crotales cymbals, and a Nigerian udu earthenware drum (Strindberg).

My first step was to consider what aspects of the music I would like to analyze and how the resulting analyzed data streams could be appropriately reflected in a camera control system. My focus for this real-time music visualization system was to more effectively illustrate music dynamics and their relationship to the compositional space. I attempted to improve upon the previous music visualization system and use camera motions to subtly convey dynamic variations in the music. In order to demonstrate dynamic variations in the audio, I created a new analysis system in Max/MSP that provides a measurement of the audio amplitude differential. The system functions as an audio envelope tracker. It records and quantifies the difference in amplitude values within the audio signal. This amplitude differential information illustrates an atypical aspect of amplitude data. Peak meters in audio typically represent decibels or amplitude values with lighted bars that

increase in number when the audio amplitude increases (Figure 6.14). I attempted to show another aspect of this data by creating a system that tracks the difference in these amplitude values. A spontaneous or

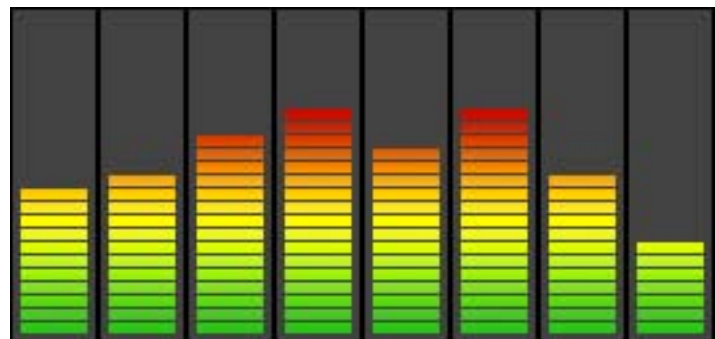


Figure 6.14: This figure shows a series of audio amplitude peak meters that represent various frequency segments in the audio spectrum

loud percussive hit triggers a large reading in the system, but successive loud hits only trigger a small reading because the difference between their amplitude and the first loud hit's amplitude is much less than the difference between an initial loud hit and silence. This audio envelop tracking system proved to be very effective in capturing the general

dynamic contrast in music, and it proved to be an invaluable tool for the operation of the camera movement in this real time animation system. This audio analysis system was replicated seven times to provide six discrete audio channels, one for each performer

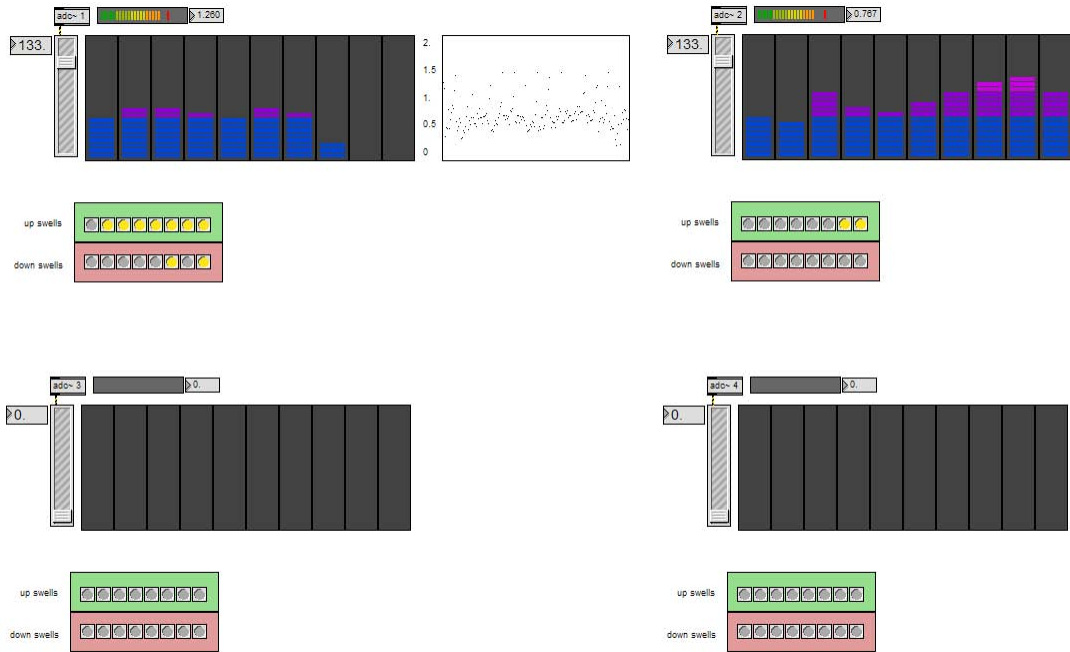


Figure 6.15: This image depicts four of the six audio channels with some analysis systems visible in the ensemble and one channel that represents a mix of the six other channels (Figure 6.15). This seventh channel represented the percussion ensemble as a whole, and it was used to guide the movements and viewpoint of the camera in the animation.

The camera rig in this setup is actually very complex in its design. The camera has a central node that is designated as its target. All of the other visual forms in the animation are generated relative to this central node or master position marker. The camera rotates clockwise or counter-clockwise around this node depending on multiple different factors including the strength of the audio envelop tracker or difference in audio amplitude and the time difference between detected audio envelopes. Quieter music may have percussive hits that are sparse when compared to a driving rhythmic section where

percussive beats are frequent and potentially louder. The camera's rotational direction and speed at which it rotates is based on these two factors so softer dynamics result in slower, subtle camera movements while large dynamic contrasts in the music produce more energetic motions.

To balance the camera's data-driven motions, some controls are built to help the artist alter viewpoints as necessary during the live performance. These include the camera's pitch (tilt) or height from the subject, zoom distance, and the ability to switch between different subjects or master nodes at the push of a button. The master node's position is governed by the audio envelope tracker, the time difference between detected envelopes, and some randomized factors based on the audio data streams. Dynamics in the music dictate the node's motions throughout the environment.

My inspiration for this real time animation system actually hit me during a walk in the woods after a significant snowfall. I had been listening to the composition by Henrik Strindberg many times in search of some visual inspiration without any success. During my walk, I began to notice snowflakes, water drops falling from icicles and I began to consider how these visual elements might sound. I immediately went home to listen to the piece. Many of the sounds and instruments in Strindberg's piece demonstrated a high-pitched "clink" or "clang" sound. They could almost be construed to the breaking of icicles or the smashing of ice on a hard concrete floor. The earthen drums presented a deeper more muffled thump that could be represented by the sound a drop of water makes when falling into a deep puddle. The inspiration of my winter walk coupled with the sounds of the instruments in *Ursprung/gläntor* became the basis for my visual theme. My research encompassed different pictures of water drops, icicle formations, snow, frost formation, and ice sculptures. I was particularly intrigued with the splash pattern of a water drop and how it created a unique formation on impact with the surface of water (Figure 6.16). I wanted to capture the same moment in time that the picture illustrates



Figure 6.16: This inspirational image of a water drop hitting the surface of water is actually a 3D generated image that was created by Ricardo Lipas Augusto from Brazil.

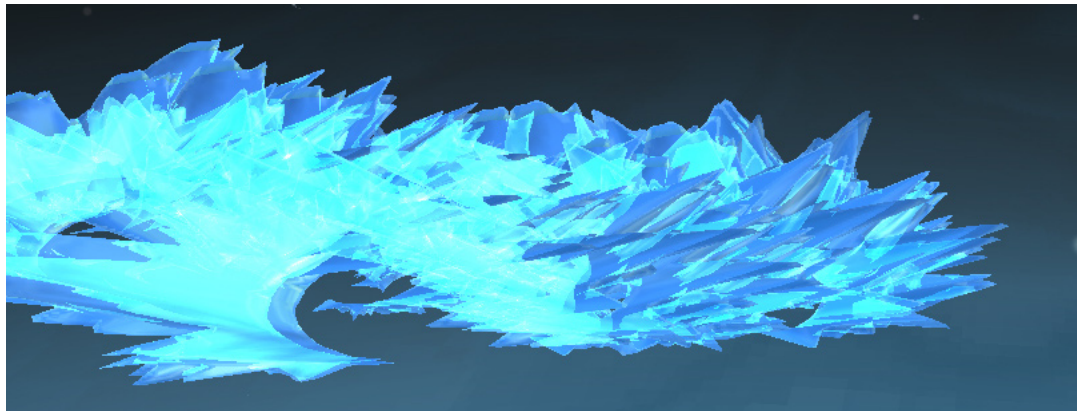


Figure 6.17: The crescent-shaped frozen splashes from *Arctic Fracture* generating based on a live audio input.

but with an icy twist. I chose to accentuate the highest arc in the splash formation, and I asked what if a raindrop were to hit the ground at a 45 degree angle and instantly freeze afterwards, what would it look like? This concept quickly developed into a crescent-shaped splash of ice that would freeze at the apex of its outward thrust (Figure 6.17). This crescent splash shape quickly snowballed into other formations. I began to create

icicles that would grow upwards from the ground like stalagmites, arcs or hook-shaped formations of ice, crescent-shaped frost patterns, and even ice formations that resembled sea urchins. The goal was to create a short visual formation of ice that could represent a dynamic burst of audio, or in the case of this piece, the clang of a cymbal hit. Each visual formation was unique and able to visually capture a specific percussive hit in a quick extruding motion. The combination of all the ice formations would create this incredibly unique and explosive growth that is representative of the percussive instruments in the piece.

Each of these visual ice formations has their own unique animation and a corresponding HLSL (high level shader language) shader. These HLSL shaders are developed with a free tool called “Mental Images Mental Mill Artist Edition” which is packaged with nVidia’s FX composer 2.0 software (Figure 6.18). Shader languages such as HLSL are programmable instructions that specify how the GPU (graphics processing

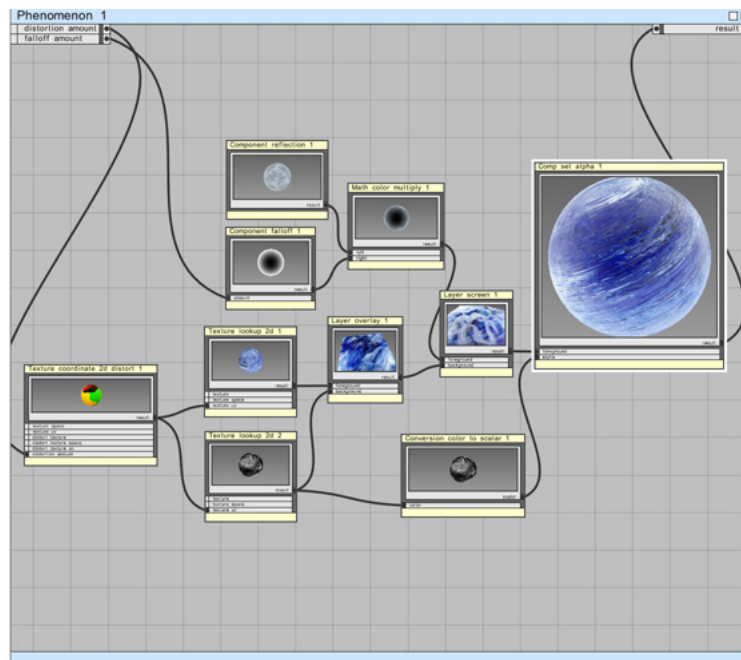


Figure 6.18: A view of the visual shader network that I used to create HLSL shaders in the Mental Images shader program. The shaders are then exported to Virtools.

unit) manages data as it passes through the 3D pipeline of a graphics card. Functions of HLSL include vertex processing that can manipulate the vertices of a 3D object or pixel processing that can manipulate a specific pixel. These effects typically include texture blending, lighting, and environmental mapping. The combination of vertex and pixel processing represents the core function of HLSL shaders in DirectX 9.0 (Programming Guide to HLSL). Mental Images Mental Mill software allows artists to create shaders through a visual node-based hierarchical system (Mental Images). All of the objects in my real-time animation are created with shaders I program to look like different textures of ice. Many of these shaders have exposed parameters that allow the artist and the programmed systems to alter select elements like color, distortion, brightness, and

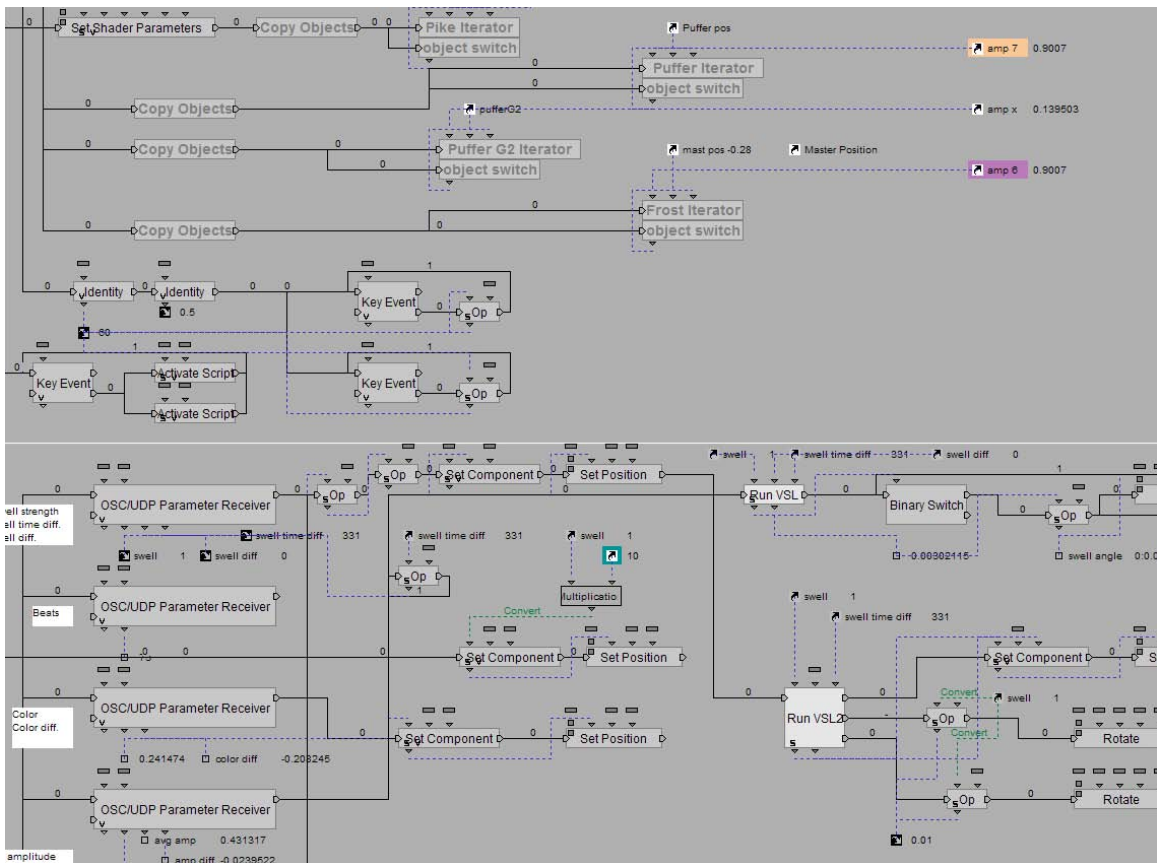


Figure 6.19: The Virtools schematic represents my visual scripting process and the decisions I make when designing the real time animation system

transparency. The overall effect is an added level of detail in the generative aspects of this real-time animation system because their surface textures can be further manipulated by the programmed systems or controls that are driven by the artist.

The programming schematic of Virtools provides a unique perspective on my process of designing real time music visualizations. The visual scripting interface can serve to outline some of the choices I make when programming (Figure 6.19). My thought process relating musical structures to visual forms must start with the translation of numerical data into a complex sequence of math operations, decision trees, object generators and transformation controls. I start with a large set of incoming data previously analyzed in Max/MSP. This numerical data consists of continuously updating amplitude values for each audio channel, beat detection triggers, pitch values, and data streams in which attributes of the audio channels are averaged together. By initially connecting values of the streaming data to the position and rotation values of temporary markers or placeholders in the 3D scene, it allows me to visually study the data in motion. I am able to get a sense for the possibilities of how I might conform the data to control objects and motion suited to my interpretations of the music. From this stage, I proceed to take control of these resulting motions by manipulating the incoming data using mathematical calculations to filter the values or by creating new markers that interpolate between the coarse or erratic motions of the originals to create smoother motions. I apply threshold or multiplier operations in order to amplify motions that emphasize gestures that help convey the essence of music I intend to show in the animation. After the data is under better control, I explore other possibilities of motion by creating conditional statements that respond to thresholds in the data to determine different directions or positions in which visual forms are generated. This is an exciting moment in my development because I can attempt many different permutations of functions until I arrive at a successful representation of the events occurring in the music.

As I build the scripts for the computer to autonomously control forms and motion based on the audio data, I analyze the resulting visuals and decide if creating controls that allow for manual overrides of the scripts could be important in order to have increased control over desired output during a live performance. In *Arctic Fracture*, I determined that building keyboard input controls that affect operations on the autonomous camera system could facilitate new viewpoints or interesting camera angles that might not be possible otherwise. This allows me to take control of the camera position when the computer drives the camera in a direction I do not approve. Dress rehearsals with the performing ensemble helped me refine and predict how the autonomous systems would react to the live audio streams. With additional keyboard controls, I adjusted the thresholds of the incoming data and their influence over specific motions in the animation. This process of implementing layers of user control that can modify the programming in real time allows for both technical problem solving and creative adaptation to the live performance event.

Each percussionist had their own visual representation that responded to their music part in the ensemble. Since the percussionists were each responsible for multiple instruments, I decided to make the visual representations modular. Each visual representation was originally tied to a specific audio channel. The crescent ice splashes were always associated with audio channel one. Because different percussionists would be playing the cymbals, I had to create a more flexible system for the visual representations. The end result is a switching system that allowed me to assign any audio channel to the crescent ice shape. I could switch the crescent splash cymbal element to different inputs depending on who was playing the cymbal part at the time or I could choose to associate the ice formation with the first percussionist in the ensemble. This flexibility in the assignment of visual elements to audio streams was a choice I made to balance the analytical capacities of the computer with the conceptual desires of the artist

and the artist's need to adapt during performance. This design choice along with others such as camera manipulators provided the artist with some control over the real time animation instead of relying solely on the computer's ability to manipulate and relate multiple data streams to specific visuals in the animation.

The real time animation system was frequently tested during some of the percussion ensemble's rehearsals. Some of the initial challenges included balancing audio levels between the six microphone inputs and adjusting the visual representation's response levels so they would focus on their respective audio input. Microphones would often pick up audio and noise from the surrounding musicians because the musicians



Figure 6.20: A live capture of the performance with the *Arctic Fracture* visualization appearing behind the musicians on stage.

were all sitting close together in a semi-circle. I had to constantly adjust audio level thresholds so each visual instrument would primarily capture the dynamics from its specified audio input. After some adjustments to audio levels and balancing between

audio inputs, the system was complete and ready for the final performance.

The two performances for Drums Downtown V ran successfully and the animation system responded beautifully to the percussion ensemble (Figure 6.20). There were some unique observations I made when comparing the development phases of the real time animation system to the live testing phases of the performances. The first observation I made was the dramatic difference in dynamics between pre-recorded audio and live audio. Dynamic intensity and diversity is lost in a recording of music. During my independent trials of the animation system using pre-recordings, the dynamic levels were relatively consistent and confined within a narrower amplitude range. Each visual representation in *Arctic Fracture* was predominantly driven by the amplitude of its respective audio source. Pre-recorded audio levels were very easy to work with so the size, shape, or color of the different visual representations would never expand too far beyond the compositional frame or visually clip above the color white. In contrast, live audio has a more expansive dynamic range. When the percussionists were playing softly, I found myself directing the camera to extreme close-up views just to make the ice formations visible in the composition. When the dynamics began to increase, I had to quickly distance the camera from the subject in order to keep portions of it within the frame. After discovering these extreme dynamic variations during the dress rehearsals, I decided to implement new limits on various systems that were being driven by amplitude data. For example, some shaders in the animation used amplitude values to control their color. I had designed the shaders to vary their shading in response to the limited dynamic range of recorded music. The dress rehearsal yielded amplitude values that caused many of these shaders to appear white, so I had to adjust and limit their response to the new amplitude data. Though I limited the response of shader control systems, I did not limit the size or motion of the ice formations. My previous visualization work for the ACCAD open house did not accentuate the dynamic contrasts enough so this was a welcomed

change when I saw the new dynamic contrasts in response to the live audio.

The second observation I made was the unique interplay that existed between the different visual ice formations. I found that switching visual representations between different audio sources was not necessary and probably over-complicated the visualization. It was fascinating to hear the different percussionist's dynamics as they varied, cross-faded, grew, and receded in response to each other. It was even more

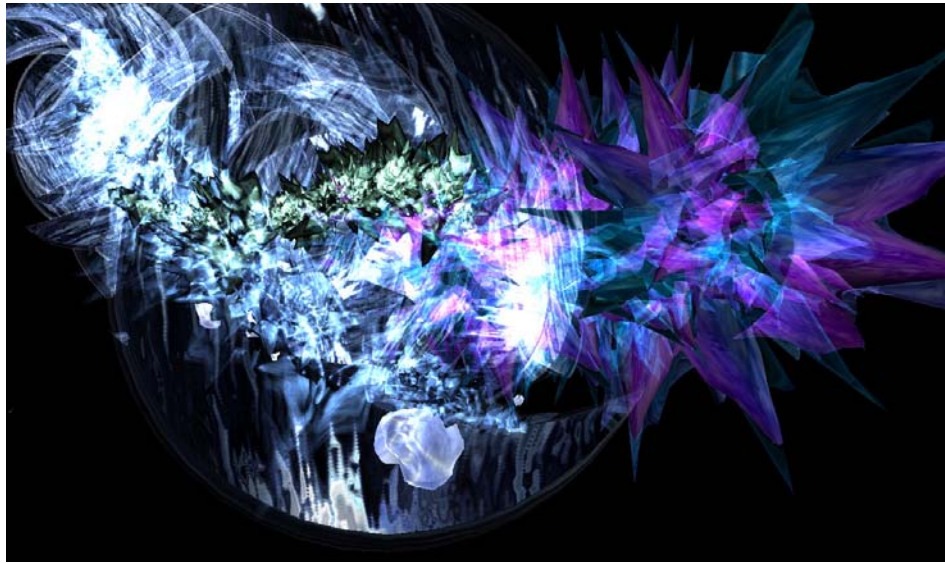


Figure 6.21: An image illustrating the dynamic interplay and variation between the different ice formations

interesting to watch as the different ice formations responded to this varied dynamic interplay (Figure 6.21). I had developed each of these ice formations to represent specific performers or instruments and my testing was limited to two-channel recorded audio. The variable dynamic developments that visually formed between the different ice formations was not something I had observed during testing and it created an even more compelling composition. One percussionist would rise to the foreground of the ensemble while other members receded in intensity to further support this rise. Then another percussionist or even two ensemble members might rise in intensity while the others faded to the

background. This communication that occurred between ensemble members was visually captured and animated. This was a distinctive visual development in my work, and I no longer thought it was necessary to attach a specific visual representation to a particular musical instrument or ensemble member. It was exciting to watch how the dynamic variations animated and responded to each other through the six different audio inputs from the ensemble.

Arctic Fracture was able to better portray the variations in music dynamics from subtle fluctuations to drastic changes because I focused on what was happening now in the music. Instead of long visual histories of music being illustrated in the previous real time animation system, dynamic changes filled the composition and created a strong visual impact. The camera rig also supported the visual impact of the animation because its position was constantly changing in response to the audio data. Additional controls were incorporated to allow the artist to further manipulate the camera angles to create top-down perspectives and views from underneath the developing visual formations which created more variability in the animation. Various incoming data streams like pitch analysis, amplitude differentials, and multiple audio channels affected to varying degrees how the central node would move through the environment so the central node was no longer attached to a predetermined path. This created a more unpredictable and visually interesting composition. The greater dynamic range of the live audio source challenged the compositional boundaries of the camera's view from being barely visible to completely filling the frame. Visualizing the communication that exists between musicians during a live performance was an unexpected and welcomed addition to the animation. This communication added visual complexity to developing forms in the animation and created an effect I was unable to foresee during my initial development of the animation system.

Arctic Fracture also demonstrated the use of a computer as a visual instrument for the artist. Micro-level control systems provided the computer with the functionality to simultaneously analyze and manipulate six different audio data streams and use that data to drive scaling, translation, and rotation values for six different ice formations, while the artist was able to exercise control over macro-level systems like a camera's viewpoint, or assigning different ice formations to different audio inputs. The characteristics of these control systems in the computer combined with my artistic interpretations and sensibilities allowed me to visually contribute to the music performance with the computer as my instrument.

The programming involved in this real time animation system provides me with a framework for future development and refinement. I can easily switch ice formations with falling leaves, bouncing bubbles, or erupting skyscrapers. In future developments, I can continue refining the camera control system to allow for more flexibility in how the camera moves in relationship to the central node or build in additional controls for the artist to manipulate the camera's position. I can introduce new targets for focusing the camera instead of relying on just one central node, and the camera can transition smoothly between these different focal points. Visual formations can develop simultaneously in different regions of the 3D environment with each formation having its own unique development while the artist uses the camera to transition between the different regions. Additional visual formations can be integrated to include more audio channels, more musicians, and larger ensembles.

CHAPTER 7

CONCLUSIONS

My journey as a musical visualization artist started with a highly analytical approach. My process concentrated on visualizing structure, pattern, and thematic development with the goal of elucidating these structures to an audience that consisted of music theorists and musicians. My studies in other artists' music visualizations like Oscar Fischinger's animations, Wilfred's "Lumias," and Disney's Fantasia inspired me to create animations that would focus on a more interpretative goal that uses visual animations to depict characteristics of music. My process goals quickly transitioned away from an analytical to a more interpretative approach. Rather than focusing only on visualizing complex structures and their development in music, I wanted to share with an audience the passion I have for music through visual interpretation informed by the emotional responses that the music and its performance can invoke in listeners. I wanted to illustrate expressive characteristics of music that would be accessible to everyone so I focused my efforts on performance-related aspects in music.

I became interested in the visual form of music and my views changed from a concrete and structural interpretation to a more artistic and abstract one. For me, music represented a moving, fluidic, and ethereal form that expanded and contracted in the space of an imagined concert hall. This ethereal representation can take on many different forms from solid spikes like a sea urchin to the gentle downpour of water flowing over some rocks. This ethereal form of music represented the basis for all of my design

decisions, and it is something I have tried to capture in all my animations. I consider this form to be the overarching visual concept in all my works, and I have tried to illustrate this form in my animations.

I focused my efforts on music dynamics and how they could affect visual formations in the animation. I also tried to incorporate my understanding of themes and structures in music into the visual images. Rather than using my knowledge of themes and structures as the principal basis for my animation, I chose to use them as a subtle influence on the choices I made when creating the animation. I figured that if patterns and themes could provide a structural foundation for music, perhaps these qualities could be instilled into my visual creations. Considering audible patterns and themes in the music helped me to create a framework for the development of my visual references.

All throughout this process the computer functioned as a tool in the conventional sense that it only functioned to help the artist create a music animation. The computer had no creative input during the execution of that music animation. When my process evolved to creating real time music visualizations in a live performance-based environment, my initial concept of the computer as a complex tool changed. As I continued to explore the characteristics of a live music performance, it became clear to me that I would need to include the role of the artist who could modify the visuals in response to the music in a real time setting. My earlier works used the computer as an instrument to create music visualizations with no creative input by the artist or the computer during the execution of that animation. During a performance I hit the “play” button and the computer performed in the exact manner in which I had programmed it. Though this was sufficient for my earlier works, I wanted to create a more interactive process between the performing musicians and the visual artist. I realized at this juncture that the computer could be more than just a player piano. It could become a piano. I discovered that the computer’s programming could be greatly enhanced with the input

of an artist. I utilized the computer's generative capabilities and combined that with my artistic sensibilities to create a work that could truly respond to a live music performance. The computer could become a visual instrument for the artist to play.

I discovered which aspects of the animation would be suitable for computer control and which aspects should be reserved for the artist. I built a workflow and a programming concept that revolves around multiple iterative visual formations. I developed an autonomous camera control system for my animations that subtly adjusts to audio data. The result was a camera system that constantly reconstructed the frame of the composition and functioned like an organism that hovered over the developing visuals in the animation. The camera was constantly moving, rotating, and adjusting in subtle motions to the incoming audio data.

An interesting observation I made during the performances was that the system and the camera movements were mostly invisible to the audience. Instead, the focus of the audience was on how the visuals unfolded within the composition, not on how the camera system had a significant impact on the perspective of the composition. The compositional frame was constantly being altered which created a more organic feel to the visual forms within the animation. The developing visual formations in the animation were never viewed from the same position so it fueled the perception of the visual images being in a state of constant evolution which paralleled the evolutionary nature of music.

Prior to the performance, I made specific artistic choices about the visual elements available for the computer's use during the performance. These included decisions about shapes, patterns, and potential directions the visualization might take. In the beginning phases of development for all of my animations, I remained distant from the musicians and their weekly rehearsals. In one respect, this was necessary because I needed to design the visuals for the animation and program the control systems. On the other hand, it would be interesting to see how my role would differ if I had the opportunity to converse

with the musicians and attend all of their rehearsals. Integrating the visuals with the music rehearsals occurred in the later phase of our collaboration because time was a constricting factor for both parties.

My role during the performance was to support the musicians by creating and building visual interest in the compositional frame. At times I would override autonomous systems like the camera rig to introduce a unique or different perspective on the developing visuals. When the music made a significant stylistic or thematic change, I would key in an appropriate change in the visual form to respond to these differences. I used my understanding of the music to visually enhance the thematic developments in the music and create an animation that would accentuate certain musical elements like dynamics, unique rhythmic patterns, or thematic statements in the ongoing performance.

The notion of the computer as a visual instrument has led me to discover my role as the real time visualization artist who “plays” it. My drive to create a visual work that truly represents a live music performance pushed me to create an instrument of my own. I discovered that the computer can be a powerful and complex instrument, but it still needs the interpretative input of an artist. In my work I will always reserve the most critical and conceptual developments in the visualization of the music for the artist to control. The computer can be programmed to accommodate and effectively respond to a live music performance, but the instinctual and expressive interpretations of an artist cannot be replaced.

In future work, I hope to further develop this concept of the computer as a visual instrument. I would like to elevate its role in a performing ensemble. Instead of just visually reacting to the musician’s performance on stage, I think it would be exciting to explore the interplay of musicians responding to a visual artist’s interpretations. The visual artist can use the computer as his or her instrument and potentially take new directions in a live visualization of music. The musicians would in turn respond to these

new visualizations. The musicians and the artist could play off each other to create a truly interactive work in a live performance setting. Jazz music has sections where the musicians can improvise and dynamically construct melodies based on a progression of chords. The jazz musicians often call and respond to each other by borrowing melodies, sharing short motifs, and reconstructing rhythms to create a dynamic, original musical performance. This interplay that exists between musicians could be expanded to encompass a visual artist. As a contributing member of the ensemble, the artist could use the computer as his or her instrument to interpret the music while the musicians respond to the developing visuals. I envision a developing role for the computer as a visual instrument in a musical performance as I continue my lifelong pursuit of creating real time music visualizations.

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