CREATING BRIGHT SHADOWS: VISUAL MUSIC USING IMMERSION, STEREOGRAPHY, AND COMPUTER ANIMATION

A Thesis

by

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ABSTRACT

This thesis outlines the research and process of creating an immersive audiovisual work titled “Bright Shadows,” an 11 minute three-dimensional animation of dynamic, colorful abstractions choreographed to instrumental music. This piece is categorized under a long tradition of a type of visual art aspiring to musical analogy called “visual music” and draws heavily from the two-dimensional aesthetic stylings of time-based visual music works made in the early to mid-twentieth century. Among the topics discussed in this paper will be an overview of the artistic and technical challenges associated with translating the visual grammar of these two-dimensional works to three-dimensional computer graphics while establishing a unique aesthetic style. This paper also presents a framework for creating a digital, synthetic space using a large-format immersive theater, stereoscopic imaging, and static framing of the digital environment.

DEDICATION

This work is dedicated to my amazing family, Jan, Tony, Samantha, and Rachel. I owe every bit of success in my life to their inexhaustible support, knowledge, humor, kindness, and love.

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I would like to thank my committee chair, Philip Galanter, for his invaluable knowledge and his dedication to helping me realize this projects full potential. This research would not be the same without his mindful dialog, observations, and guidance throughout every step of the process. I would also like to thank my committee members, Carol LaFayette and Stephen Caffey, for the wonderful insights and invigorating enthusiasm they brought to this project.

Enormous gratitude goes to all the faculty, staff, and students at the Viz Lab for the invaluable lessons I have learned and experiences I have shared with them. The knowledge, skills, and friendships that I have gained there will stay with me for the rest of my life.

My deepest thanks to my family for giving me the opportunity and support to follow my passions in life. Thank you to Sarah Beth for loving, helping, and inspiring me.

NOMENCLATURE

3D	Three-dimensional
2D	Two-dimensional
NURBS	Non-uniform Rational B-spline
IVC	Immersive Visualization Center

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CHAPTER I

INTRODUCTION

The comparative study of music and language is drawing an increasing amount of research interest. Recent neuroimaging data suggests an overlap in the processing of syntactic relations between language and music [2]. Music also shares a number of basic processing mechanisms with language such as the ability to integrate elements into syntactic structures and to extract nuanced emotional meanings from acoustic signals [3]. Furthermore, language is proven to have a powerful neural relationship with non-verbal communication, commonly known as body language. Perception of body language has been estimated to constitute up to 60–70% of human social communication [4]. People depend on body language to help them interpret the meaning and emotional context of language. Such as language is enhanced through body language, music can often have a poignant expression and amplification of its emotional intent through visual mediums such as dance, paintings, theater, music visualizers, and film. This is often categorized as ‘visual music’, a blanket term for visual arts that aspire to musical analogy [5].

Visual music has taken many forms over its lengthy past. "The history traced by visual music includes paintings, photographs, color organs [instruments that produce colored light], films, light shows, installations, and digital media" [5]. The specific category for which this project is based is defined as follows. "A time based narrative visual structure that is similar to the structure of a kind of style of music. It is a new composition created visually but as if it were an aural piece. This can have sound, or exist silent" [6]. Many of the experimental films that fall under this definition consist of moving forms that embody an abstracted, gestural quality of body language and dance. There is a simplicity to these appealing and evocative works. Famous artists who pioneered this type of visual music beginning in the 1920's include Walter Ruttman, Oskar Fischinger, Viking Eggeling, Hans Richter, and Len Lye.

For many visual artists of the early twentieth century, music embodied what they believed the visual arts should ideally be achieving [7]. It was believed by these artists, as it was believed by the abstract expressionist painters of the early 1900's who inspired them, that it is only through the depiction of non-representational forms that visual media could aspire to the "purity" and "self-sufficiency" of music [8]. This means that their films were comprised of forms that refused to invoke any real-world analogy to places, objects, or living beings. As musical instrumentation or "absolute music" is inherently abstract and does not contain a direct reference to any specific thing, neither should visual music.

Due to their non-representational approach, the subjects in their films could not exist in the natural world; therefore, artists had to construct them through various means such as hand painting, light projection, or other forms of experimental animation. The process of animating their films a single frame at a time was often lengthy, tedious, and made more difficult by the attempts to perfectly synchronize their moving images to music.

Modern technology can help alleviate some of the challenge of choreographing and synchronizing animation to sound. With computer animation software, one can use data extracted from a digital copy of his or her music to procedurally synchronize events such as motion to musical notes or percussion. These techniques are utilized heavily in real-time, interactive visualizers and light shows out of basic necessity; yet, they are rarely used for pre-rendered 3D graphics. Adapting sound analysis techniques to aid in the production of temporal visual music works could allow a precise audiovisual synchronization to complex rhythmic structures too difficult to time by hand. An interesting, albeit shallow, application of music analysis techniques to automate computer animation can be seen in the "Animusic" short films of the early 2000’s [9].

Computer animation and rendering techniques also allow simple and accurate methods for producing high-quality 3D stereographic video, a pursuit for a number of these experimental animation filmmakers including Oskar Fischinger, Norman Mclaren, and Harry Smith. "The right and left eye information were animated side by side on the same film frame, and a prism used to overlap the projected images and code them for Polaroid glasses." [10]. With modern computer algorithms, the parallax for the left and right images are generated based on precise mathematical calculations, therefore assuring accurate and consistent depth cues for all elements in the scene.

By using a large, wide-format display, I have attempted to create an extension of the space that the audience is occupying. The motivation for creating this space stems from a desire for the audience to feel as if the forms and motion used the visual music piece are inhabiting the same space as the audience. This three-dimensional presentation of animation would attempt invoke a similar feeling to that of live performers inhabiting a stage space in a theater. In an unpublished typescript, Oskar Fischinger, one of the most celebrated visual music artists, wrote about his plans for implementing stereoscopic 3D in a film that was never finished.

"The technique developed in 'Motion Painting Number One' will be combined with the deep-space creation developed in the Stereo Paintings, with the idea in mind of bringing this new creation to the largest possible number of people at present and in the future. To bring them to a closer participation, understanding and love toward Art. ...In a Stereoscopic presentation (which does not eliminate a non-stereoscopic presentation) the almost fantastic precision and space reality brings about a completely new field of Art expression into existence. Future Artists will have a new field of expression. Space itself frees them from the two dimensions of their present day canvases. There is a new infinity without limitations given to use through Space Paintings in Motion and color and sound" [11].

Fischinger was not the only visual music artist considering stereoscopy in his films. It was Walt Disney's original intention to release the 1940 animated film Fantasia in a panoramic widescreen and stereoscopic 3D format, but he could not muster the funds to do so. "Fantasia was released in 1940 to relatively poor box-office attendance, but over the years and through repeated releases it has...taken its place as a classic film and the best-known example of visual music." [5]. The method of stereoscopy these artists experimented with, anaglyphic stereo severely altered the color of their films; however, this was the only cost-effective option available to these artists at the time.

Modern methods of stereoscopic imaging, such as light polarization and active shutter 3D, are more effective at preserving color accuracy and clarity of the original image.

In most cases, employing computer animation as a tool to create avant-garde music animation films can allow artists to focus more of their energy on the creative and aesthetic aspects of their work. However, there is a particular quality of hand-drawn visual music animation that becomes exceedingly difficult with modern computer-generated animation. Many of the forms that Oskar Fischinger, Len Lye, and Walter Ruttman danced across the screen were amorphous. In other words, they would constantly and effortlessly change their visual characteristics such as size, shape, and structure in limitless and unpredictable ways. As all objects and living things are bound by the physical laws of the universe, this shapeless, amorphous quality further differentiated the subjects of their films from the physical restrictions of the real world and carried them further into the realm of non-representation.

With computer animation software, the form of a three-dimensional object is defined by connecting points in 3D space governed by rules such as a specific topological order and pattern. The resulting object is often referred to as a "mesh" and once defined, a mesh can be very easily translated, scaled, and rotated in 3D space. However, any change of the topology of the mesh must be done carefully and deliberately. Most standard applications of computer-generated animation such as commercials, animated films, visual effects, and scientific visualizations do not commonly require the frequent changes of form of avant-garde animation; subsequently, current computer animation software is not designed for meeting these needs. Bringing the liquid and elastic properties of the hand-drawn shapes of visual music animation presents a significant challenge when using tools built on mathematics and computer algorithms. To address this challenge, custom algorithms are needed for each type of morphological state change that are not a part of the standard computer animation toolset.

CHAPTER II

BACKGROUND AND LITERATURE REVIEW

"Visual music traces the history of a revolutionary idea: that fine art should attain the nonrepresentational aspects of music" [5]. Nonrepresentational music is often referred to as "absolute music", or "instrumental music in a pure and autonomous form" [8]. Absolute music is often described as aesthetically pure, emotionally intense, and self-sufficient by artists and academics since the 1800's for its ability to evoke feelings without using language. Around 1910, artists in many European countries--simultaneously and often unknown to one another--took to the path of "absolute painting" using a variety of techniques and styles.

One of the main advocates was Wassily Kandinsky, who not only produced some of the first non-representational paintings, but also developed a comprehensive aesthetic theory of non-representational art in his treatise" [8]. Wassily Kandinsky, along with other artists in the early 20th century, championed a radical approach to painting using purely abstracted forms. These forms were influenced by visual associations made from listening to music.

Other abstract painters during this period that referenced music through title or compositional structure included Frantisek Kupka, Georgia O'Keefe, Mikalojus Knostantinas Ciulionis, Henry Valensi, Morgan Russell, and Paul Klee. Kandinsky and Kupka asserted that "the formal abstract structures of musical composition pointed the way towards a new art, while music's direct and emotional appeal indicated a condition to which [visual] art should aspire."[5]. From there, visual music began to evolve from the static to the temporal. Forming an experiential synthesis between music and painting was an obviously limited fusion due to the immobility of paintings. "Until well into the nineteenth century, the experience of audiovisual arts was bound to a unity of space and time (and action, too, in a certain sense). The technical media of photography, Gramophone recording, silent film, talking film, and video made it possible to reproduce sounds and images, but they also separated them only to slowly reunite them again" [7]. Moving visual music out of stasis and into a realm of motion and spectacle were the inventions of the kinetic light machine, the color organ, and the motion picture camera. It is the philosophy and visual approach of the artists who pioneered visual music in the form of avant-garde film and color-hearing composition that I wish to evoke in this piece.

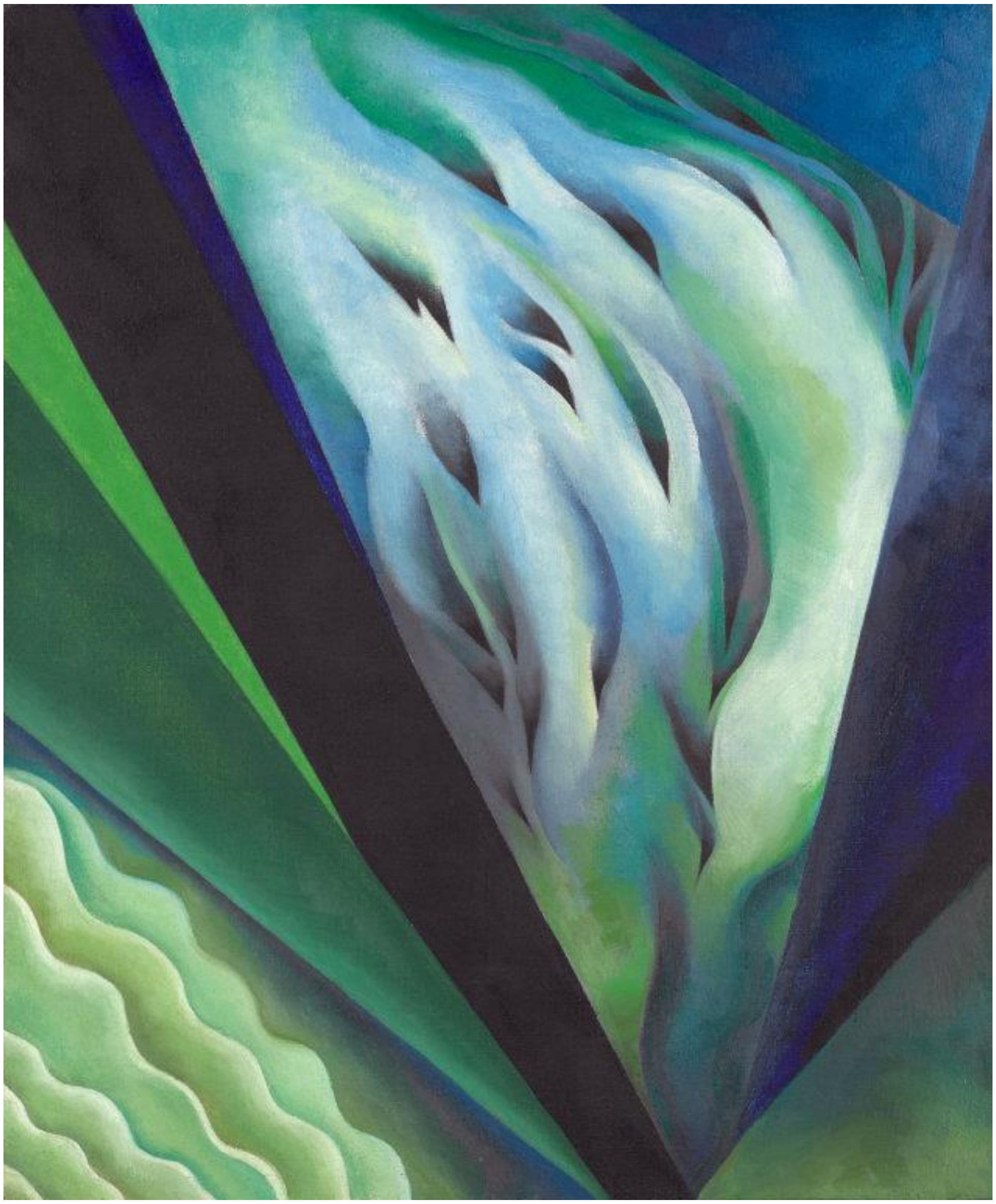

Figure 1: Blue and Green Music by Georgia O'Keefe. [12]

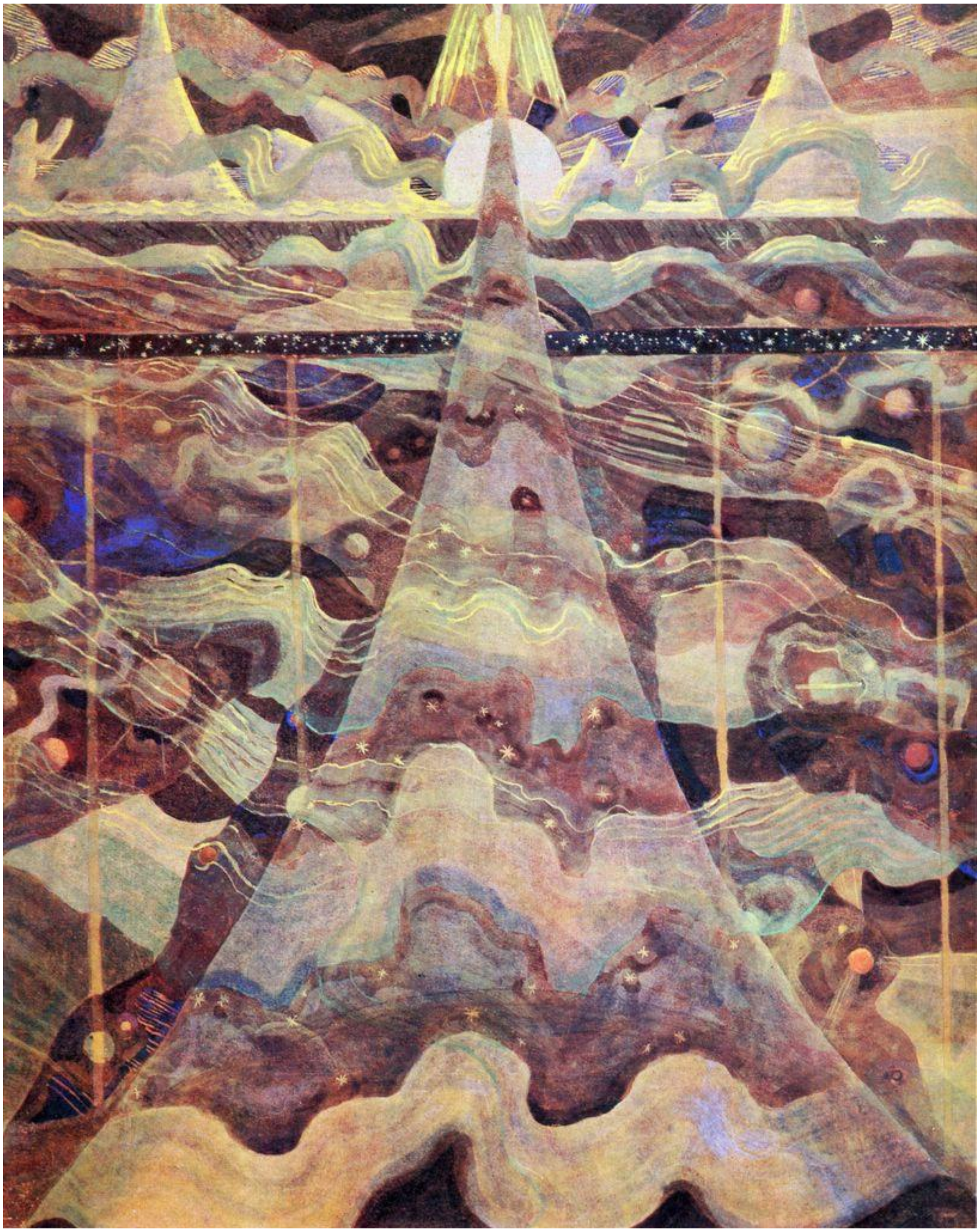

Figure 2: Sonata of the Stars by Mikalojus Ciurlionis. [13]

These artists, along with the abstract expressionists, believed that the only way to achieve an emotional response at the level of music was to remain in the realm of abstraction. Hans Richter felt these "abstract 'evolutions and revolution' to be 'roughly analogous to the sound of music in our ears'" [5]. Other visual music artists from this philosophy of visual music that I will be referencing include Walter Ruttman, Viking Eggeling, Oskar Fischinger, John and James Whitney, Elias Romero, and Jordan Belson whose work spanned across decades. Theorist/inventor Adrian Klein wrote: "...somehow or other, we have got to treat light, form, and movement, as sound has already been treated. A satisfactory unity will never be found between these expressive media until they are reduced to the same terms" [14].

CHAPTER III

METHODOLOGY

Artistic Intent

The tradition of visual music has continued well past the early to mid-20th century and is very much alive today. I have chosen to focus on this earlier time period of visual music as my main source of visual inspiration because I believe the simplified style of these early artists, rooted in formalism, is an approach to constructing non-representational media that does the best at avoiding objective associations. I believe that the further a form deviates from simplicity, thereby increasing its uniqueness, the more likely it can spark objective associations in the viewer. Visual complexity gives a specificity to forms that simple constructions of shape, line, and color avoid by maintaining a quality of objective ambiguity. This is the same kind of objective ambiguity that absolute music inhabits by avoiding representation through language.

In the tradition of the formalist, avant-garde visual music animations of the early to mid-20th century, the intent of this film is to visually interpret the emotional states and progressions of an absolute, or purely instrumental, piece of music using color, non-representational form, and motion. Rather than superimposing a visual representation on a non-representational musical work, thereby introducing an alternate interpretation of the work, I am attempting to translate my emotional response of the music to accompanying visuals. The goal is create an audiovisual harmony by visually expressing how the music makes me feel using non-representational form.

It is not my intention to present this animation as a film in the traditional sense. Like many of the early visual music works, there are no cuts to the frame of action either spatially or temporally, nor is there any global motion of objects from the perspective of the viewer such as perceived camera motion. I have tailored this piece for a large, panoramic screen coupled with stereoscopic 3D projection to synthesize a virtual environment. By keeping a consistently defined, 3D space and no film cuts, I have attempted to emulate the sensation of watching a live theater or ballet performance rather than a film. This static frame approach is consistent with common qualities of many traditional visual music films that I have extrapolated to a larger, more vivid 3D space.

I do not intend for the audience to feel as though they are peering through a window to another space by drawing attention to the edge of the frame. By keeping a solid black background behind the animated subjects, I am attempting to hide the boundary between the screen and adjacent walls in the darkened room so that negative space surrounding the forms appears more like an extension of the room than the edge of a movie screen.

Aesthetic Design

Visual music was born out of the exciting, post-impressionism era of art where paintings took on an entirely different purpose and meaning. Rather than reproduce or interpret subjects from the real world as was done for centuries, expressionist painters created entirely new forms and spaces that served the purpose of evoking subjective moods and ideas, i.e. Formalism. "No longer content simply to reproduce the visible world, painters instead sought to endow their canvases with the emotional intensity, structural integrity, and aesthetic purity that they attributed to music" [5]. Among the vastly different interpretations of how music can look when translated to visual mediums, there were a surprising number of visual motifs and design qualities that are shared between these works due to the direct influence of expressionist painters.

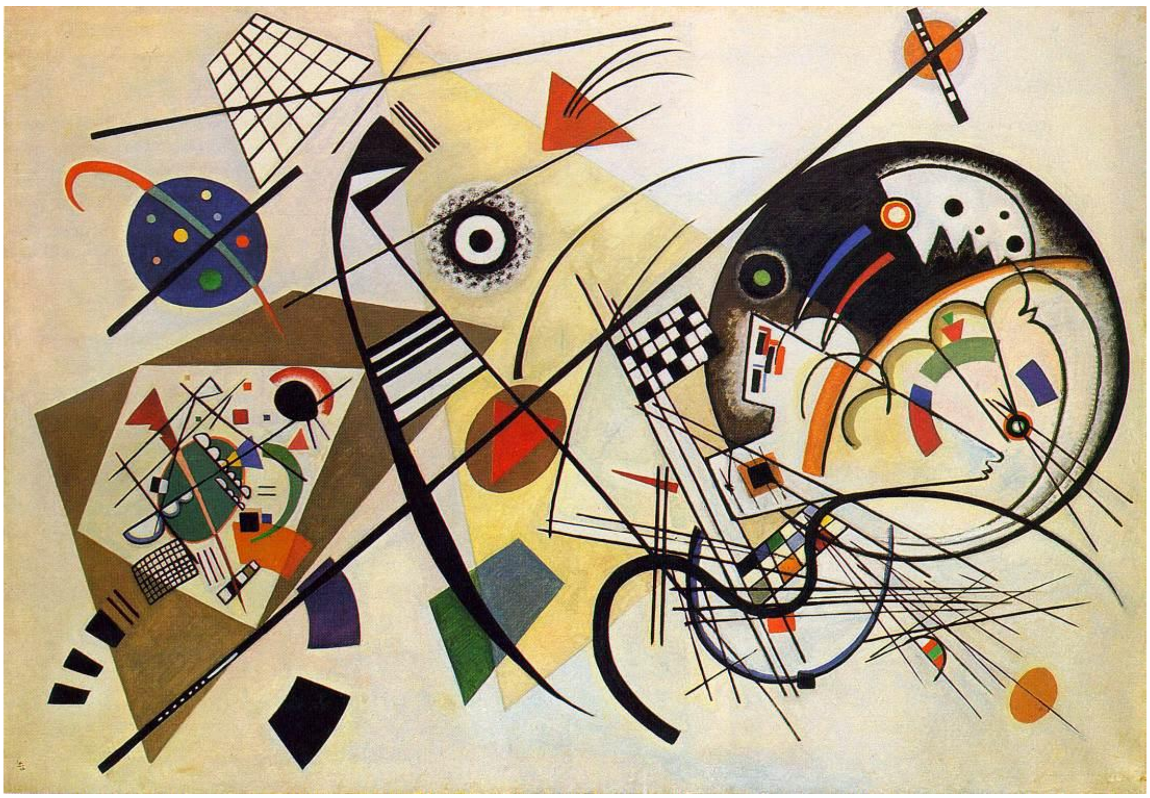

Figure 3: Transverse Line by Wassily Kandinsky.[1]

The animated subjects of visual music films were most commonly constructed as simple, flat forms with linear, curvilinear, or rectilinear silhouettes that frequently changed size and shape in accordance with the music and their motion. They often stretched out in the direction of their motion and bent as they turned, much like how one might see a snake bend as it changes direction. These forms might quickly pop in and out of existence or evolve into an entirely new form. They were rarely given any kind of three-dimensional properties such as shading or textural qualities and would often be something as geometrically simple as ovals, rectangles, or even lines.

I needed to establish how these two-dimensional design qualities might look if they were extended into three dimensions. In order to uphold the concept of geometric simplicity, I imagined the most obvious three-dimensional counterparts to the common shapes of visual music. Circles became spheres, rectangles became rectangular prisms and so forth. The smooth, simple forms of formalist sculpture and modernist architecture also gave me insight into how artists prolific in this time period thought about three-dimensional expressionism. There is an example of a stop motion visual music film made by Oskar Fischinger in 1935 called "Composition in Blue" that serve as an example of three-dimensional visual music. It was important to consider the relationship of positive and negative space in three dimensions in the same manner as architectural and sculptural design due to the stereoscopic nature of the project.

Color is a vital component of visual art and is especially critical in visual music. The color choices made for each movement directly influence the emotional impact and interpretation of the music. To further reinforce the sense of live theater or Ballet, I chose to use color in a way that would invoke the appearance of stage lighting. Rather than having intricate color patterns and complex color relationships, I used color to portray a sense of mood lighting to set an emotional tone, enhancing the emotional themes of each movement. Color palettes with subtle hue variations as opposed to strong color contrast were used in order to achieve this look, along with strong shading and directional shadows from implied light sources.

With a visual presentation more analogous to live performance, I approached the visual design from the perspective of creating independent, locomotive forms that move through three-dimensional space rather than attempting to construct the types of holistic image compositions that are frequently used in painting, photography, and films. As stated earlier, these bodies are mostly contained within the edge of the frame and are placed in front of an entirely black background. Examples of visual music animations that follow this trend are Oskar Fischinger's black and white studies, Viking Eggeling's Symphonie Diagonale, and John Whitney's Matrix Films. It was my intention to speak the same visual language as these artists by invoking many of these commonalities between musical expressionist artists in my work, while establishing a unique style of my own.

Synthetic Space and Immersion

It was important to analyze how the attributes of the space would influence the perception of the piece and how I might use the space to further emphasize the idea of viewing a live performance rather than watching a film. After years of viewing films in a commercial cinema, most people have an expectation of what they might experience when entering a typical movie theater. Choosing a different kind of venue or display for the piece would help to remove some of the cinematic associations with a traditional theater.

I decided to use an immersive theater on campus at Texas A&M University called the Immersive Visualization Center, or IVC, for short. The IVC is equipped with a large, wide-format, rear-projected curved screen that wraps around the peripheral view of the audience. The screen measures 25 feet wide by 8 feet tall with a curve radius at 12 feet and a pixel resolution of 3,200 by 1,024 creating a high resolution image that engulfs the view of the audience. By utilizing almost complete visual immersion, I am attempting to further remove the viewer from their everyday objective world into a synthetic space of non-representational abstract forms.

Another favorable characteristic of the IVC was its ability for stereoscopic projection. This was a technique of considerable interest from early filmmakers and visual music artists. In the 1940s, Lauded film director and film theorist Sergei Eisenstein stated that stereoscopic cinema “would have the power for the first time ever, to 'involve' the audience intensely in what was once the screen and to 'engulf' the spectator in a manner no less real and devastating with what was formerly spread across the screen" [15]. Utilizing stereoscopy adds another layer of immersion that engages and expands the viewer’s spatial awareness as well as strengthening the visual connection with live theater by creating a synthetic three-dimensional space.

Stereoscopy

Stereoscopic cinema has evolved and advanced a great deal since the 1940s. The technology used to create and view stereoscopic images have become ubiquitous, streamlined, and inexpensive. This is echoed by the prevalence of stereoscopy in nearly every large budget commercial film released in movie theaters.

It is common practice to change the perceived depth field of the image from cut to cut in modern stereoscopic films. Filmmakers often increase or decrease the interocular separation between the left and right eye to exaggerate or diminish the strength of stereopsis in the scene. This is a technique that can enhance the feelings that filmmakers attempt to illicit. For example, a director might want to create a sense of claustrophobia by making the space seem shallower, or a sense of grandiosity by increasing the depth effect and making the space seem larger.

In opposition of the frequent cuts and changes in space utilized in films, it was my intention to create a fixed synthetic space for the actors on screen. Therefore, I needed to keep my interocular distance constant throughout the piece. To make the audience feel as though the action was happening in an extension of the space they were occupying, I needed to create a stereopsis effect that would be consistent with the actual parallax that would occur if the forms were real and extending backward, beyond the plane of the screen, or forward into the theater itself. This would create a more direct synthesis between the rendered space and the space of the theater.

Music Selection

One of the most important decision made on this project was to choose the musical work that my animation would accompany. Above all else, the priority was to maintain a tight experiential relationship between the music and the visuals so that the two components reinforce each other conceptually and aesthetically. Ideally, viewers should perceive that both elements blend together as compliments to a whole experience and it should never be apparent whether the music or the visuals were made initially. This makes the selection of the music a critical decision in that it will inform and dictate nearly every aspect the animation including length, pace, complexity, and emotional progression.

In order to be faithful with the writings and opinions of abstract expressionist and visual music artists of the 1900's, the only unconditional requirement was the absence of any lyrical or vocal elements. To these artists, "What became known as "absolute music," instrumental music in a pure and autonomous form, offered a rich model of abstraction and formal integrity" [7]. For instance, singing about boats or cars directs the listener to think about these things rather than lets him or her interpret their experience from an indirect, non-objective, perspective.

I sought to choose a style of music outside of common, widely enjoyable genres out of a personal intuition that a greater appreciation and understanding of music can develop when paired with a visual component that mirrors the timing, rhythm, structure, and emotional context of the music. By adding a visual dimension to less easily-approachable music, I could potentially lead open-minded viewers, as well as myself, to an appreciation and enjoyment for musical stylings that are reflexively overlooked out of unfamiliarity. Though, I still wanted music that consisted of universally appealing elements such as real instruments, pleasing tonal relationships, and high quality recording. These requirements were exceedingly difficult to meet given the restriction to royalty-free, public domain music.

After weeks of searching, I stumbled upon recordings from a concert held during an avant-garde music festival in 1986 called the Festival Internazionale di Musica Contemporanea in Torino, Italy [16]. The opening performance, titled Ombres Lumineuses, was a twelve minute Avante Garde composition split into eight distinct movements written by a composer named Costin Miereanu. The movements were composed of arrhythmic arrangements of acoustic and electroacoustic instrumentation layered to create otherworldly musical soundscapes. There appeared to be very little melodic structure to the instrumentation which unfolded in a sort of harmonic, controlled chaos. As if the cacophony of layered sounds from a natural environment such as a jungle or even a modern city were indirectly translated to musical instruments.

This was an approach to music that I found rich for visual exploration for many reasons. I wondered how this concept of layered musical actors working independently yet harmoniously with each other might be expressed visually. Having separate instrumental layers would allow me to define a particular visual actor as an embodiment to a specific instrument. These independent bodies could be layered visually and act separately but still amount to a visually harmonic whole such as instruments in this musical composition act separately yet remain holistically complimentary.

The sensation of a synthesized musical environment that Ombres Lumineuses creates also aligned perfectly with my desire to create an immersive visual experience for the viewer. I had the ability to synthesize a visual analogy to the musical soundscapes and place the viewer in the center of it by surrounding the audience spatially and enhancing their sense of presence with stereoscopic 3D. With a suspension of disbelief, this would create an illusion of experiencing an entirely unique and formally abstract audiovisual environment.

Each section of the piece is self-contained with very little musical evolution or progression. The transition between these movements are mostly immediate; yet, there is a palpable emotional progression from movement to movement that amounts to a whole, greater than the sum of its parts due to a thematic tension that steadily builds across the composition. The piece concludes with an aggressive, climactic movement followed by a movement of otherworldly, hypnotic layering of instruments that feels alien to the rest of the piece. The contrast between these two final movements coupled with the incongruity of the finale gives this composition a satisfying conclusion.

It should be noted that due to the extreme length of the composition, I decided to edit out the fourth movement to meet the time constraints on the project. I would have preferred to keep this movement in order to retain the full narrative intent of the original composer but high quality computer animation is difficult to produce and the piece was much longer than I originally planned for when I began my music search. I am confident that overall emotional integrity of the music is maintained without this movement and the shortened version is poignant enough to help me reach my artistic goals with the project.

Technical Approach

I believe the most powerful and intuitive tools for generating geometric, music-driven, three-dimensional animation lies within consumer 3D animation software. Utilizing these programs have allowed me to create moving forms with mathematically accurate spatial and depth cues such as linear perspective, stereopsis, lighting effects, shading effects, and motion parallax which all combine to contribute to a believable sensation of three-dimensional space.

Three-dimensional animation software is used daily to create both photo realistic and artistically stylized visuals for film, animation, architectural visualization, scientific visualization, engineering, and so on. The processes to create high quality computer animation have evolved and become streamlined over the course of several decades of use and refinement. Some of the techniques available to modern commercial animation software include the computation of visible light that scatters beneath and bouncing off the surface of objects, the generation of complex and detailed surface textures, spatially accurate motion blur, and realistic shadowing. These are merely a small number of examples of the countless algorithms and techniques that are used to create high fidelity 3D imaging today. Additionally, most 3D animation programs offer the option to expand its features to suit specialized needs by allowing the integration of customized plug-ins and software.

Partial Automation

Due to the nature of this project, creating visuals that are choreographed to musical events, I utilized digital sound analysis techniques for generative data mapping to visual events such as motion or color changes. I was able to drive much of the timing of the animation through computer algorithms rather than synchronize the motion of each moving body by hand, thus, greatly reducing the burden of deliberately timing every single visual accompaniment to sound.

Music visualizer programs such as the iTunes visualizer and Winamp are popular examples of an application of digital music analysis to automated visual stimulus. However, due to the lack of any direct human intervention in the procedural generation of visual accompaniment to music, visualizers often lack the interpretive specificity and emotional intent of a carefully and consciously constructed choreography. The formulaic nature of these purely reactive systems often become apparent over a short time and therefore invoke only a fleeting sense of interest to most viewers. It was crucial to avoid the simple pattern recognition that simple procedural systems invoke and portray a more complex, performance-like relationship between the visuals and the music. Therefore, using sound analysis algorithms to aid and not dictate the timing and color responses of this piece allowed me the precision and complexity of purely automated visual music without losing artistic control.

CHAPTER IV

IMPLEMENTATION

Software and Tools

There are numerous options for high quality commercial 3D animation software and I needed to select a program that would suit the unique demands of this project. Most software can be used to create all types of generalized 3D imagery, but is specialized and streamlined for the needs of a particular industry i.e. feature animation, video games, architectural visualization. Abstract animation is type of work is not commonly produced and therefore, did not have an obvious companionship to any particular software. Due to the distinctive challenges that this project would bring, the flexibility of the software would be crucial.

For its completely accessible and modifiable data handling structure and easy customization abilities with integrated scripting and programming solutions, I turned to Side FX's Houdini as my software of choice. Houdini is used heavily in the creation of high quality visual effects for film and feature animation due to its flexible nature and dedication to procedurally work flows. Additionally, the ability to animate procedurally has allowed me to create visuals that are driven by musical input with relative ease. Robust tools that analyze sound are already built into Houdini and are well integrated with all of Houdini's other tools. It gave me the ability to create a specialized method for analyzing the music for particular attributes and use that data to automate actor animations in a real-time, interactive viewport. This real-time feedback was tremendously helpful in letting me iterate on my work quickly and efficiently.

I was required to adopt Autodesk's Maya as a rendering platform in order to take advantage of the large network of computers used for rendering, or render-farm, at Texas A&M's Visualization Lab due to its lack of support for Houdini. I exported scene description files from Houdini that were read with Maya so they could be sent to the render-farm. All of the lighting effects were created with Maya's lighting tools and Pixar's Renderman was used as the rendering engine. The use of Maya and Renderman were dictated out of necessity rather than choice. It would have been simpler to render directly from Houdini rather than add the extra steps needed for Maya and Renderman; however, due to the extreme length of this animated work, it was crucial to utilize the added rendering capabilities of a render farm.

For creating the surfacing and texturing effects of my work, I turned to Pixar's SLIM application. SLIM has a similar approach to Houdini in that they both rely on procedural methods to generate artwork through manipulating data in a graphical, node-based user interface. Houdini approaches surfacing development in a similar manner and would have been better suited for this project because of their extensive integration with the rest of Houdini's tools. However, due to the reliance on Renderman for rendering, Houdini shaders were not a viable option.

Audio Analysis Technique

The goal for the audio analysis in this project was to synchronize certain musical events and instrumentation of choice to coinciding visual events. Automating the discovery of specific musical events was one of the most technically challenging aspects of this project because all of the instrumentation was mixed together in a stereo track. Had I had access to a multitrack recording, with each instrument on an independent track that is later mixed into a musical whole, this would have been a far simpler task. I devised a method to extract specific instruments and tones from the audio in order to drive the more complex animation with little to no manual assignment. To build this, I used Houdini's exceptional CHOP, or “Channel Operator”, tools which won a technical achievement Award in 2002.

This first step of this process was achieved with a parametric EQ function to isolate a frequency range that an instrument or tone of interest was mostly dominant in. The tool that allowed me to do this was already available among Houdini's CHOPs toolset. When the right frequency range was found, mainly through trial and error, most of the other sounds and instruments were filtered out of the waveform and very clear spikes took shape at the exact times when the desired sound was most apparently audible.

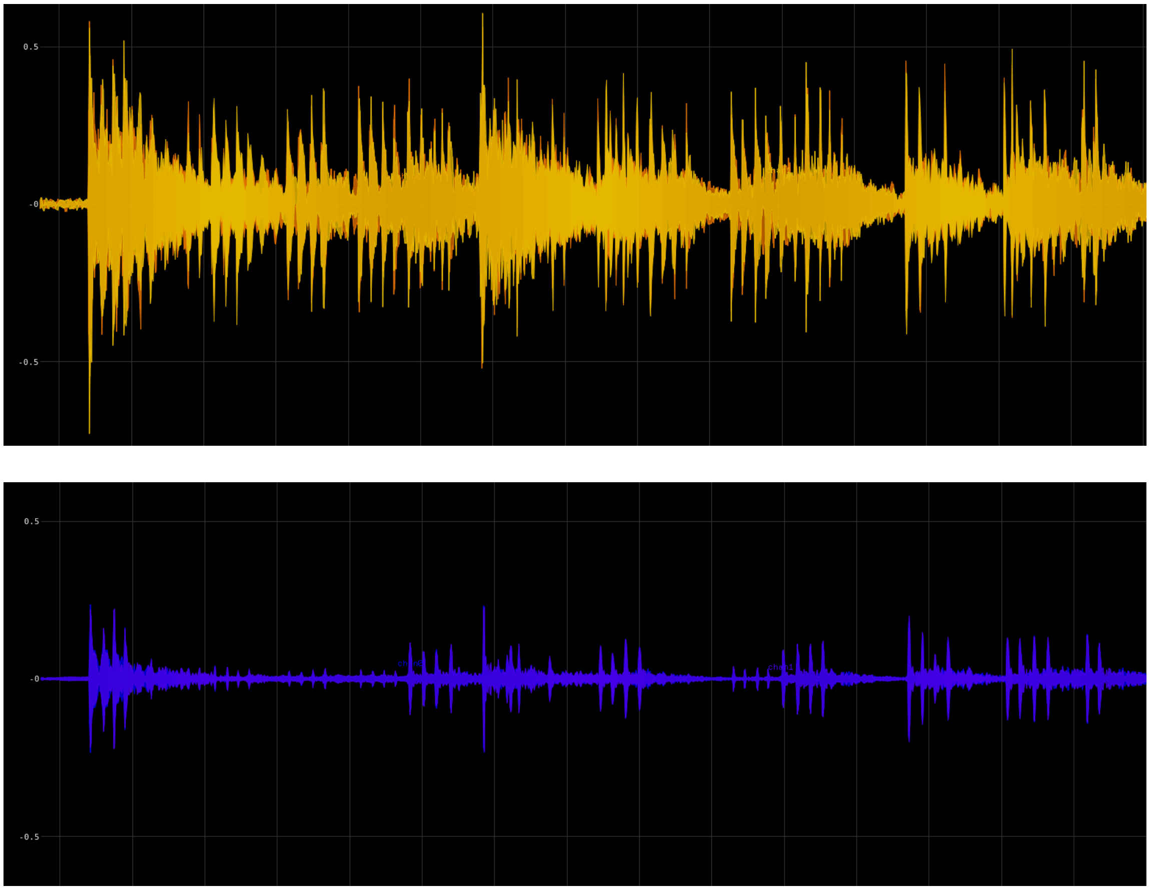

Figure 5: Initial waveform (top) and waveform with an isolated frequency range (bottom).

From this modified waveform, I created a method to analyze precisely when spikes in the audio were occurring. Despite being clear to the human eye where these spikes were, the waveform data remained too unwieldy to analyze with any simple test. For instance, valleys in some parts of the waveform would have greater amplitude than the tops of spikes in other parts of the waveform, making a volume magnitude test ineffective. Therefore it was necessary to analyze this waveform with a more finely-tuned method.

First, I removed the lower half of the new frequency isolated waveform using an envelope operator to prepare it for the modification and testing functions. I will call this waveform signal A and it will be represented as the red signal in the figure below. Then, I applied a Gaussian channel filter to the data which samples the audio with a Gaussian distribution around the current time and averages them together. This has the effect of making peaks and valleys less pronounced but still visible and true to the times that they occur. This gives me signal B, illustrated in yellow in the figure below, which is a new waveform that serves as a normalization metric I can use to test for abnormalities in the original data, i.e. spikes. This was a matter of simply checking when signal A exceeded the amplitude of a signal B across the waveform. However, I needed to add a constant value to signal B before performing this check in order to single out only the most significant spikes in the waveform. This addition variable was adjusted each time this process was carried out depending various factors such as the relative magnitude of the spikes in a particular waveform and the overall amplitude of each waveform.

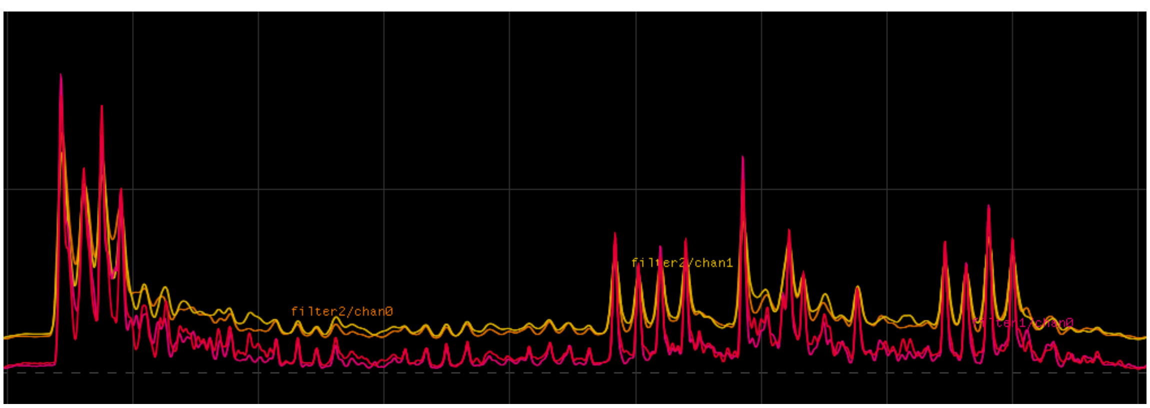

Figure 6: Signal A and B of waveform analysis function.

The method described above was an effective way of determining when significant musical events occurred in the audio track with about ninety percent accuracy. There were many occurrences of audible sound events in the musical piece with no coinciding observable amplitude spikes in the waveform which made this algorithm ineffective in some instances. It was necessary to allow myself to manipulate the data after the analysis to account for any of these audiovisual discrepancies in the waveform or even accommodate for any desired artistic alterations. This was achieved by converting signal A to an editable spline curve that could be manipulated on the few occurrences where the algorithm failed in order to trick the signal evaluation. Another way around this shortcoming could have been to time the missing events by hand, but by modifying signal A and the test itself, I now had a single, unified signal for generative data mapping to my animation as I saw fit.

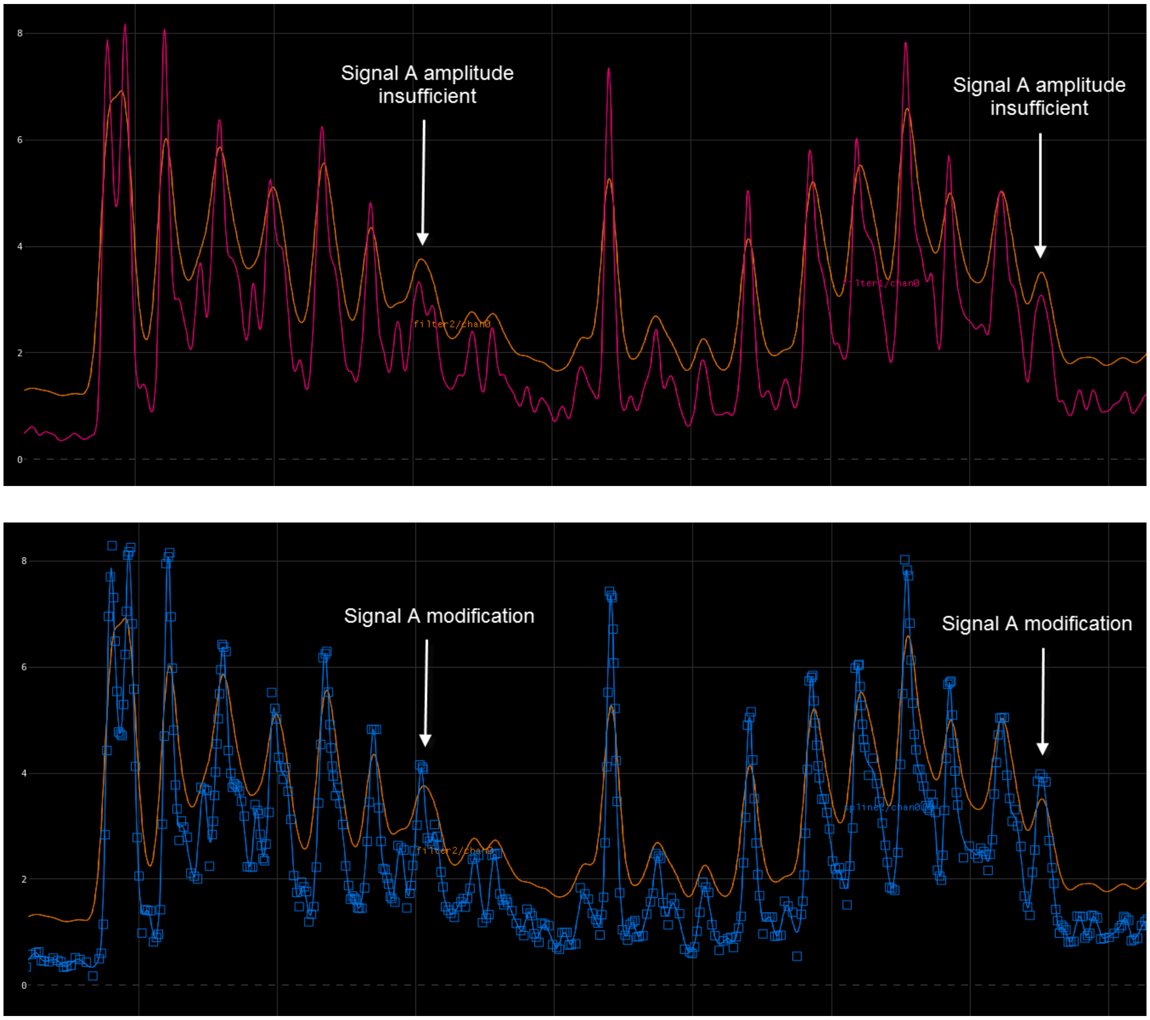

Figure 7: Original evaluation waveform (top) and signal corrected waveform (bottom).

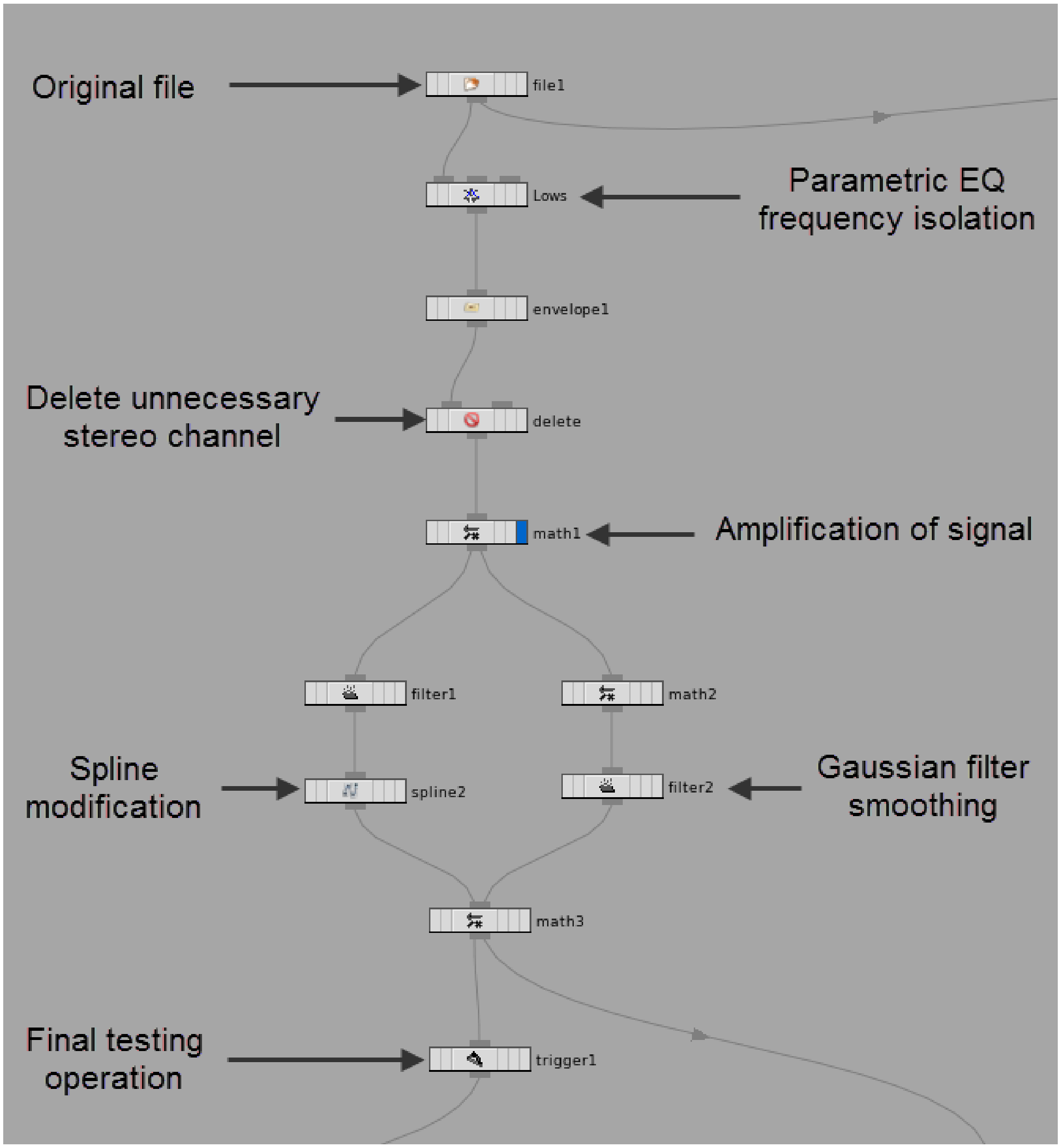

Figure 8: Signal evaluation node tree from Houdini.

Immersive and Stereoscopic Rendering

As stated earlier, the design goal of stereoscopy in this project was to accurately recreate the parallax that would occur if the audience were viewing real moving forms inside the theater and beyond the plane of the screen. To do this, I used the dimensions of the IVC to build a digital representation of the theater inside the computer animation software. I could use this replica as a reference to help me visualize where in the space the audience would perceive the animation to be taking place; For instance, how close the figures would appear to them or on what side of the screen. I then placed a camera directly in the center of the seating area of the computer replica facing the screen so that the edges of the frame of the camera would align to the precise measurements of the IVC screen.

In computer graphics, stereoscopy is achieved by rendering a three-dimensional scene from two slightly different viewing angles, representing the left and right eye of the viewer. The distance between the cameras, referred to as the interocular distance, will determine the strength of the stereoscopic effect. The further the interocular distance is, the more pronounced the effect will be. Adult eyes typically have an interocular distance between 65 and 75 millimeters apart. Therefore, in order to accurately recreate the stereoscopic effect that the viewer would have in the IVC, I spaced the left and right cameras according to the representative distance of 70 millimeters in the IVC computer replica, accurately reflecting what an average person's interocular distance would be inside the digital space.

Another important aspect of stereoscopy in film and computer graphics is distance at which the angles of view of the respective left and right cameras are converging to a focal point. This point of convergence is the point of zero parallax, where there is no difference between the left and right views of rendered objects at this distance from the camera. (See figure below) The distance of zero parallax was defined as the distance from the camera to the IVC screen, normalizing the stereo effect so that objects would appropriately extend beyond the plane of the screen when it was appropriate. Houdini allowed me the ability to easily adjust this value with a built in stereo camera rig.

Lastly, "When the horizontal disparity, in other words the difference between the two retinal images in natural vision, denoted by the angular differences, is too high, the images can no longer be fused by the brain and are perceived as double outlined (diplopia)" [17]. This will occur when objects in the 3D scene come too close to the camera, exaggerating the distance between the left and right eye to uncomfortable levels. The animated subjects were never rendered extending anywhere over half the distance beyond the plane of the screen toward the audience to limit the effect of eye strain due to Diplopia.

It became apparent that after setting the position and viewing dimensions of the camera inside the IVC replica that the image toward the left and right edges of the frame were becoming extremely warped. This occurred because of an extremely wide angle lens that was needed for the computer generated camera to match the extreme dimensions of the IVC screen. To address this problem I created two more digital cameras inside of Houdini juxtaposed to the center camera to accommodate for the wide aspect ratio. This resulted in an array of three stereo camera rigs positioned at the eye point of the viewer each oriented to their respective left, middle, and right sections of the screen. Additionally, each stereo camera rig is equipped with a left and right camera for stereoscopic rendering bringing the total camera count to six. These six individual renders were later stitched together with Houdini's node compositing tools to create two cohesive pictures, the left and right eye, that were compiled into a single, stereoscopic, wide-formatted video. The total pixel resolution rendered for each eye matched the IVC's maximum resolution capabilities of 3200 by 1024 pixels.

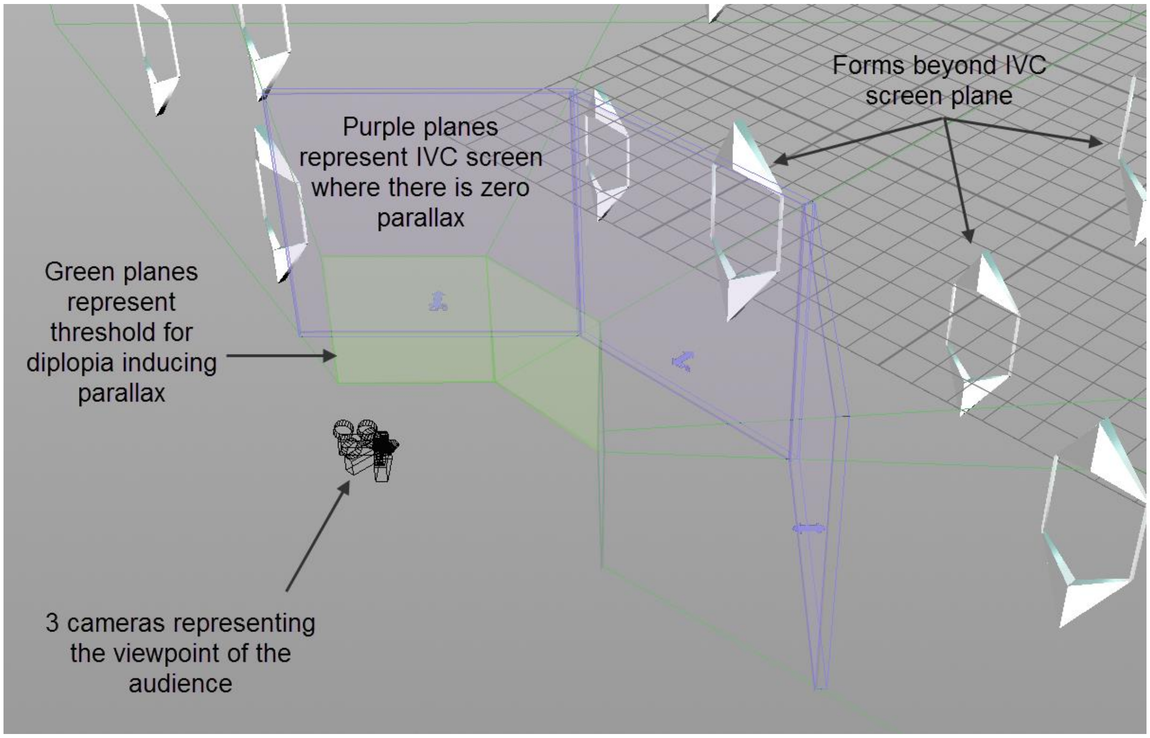

Figure 9: Screenshot of IVC camera rig and layout from Houdini viewport.

Challenges of Amorphous Geometry

There are many benefits inherent to using three-dimensional computer generated animation versus two-dimensional hand-drawn animation. One such example is the benefit of only having to create an object or character one time. Although creating a computer generated asset is often more complex and time consuming than creating a two dimensional drawing of the same thing, once the asset is created the user only needs to move or pose the asset for every frame of action rather than redraw the asset from scratch as is done with hand drawn animation. An analogy of this benefit can be illustrated with the practice of creating assets for stop frame animation. Once the asset is created, it only has to be posed from frame to frame to invoke the illusion of motion rather than recreated for every frame.

The exception to this occurs when the asset changes its shape or topology in some way from frame to frame, such as a cube morphing into a sphere. To create this effect over twelve frames, a stop frame animator would either have to create twelve unique objects that each represent a stage in the transition from cube to sphere and replace them with every frame or sculpt the transition using a malleable medium such as clay. Conceptually, the clay molding technique from the stop frame animation analogy applies to computer animation in that every stage of the transition must be modeled for every frame of animation and the animator can modify a previously built model rather than build every transitional model from scratch; In practice, however, modification allowances to 3D computer models are limited by the structural network and number of polygons that make up the model. For example, a simple cube modeled in 3D would be made up of six polygons, one for each face of the cube that are stitched together and oriented to the shape of a cube. Polygons are planar by nature and models with curvature require many polygons to approximate their curved forms. Therefore, if an artist were to modify a cube to embody the morphological states between a cube and a sphere, he or she would either need to accommodate for the sphere's topological requirements when building the original cube or build new models for each frame that address each transitional model's own topological requirements. The complexity of this problem compounds with the increasing difference in topology between any two states.

In contrast, topological changes are not a technical challenge in crafting traditional 2D animation. If an animator wants to apply a physical change to his subjects across a number of frames, he or she needs only draw the subject’s transitional states across the subsequent transitional frames, a process that adds little to no technical challenges to drawing the subject without any physical or topological changes. Visual music animators using a two dimensional medium were not restricted by the constraints of three-dimensional topology and therefore could constantly morph and redefine the forms in their work, as they often did.

Recreating the free flowing, amorphous forms of traditional visual music work would require a specialized approach. These challenges were met with the procedural modeling approach to creating computer model assets in Houdini. Polygons can be generated as the result of governing rules rather than explicit spatial definition. Rather than defining the size, position, and orientation of each polygon by hand, changing the rules that dictate the spatial properties of polygons over a period of time will create motions in polygons themselves resulting in dynamic topological changes. Designing systems to build models allowed me to move away from the statically defined modeling typically seen in computer animation and approach the dynamic morphology of 2D animation. Each animation system required a unique approach to morphological transitional states and will be further elaborated in their respective movement sections.

CHAPTER V

RESULT

Movement 1

The sounds of the first movement of Ombres Lumineuses consists of quiet synthesized tones and bells with sparse supporting instrumentation like bells, tambourines, and triangles that paint a mysterious and alluring tone. Tension in this introductory movement slowly builds when the layered texture of sparse tones become progressively louder and denser.

To support the tense and mysterious mood evoked by the music, I chose to leave much of the visual form obscured in shadow. The scene is lit with dark, cool colors dominated by varying hues of deeply saturated blue light. Brief glimpses of the shadowy forms are offered by the sparse instrumentation of the music that trigger the illumination of a singular form, as if the light and the sounds were part of the same event. Each form type coincides with a type of sound in the musical accompaniment, such as bells and different frequencies of synthesized tones. These independently acting, yet visually similar forms create an ordered chaos of separate actors contributing to a visual whole, much like individual performers contributing to the auditory whole of a symphony. This is a visual design approach that is used frequently throughout the piece.

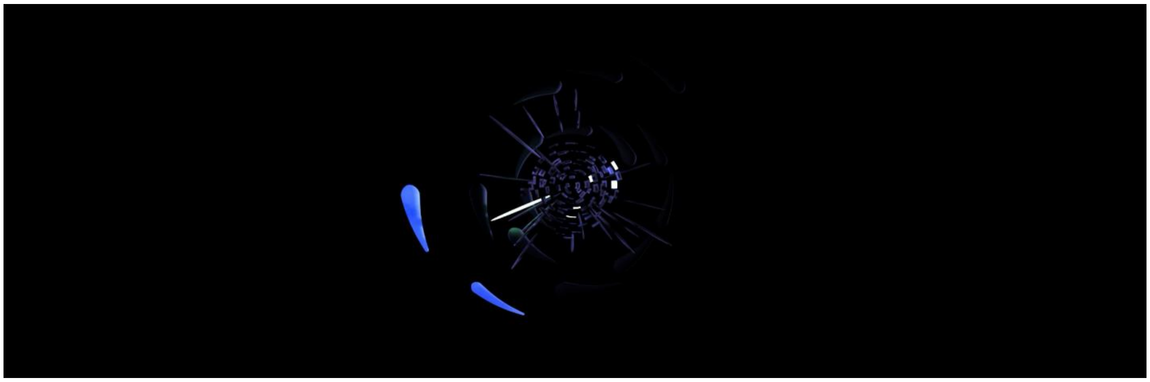

Figure 10: Still from movement 1 of Bright Shadows.

It is important to note that in the black background in the figure above represents the actual aspect ratio of the curved, 25 foot by 8 foot screen and that the viewers are unable to see the entire image at once. The forms in this particular figure would fill up the entire view of closest audience members to the screen despite only occupying roughly a third of the total screen.

The audio analysis technique was used to extract three different instrumental tones from the music to drive the animation, a low frequency synthesizer, a high frequency synthesizer, and bells. Each extracted instrument corresponded to a type of form shown above. The low frequency synthesizer represented the configuration of rectilinear forms in the center of the composition, the high frequency synthesizer with the long linear forms, and bells with the tear-drop forms at the perimeter. When the audio analysis detects an instrument played in one of these three categories, a random form from the corresponding form type lights up.

The forms slowly swirl around the center of the composition and slowly gain speed as the tension of the movement builds. Their motion is dictated by a particle simulation using radial forces, with each particle representing the location of a corresponding form. A repulsion force was added to the particles to make sure no two particles came within a colliding distance of each other. Using a particle simulation to drive motion rather than simple matrix transformations adds visual complexities and organic qualities to locomotion such as subtle imperfections, momentum constraints, non-linearity, and emergent behavior without explicitly defining every action by hand.

Movement 2

The slowly building tension of the first movement climaxes with an abrupt launch into the next movement, a dizzying yet beautiful tapestry of instruments woven into a complex environment of sounds that are almost indistinguishable from each other. The rapid pacing and audible complexity of this movement is heavily contrasted with the quiet and sparse instrumentation of the introduction where the separation between instruments is mostly distinct and clear. The only clearly distinguishable audio event was a loud, arrhythmic flute that occasionally burst free of the rich soundscape. This was a very playfully sounding movement with a lot of action and speed.

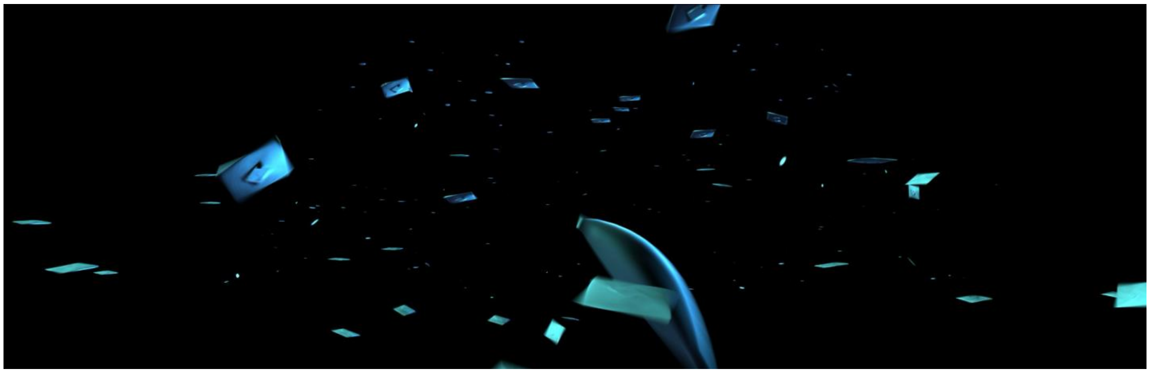

Figure 11: Still from Movement 2 of Bright Shadows.

To characterize the action and uniformity of this movement, I used dozens of only one type of form that floated around the stage and very energetically spun around their own center of gravity, similar to a spinning top. When the loud flute was detected by the audio analysis, a randomly selected body leaped from one area of the three-dimensional stage to the other with tremendous speed, as if the flute sound itself was a byproduct of this speed. The form stretched and warped as it dashed through the space creating streaks of motion with a length that corresponded to the speed of the dash, similar to the commonly used squash and stretch effect in 2D animation.

This stretch effect was the most difficult technical challenge of this section due to the morphological change to the topology of the forms. It was accomplished by defining the structure of the form with three points dictating the top, middle, and the bottom points of the geometry. The algorithm that generates the geometry rebuilds the form every frame depending on where these three points are in relationship to each other. For instance, if the top and bottom points are far away from each other in space, the geometry algorithm will create a long form to accommodate for their distance.

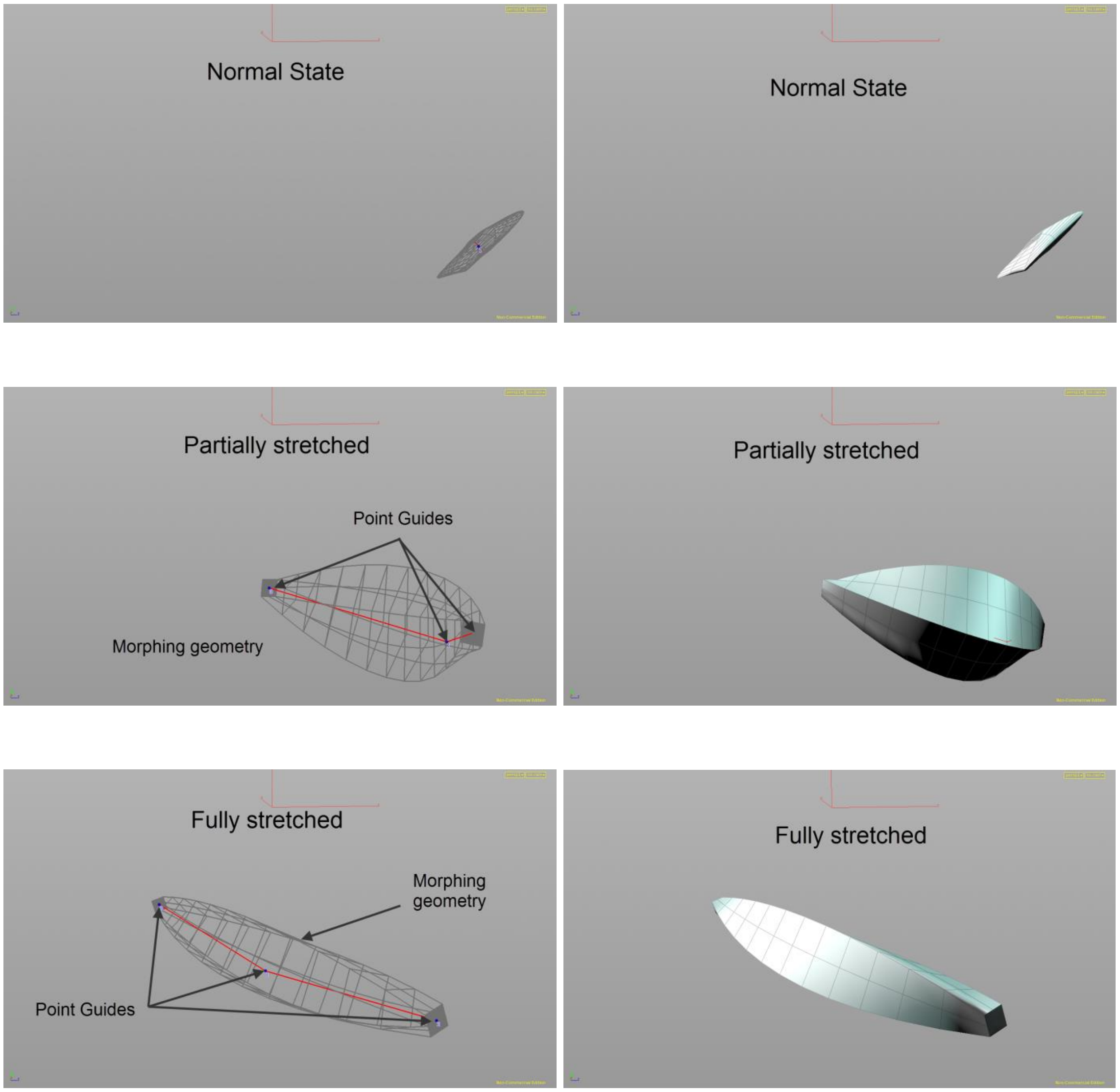

Figure 12: Illustration of stretching effect (chronologically from top to bottom) with wireframe representation (left) and shaded representation (right).

The second step of this effect was to define how the velocity and direction of these top, middle, and bottom points would stretch and warp in relationship to each other based on the direction and velocity of the forms motion. This was achieved by altering their positions based on where the form was traveling in time. The top point represented where the form was at present time, the middle point represented where the form was one frame prior to present time, and the bottom point was moved to the position of the form two frames prior to present time. This lagging relationship of points created a warping effect for the geometry that automatically accounted for the velocity, curvature, and direction of the leap.

The floating and leaping motions of the actors were defined with a particle simulation in a similar manner to the previous movement. Each particle coincided with the position of an actor in 3D space and the motion of these particles were driven by various forces such as a repulsion force to keep the actors from leaving the stage and bumping into each other. The spinning and wobbling motion of the forms were generated with rotational matrix transformations driven by modified sine waves and the leaps were created with strong impulse forces to the particles triggered by the generative data mapping from the audio analysis.

Movement 3

The whimsical, playful, and energetic soundscape of the second movement is interrupted the bold, passionate, and even aggressive third movement. The music is dominated by a fiery and intense staccato flute that creates a wavering vibrato between two neighboring notes and is unpredictably appearing and disappearing throughout the movement. Accompanying the lead instrument is an array of light percussive sound that serve as a textural backdrop to the instrumental centerpiece.

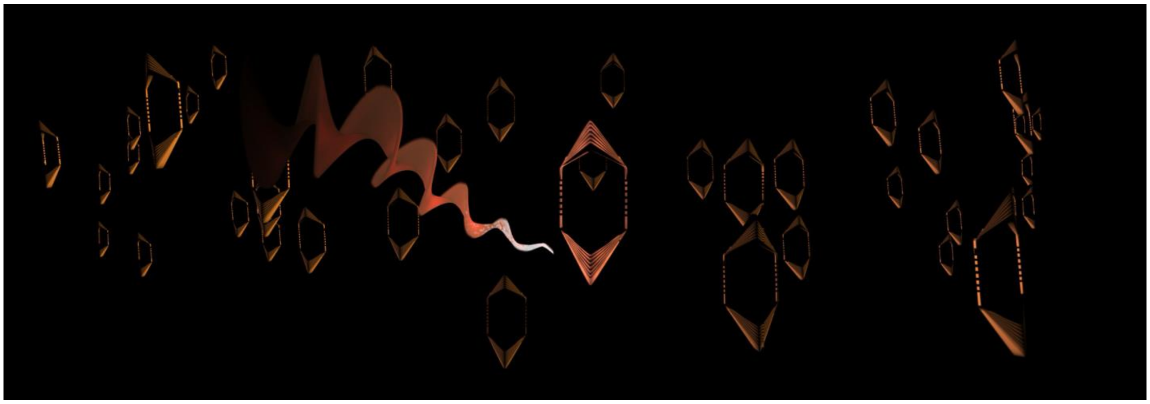

Figure 13: Still from movement 3 of Bright Shadows.

The intensity of this movement is conveyed with a warm color palette of orange hues contrasting with the blue and green hues of the cool color palettes in previous movements. The flute is represented by a sharply curvilinear, ribbon-like form aggressively cutting through the space as the instrument is heard. The hexagonal forms floating around the space shiver and illuminate in response to the audio analysis of the percussion. The system will choose the closest of these forms to the meandering ribbon form to react to the percussion at that given time. This keeps the audience visually focused on the area around the ribbon and establishes a direct relationship between the two visual elements.

The ribbon was one of the most technically challenging forms to create in this entire work. Rather than using particles to dictate the motion of the form as was done in previous movements, particles were used to generate the form itself resulting in a topology that was constantly morphing and evolving. The challenge of this approach came from a need to precisely control the direction and timing of the particle emissions to ensure that they could be connected in a way that would make a fully coherent piece of geometry throughout the entirety of its changing states.

The first step in achieving this effect was to define the path that the ribbon would take by drawing a spline curve in 3D space. It would have been possible to automate the path of the curve but a more precise level of control was desired for this effect. The ribbon system would then use the path to emit particles along, starting at the beginning of the path and moving along to the end of the path in synchronicity with the appearance and disappearance of the flute. Two particles are emitted in tandem at an interval of 1/60th of a second at obtuse angles to the tangential direction of the current position on the spline curve. As the emitter calculates the proper angles to emit the particles at while moving down the spline curve, it spins at an angle perpendicular to the tangent of the spline curve creating a spiraling motion around it. After the particle is emitted in its calculated direction, it travels at a constant velocity for a specified amount of time and eventually disappears.

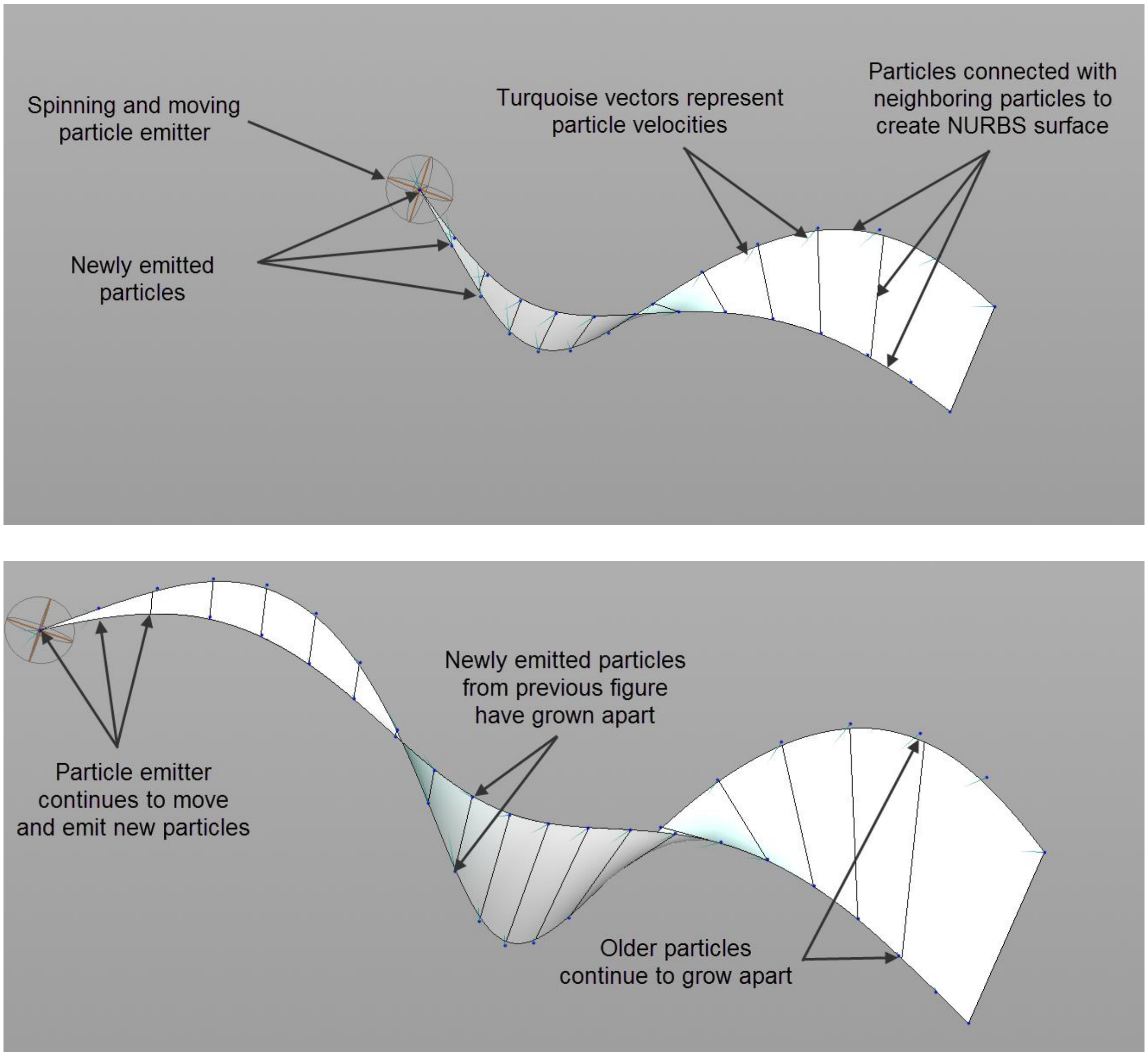

Figure 14: Illustrated progression of ribbon effect (chronologically from top to bottom).

The cumulative positions of all particles emitted over time are used as a positional guide to construct geometry around. Because all particles are traveling at different angles from their source position, their relative distance from each other grows apart over time causing their corresponding polygons to grow. This creates the sharp, cutting front edge of the ribbon where new particles are very close together and a wide back of the ribbon where older particles have drifted apart. This geometric property coupled with easily adjustable parameters in the angle and velocity calculations results in a dynamically evolving form with expressive features seen more commonly in 2D hand-drawn animation than 3D computer graphics.

Movement 4

The fourth movement marks the center of Ombres Lumineuses and is the longest movement of the entire piece of music. Percussion moves at a slow, contemplative pace counter to the attention seizing sounds of the prior movement. As various types of drums and cowbells dryly beat on at random intervals, usually in clusters of four rhythmic strikes, the movement builds a meditative, hypnotic atmosphere that allows the mind to drift away. There is no real sense of tonal progression apart from a gradual increase of frequency and layering in percussion.

To reinforce an atmosphere of contemplation and uniformity, I chose to create a visual environment with more stasis relative to the other, more energetic movements. This segment takes a sculptural, or even architectural approach to the visual design in that the position of all actors remain static throughout, with motion only through rotation around each actor's center of gravity. This anchoring of the forms is visually unique to this movement and was done to create a sense of continuity and comfort, reinforcing the meditative atmosphere that the music constructs. Additionally, all forms persist on the screen space throughout the movement, neither vanishing nor appearing as is common in all other movements, further establishing a sense of spatial continuity.

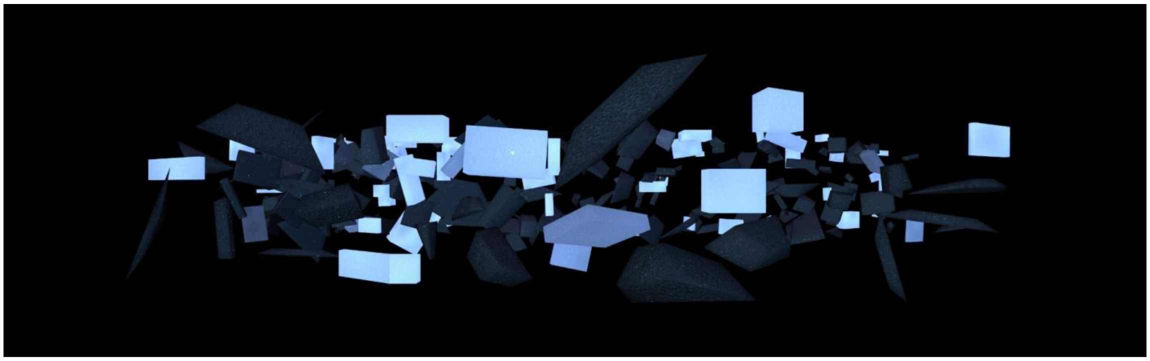

Figure 15: Still from movement 4 of Bright Shadows.

The extended length, consistent structure, and instrumental simplicity affords the viewer time to ponder a more complex relationship between the audio and the visuals. Each form begins as a trapezoidal prism slowly rotating around its own center of gravity and subtly changing its trapezoidal dimensions. The size, shape, and rotational axis of each trapezoid are influenced by spatially defined noise patterns moving slowly through the space creating subtle visual similarities between forms located next to each other. The forms are darkly lit with glittery surfaces that shimmer at the frequency of their angular velocities.

As percussion plays, a randomly selected form will switch from its chaotic state described above to an ordered state. The form will light up from the inside, morph from a trapezoidal prism to a rectangular prism, and align itself parallel to the X, Y, or Z axis by springing and wobbling into place. After a form switches to its ordered state, it will gradually misalign itself from an axis, lose its rectangularity, and fade its internal light source. At no point do all forms in this composition reach a fully chaotic or ordered state, even as the percussion increases in frequency creating a constant interplay between order and disorder.

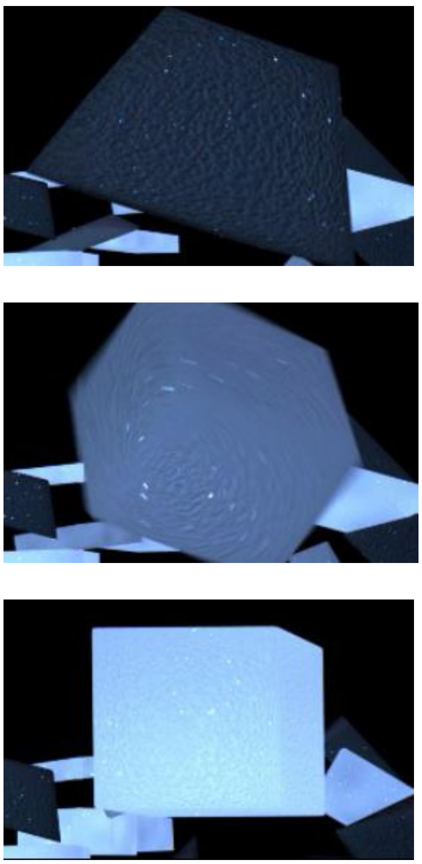

Figure 16: Progression of forms from chaotic (top) to rotating transitional (middle) to ordered state (bottom).

Defining how these forms would switch between their aligned and maligned states was the greatest technical challenge for this movement. The transitional motion had to appear natural and smooth, yet had to account for any possible starting and ending orientation of the forms. This was achieved by blending between rotational values of the randomly calculated disordered state and a quaternion rotation toward the predefined ordered state. Quaternion rotations were used to eliminate any potential occurrences of gimble lock caused from randomized matrix rotations and as an aesthetic preference. The axis for the quaternion rotations were calculated with the cross product of the ordered orientation vector and the disordered orientation vector and the angle was determined by taking the arc cosine of the dot product of these two vectors. The blending coefficient between these two vectors was created with a predefined animation curve shown below.

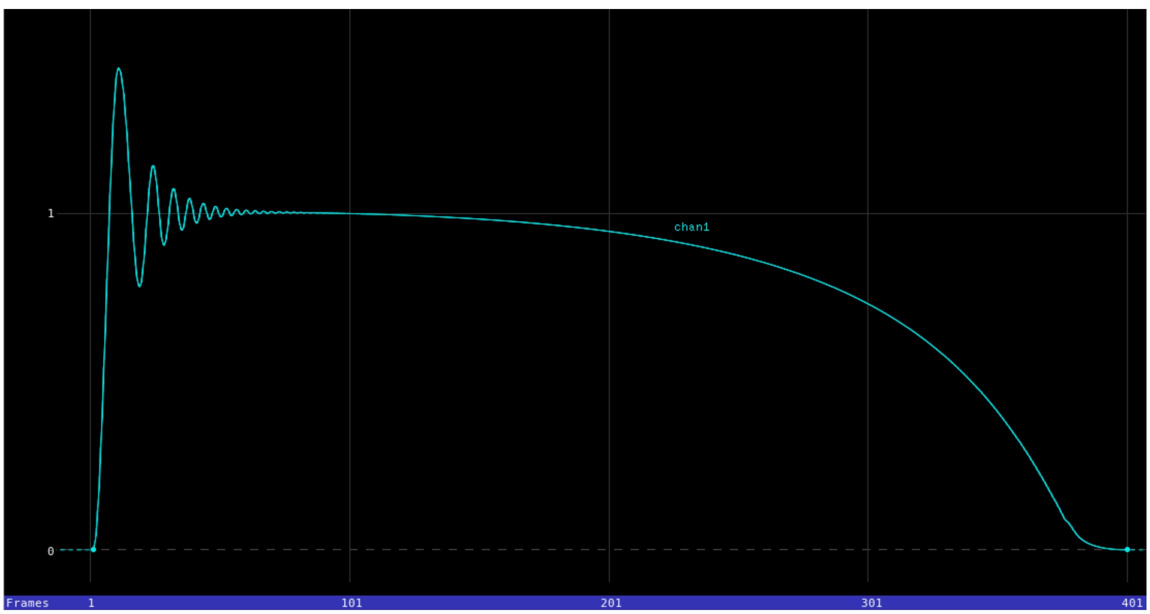

Figure 17: Animation curve used for blending coefficient between ordered and chaotic states.

The Y axis of the graph illustrates the blending coefficient value where 0 represents the fully disordered orientation vector and 1 represents a fully ordered orientation vector, and the X axis represents time in frames. When an actor is chosen to switch to its ordered state by the audio triggered selection algorithm, its X value is set to 0 and is incremented by 1 for every frame after the trigger event. As illustrated by the graph, the form will quickly move toward its ordered vector, overshoot it, and then wobble around it until it finally settles on perfectly ordered. Over time, the order will gradually fade back to its disordered state at an exponential rate.

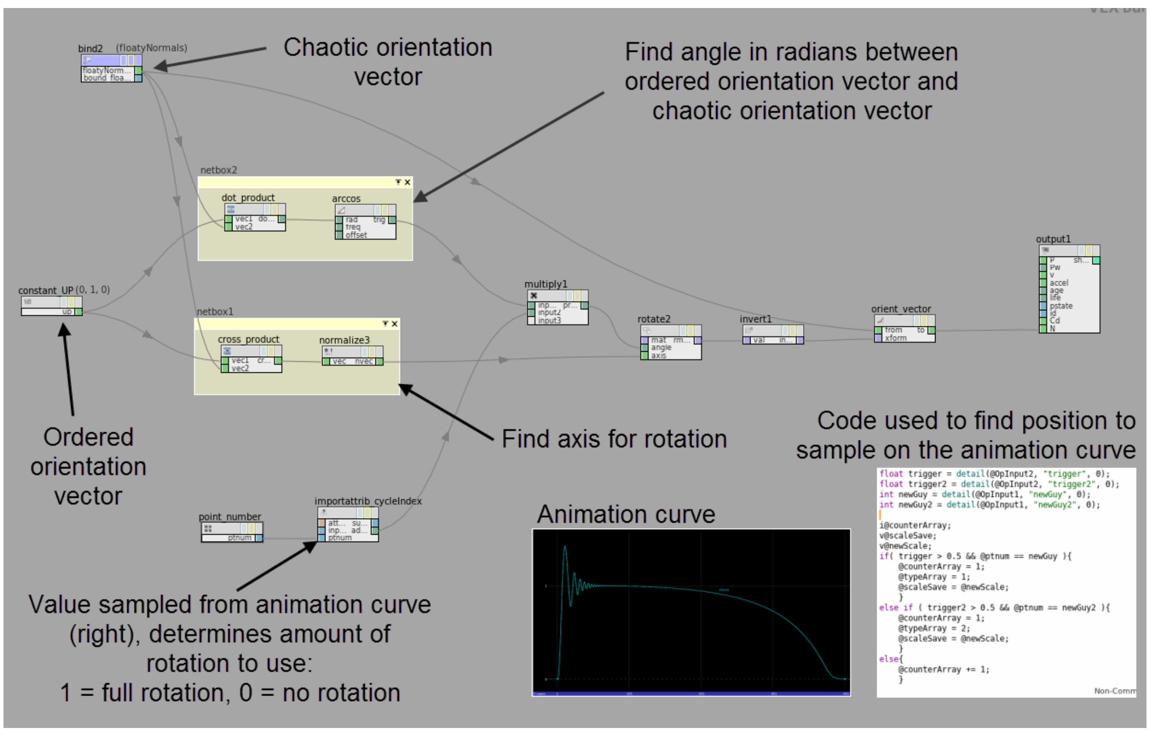

Figure 18: Houdini node network used for rotating all forms in movement 4.

Movement 5

The fifth movement is an exciting movement that yanks the listener out of the methodical, contemplative atmosphere of the fourth movement. Replacing the steady, dry percussion are booming and resonant bursts of sound likely made by large chimes or bells accompanied by various wind instruments. The instruments blend seamlessly to create beautifully sonorous tones of slightly different pitches but only occur less than a dozen times leaving periods of complete silence in between. The dualism between explosively rich tonality and eerie silence creates a dramatic tension that is both haunting and beautiful.

Illustrating these sonic bursts are large moving sculptural forms composed of wedges that emanate from a single point and radiate outward. These wedges are fast moving initially but slow down exponentially over a short time, analogously to the motion of embers bursting from fireworks. As they move outward, they vibrate around the axis of their directional path and shorten in length to a point where they appear more as thin fragments of egg shells than the wedges they began as. As the reverb of the corresponding sounds fade to silence, so do the bright, pink-hued sculptural forms fade to darkness.

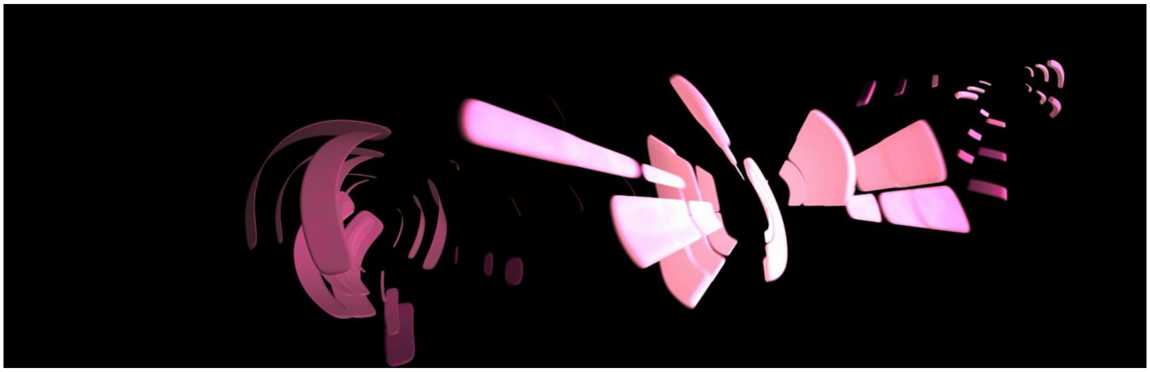

Figure 19: Still from movement 5 of Bright Shadows.

In 3D computer modeling, polygonal spheres are most commonly defined with the same configuration of latitudinal and longitudinal spans used for global measurements. The positional data points that defined these spans served as a directional guide for the particle emission paths. The first step was to divide the sphere into separate longitudinal spans and cut each span down to smaller arcs of varying length and positions. This process is illustrated in the figure below.

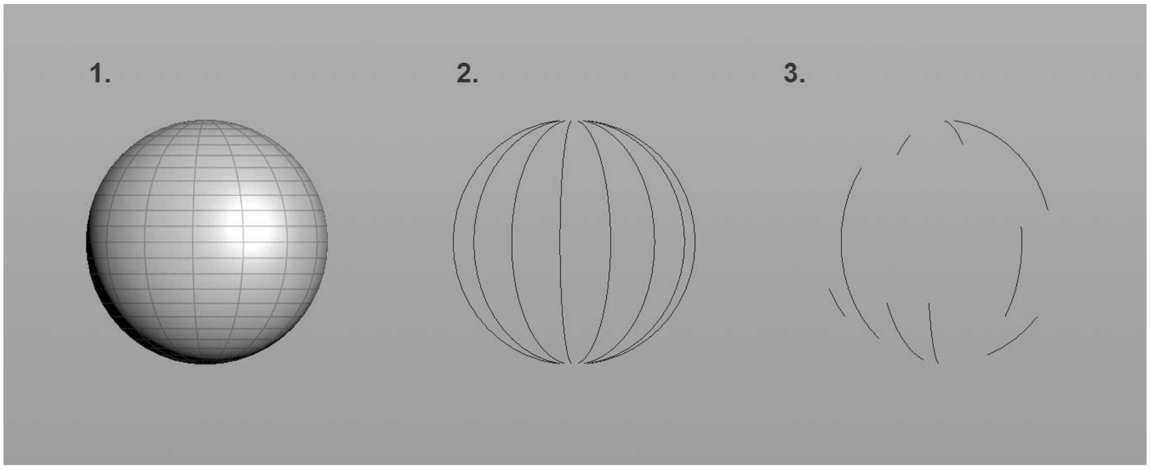

Figure 20: Using a sphere mesh to define the particle motion targets for the bursting forms of movement 5.

A particle emitter placed somewhere inside the sphere then shoots one particle for every point position that is used to define the remaining arcs at a given frame. The particles are grouped together by their arc numbers and connected to form their own arcs. As the particle defined arcs move away from their emitter over time, a trail of six arcs will be created from the position of the arcs in its previous frames and connected to the original arc to create the long geometric fins.

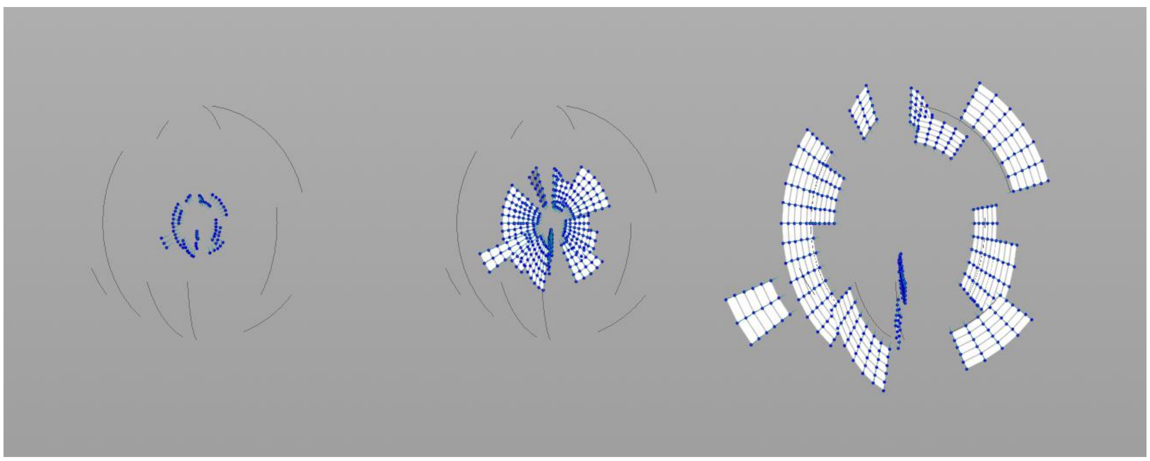

Figure 21: Procedural fin generation and animation using sphere mesh targets.

Slowing the speed of the particles down over time has the effect of changing the shape of the fins as their speed changes; The faster the particles move, the more the fin shape gets stretched out. When the particles get slowed to a standstill, the long fins squash down to thin looking arcs. This type of speed influenced squash and stretch aesthetic was also seen in the second movement and was heavily influenced by the stretching and compressing of moving bodies in Oskar Fischinger's visual music studies.

Using a sphere as a guide to influence the shape of the fins offered many opportunities to alter the look of the sculpture for every chime while keeping a visual consistency. Scaling, translating, or rotating the sphere relative to the particle emission point would warp the shape and curvature of the fins in very interesting and unexpected ways. Modifying the shape and location of the sphere guide was perhaps the most important control in art directing the look of each sculpture. After the fin shapes and motion were defined, an extrusion operation was performed on their polygonal faces to give them three-dimensionality, essentially converting a perfectly flat surface to a thin sheets. They were then duplicated twice and scaled up to create their three banded look.

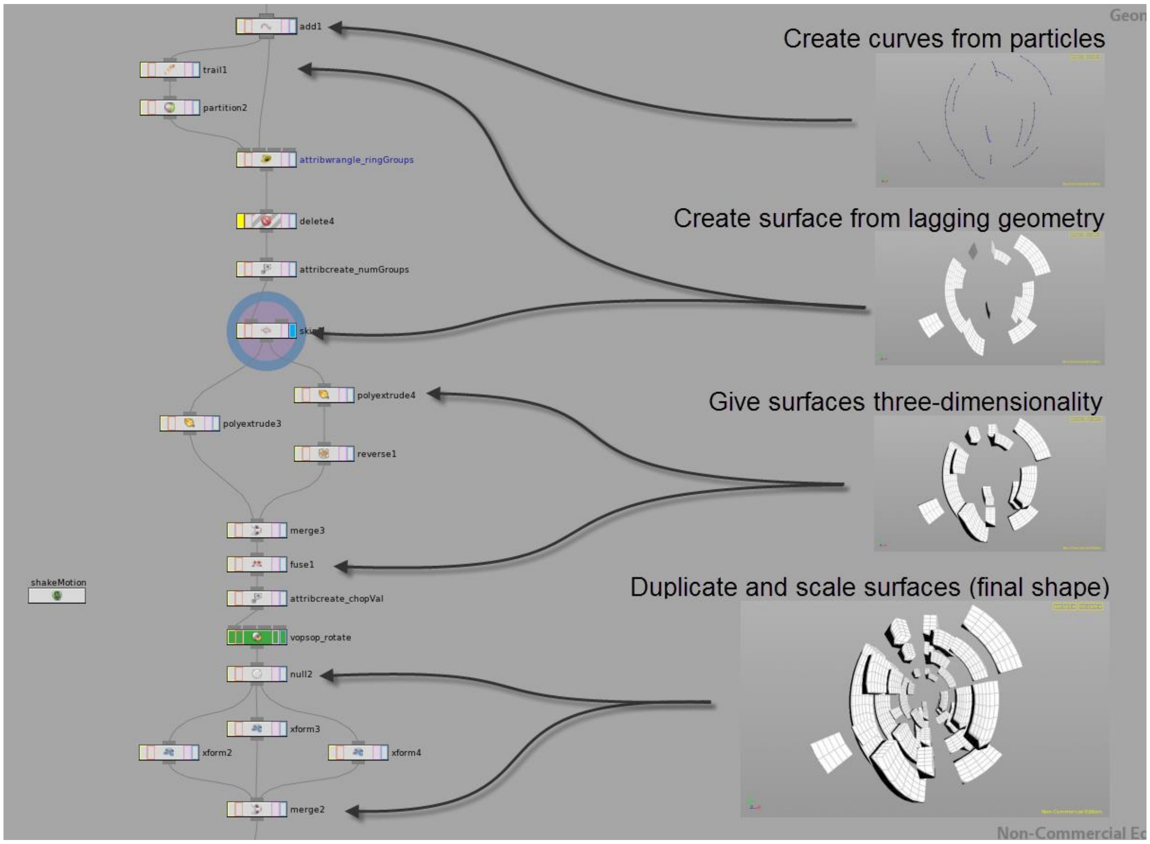

Figure 22: Houdini node tree of method for procedurally modelling bursting forms with corresponding visual examples at different stages of the algorithm.

Movement 6

There is no traditional story arc in this animation, yet I think of the sixth movement as a sort of dramatic climax to Ombres Lumineuses. There is a buildup of tension from the contrasting beauty and silence of the fifth movement which explodes into a very loud and aggressive percussion followed by long periods of silence. There is a palpable feeling of conflict and unpleasantness to this movement that I wanted to enhance with the visual design and motion of the actors.

Silence in this work is manifested visually by darkness on the screen. In my experience, it can be uncomfortable to sit in a dark theater with no light emanating from the screen or elsewhere in the theater and I wanted to utilize this discomfort to enhance the anxiety of this movement. Exploding out of the silent darkness in tandem with the loud percussion are triangles of varying shapes and sizes that hurtle themselves in a tandem, flowing stream toward the audience. This is the first time in the piece where the stereoscopic effect pushes the perceived position of the forms past the plane of the screen into the theater space which is done purposefully to make this movement feel more intense and unpredictable. As each drum beat sounds, the forms warp and distort into long, blurry white streaks with hints of red; this warping only lasts for a single frame and changes every time there is a new drum beat, adding to the theme of intensity and unpredictability.

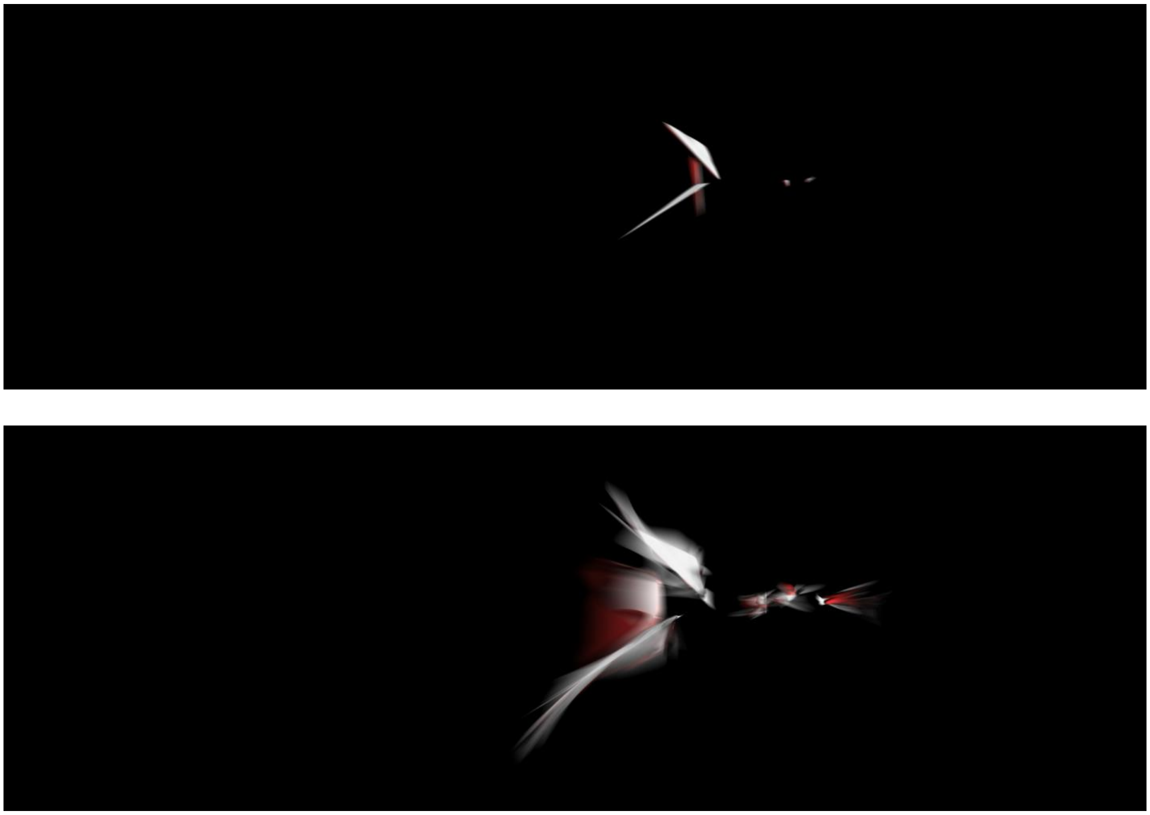

Figure 23: Stills from movement 6 of Bright Shadows with and without motion blur distortion.

This movement was less demanding from a technical perspective; yet, is one of the more visually striking movements. The most interesting technical challenge came from the warping effect. This was achieved by adding a spatially coherent noise function to the velocity vectors of the geometry as the audio analysis detected a drum beat. Renderman's rendering algorithm uses velocity vectors to determine what the motion blur of an object should look like; so, by altering these values, I could change the look of the motion blur to stretch and warp to any direction I wanted despite how the object was actually moving. The rapid switching between normal and tampered motion blur creates a dramatic and unnerving effect, especially on a large immersive screen.

Movement 7

The seventh movement marks the final and perhaps most important movement to Ombres Lumineuses and this animation. A crescendo of intensity over the previous three movements culminates in a furious explosion of aggressive sounds and concludes in an extended silence. As a gentle synthesized hum slowly fades in at the beginning of the seventh, a faint, ghostly melody emerges through something sounding like an augmented wind instrument. What is remarkable about this riff is that it repeats at a regular interval of time which surprisingly has not been done in the piece of music until this point. Up until the finale of Ombres Lumineuses, rhythm and repetition have been methodically avoided despite being fundamental to most forms of music. The listener is finally introduced to a tempo, something that is naturally expected in most music, long after he or she becomes acclimated to its absence. This use of rhythmic contrast gives this particular movement a mesmerizing and ethereal quality despite its placidity relative to the rest of the piece.

It was important to introduce something new to reinforce the importance of this moment so I decided to create something less systemic and more explicitly "hand directed" than anything preceding it. The melody is characterized by two tear-drop shaped forms moving in parallel on a predetermined path. These forms then morph into two concentric rings that expand and then disappear. This amounts to what can be described as a kind of temporal sculpture, or "liquid architecture" [18] that repeats as the melody repeats. The path of the tear-drops are mostly consistent every time they reappear; however, a small noise function was applied to the path to slightly alter it for every repetition. This was done to add a small amount of imperfection to the motion, much like the minor imperfections of a dancers' motions. Even if choreography dictates a dancer to repeat his or her actions, no motion can ever be perfectly reproduced without some amount of human error.

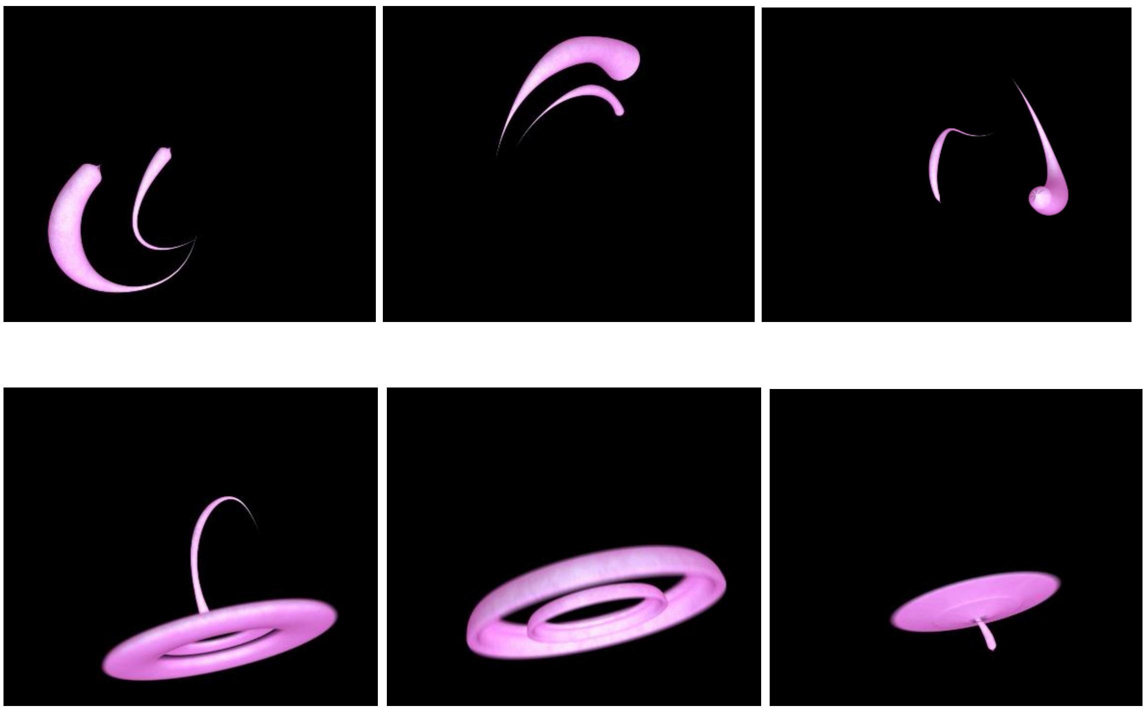

Figure 24: Temporal sculpture at different morphological states.

The first step of creating the tear-drop effect was to draw two three-dimensional bezier curves to define their paths. The bezier curve, initially defined through placing only a dozen or so points, is then resampled to have a couple hundred equidistant points along the path. It is much easier to modify create and modify smooth, expressive curves using only a few points than hundreds of points which is why the curve is resampled rather than starting with that many points from the beginning. A NURBS circle is then created at every single point of the new curve and tangentially aligned with it.

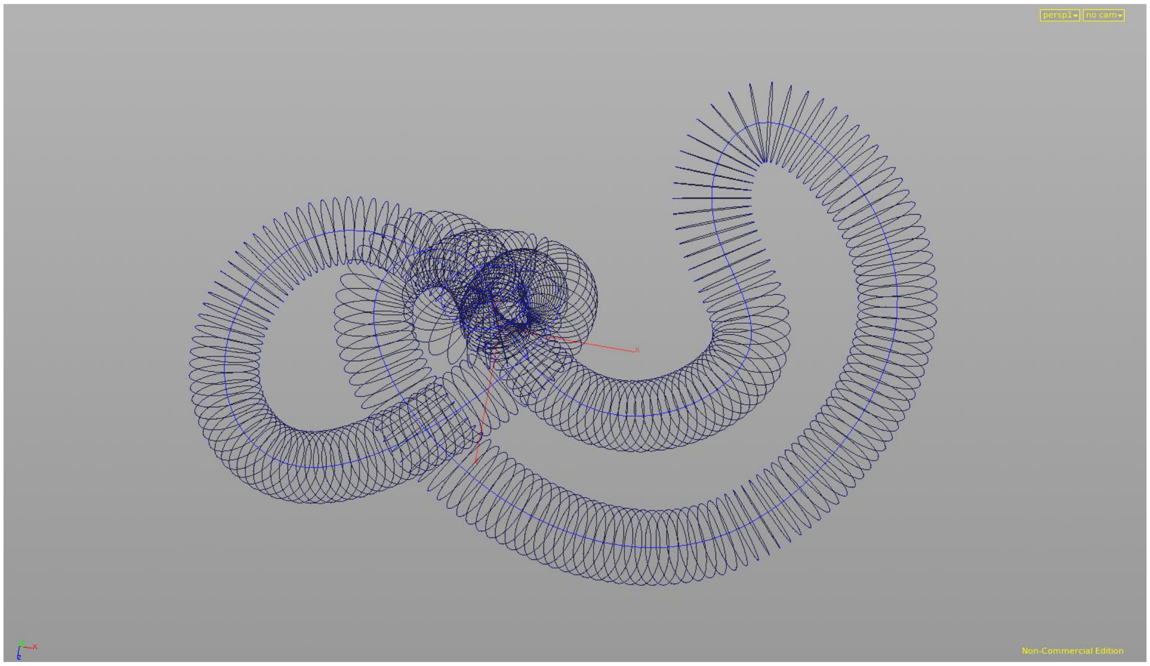

Figure 25: Bezier curve defining the path of the tear-drop form with circles copied and aligned to path.

A separate, two-dimensional bezier curve was drawn to define the tear-drop shape profile. Then, the profile was used to set the scale of the NURBS circles along the curve by shifting the profile data along the curve using a Houdini expression. Finally, all circles were skinned to create a continual surface for the tear-drop. In the final effect, it appears that the tear-drop forms are moving; however, this is an illusion caused by the sequential scaling of the circular ribs defining the shape along a path, similarly to how we interpret lights moving around a marquee when in fact they are separate, static lights illuminating in tandem.

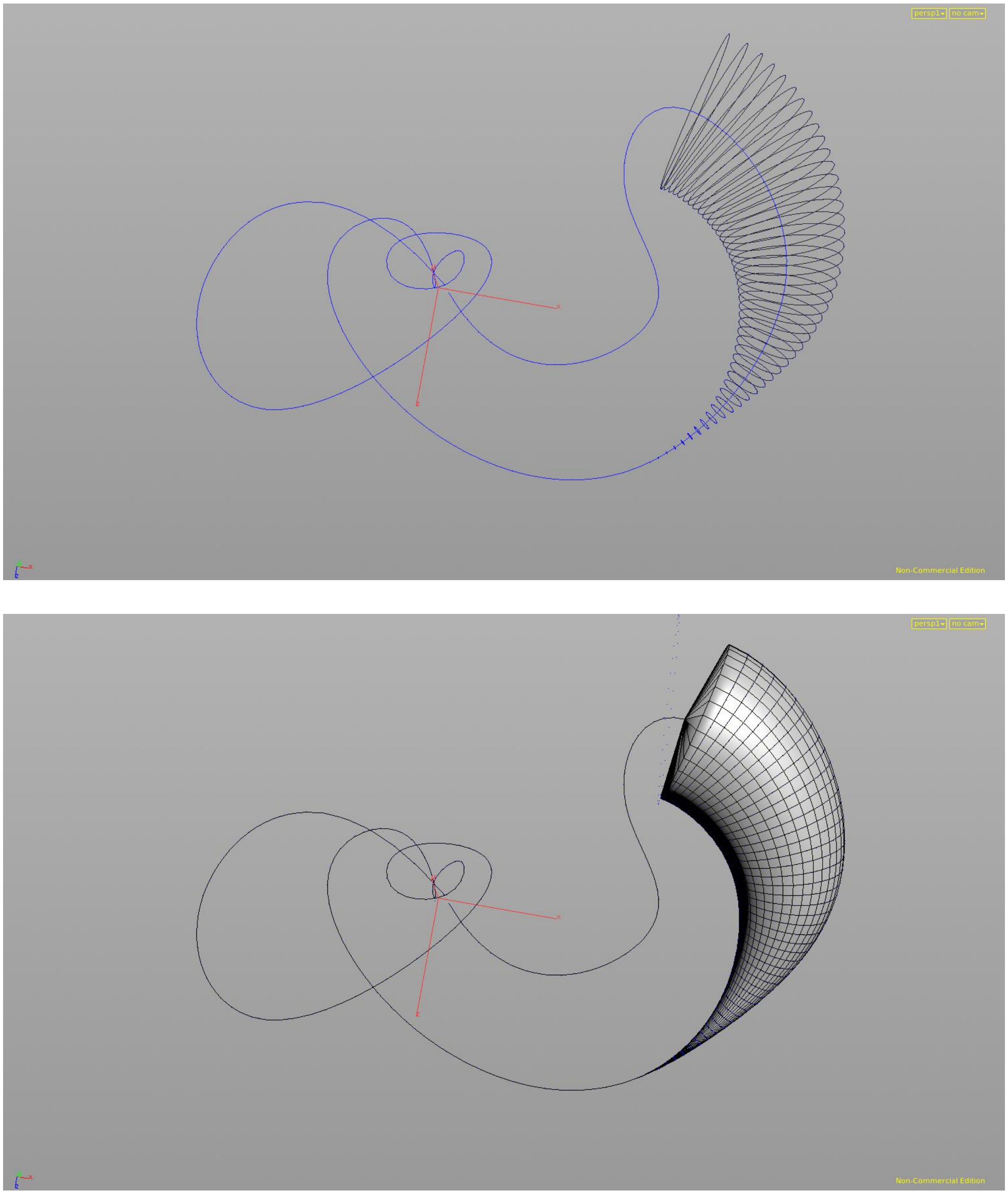

Figure 26: Copied circles scaled to match profile curve (top) and new mesh created from skinning circles along the path (bottom).

Keeping the tempo for most of the movement is a faint, electroacoustic hum that repeatedly quivers in a consistent pattern. To illustrate this hum, I created many layers of concentric rings that oscillate in a motion toward and away from the audience. This motion starts from the centermost ring and radiates outward to cause a kind of pulsing effect in timing with the tempo. Small white spherical lights appear and disappear in congruence with the pulse like motion that temporarily illuminate the form in the darkened scene.

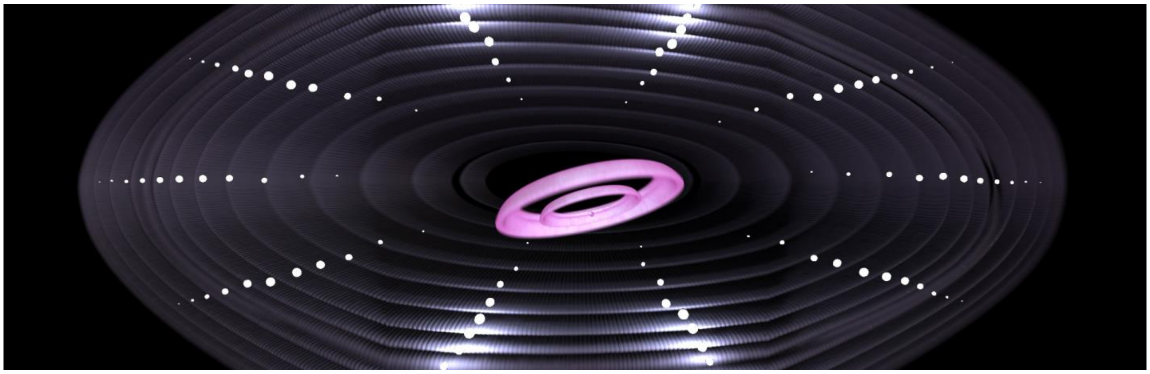

Figure 27: Still from movement 7 of Bright Shadows.

A sine function was applied to the perpendicular axis of each ring to create the forward and backward oscillation motion. The phase of this sine function for each ring slightly shifts the further away it is from the center most ring, creating the pulsing effect. As the movement progresses and the synthesized hum gets louder, the concentric rings slowly change their orientation so that they are pulsing in an upward motion rather than toward the audience. Even though nothing has changed in the motion of the form, a different perspective of it changes how it is perceived. No two rings are touching each other, yet their motion is linked in a way that suggest a singular, connected form. This is further enhanced by a radial noise function that warps each ring in similar way, keeping a structural continuity between each ring. This noise function slowly changes over time making the form feel more organic and dynamic.

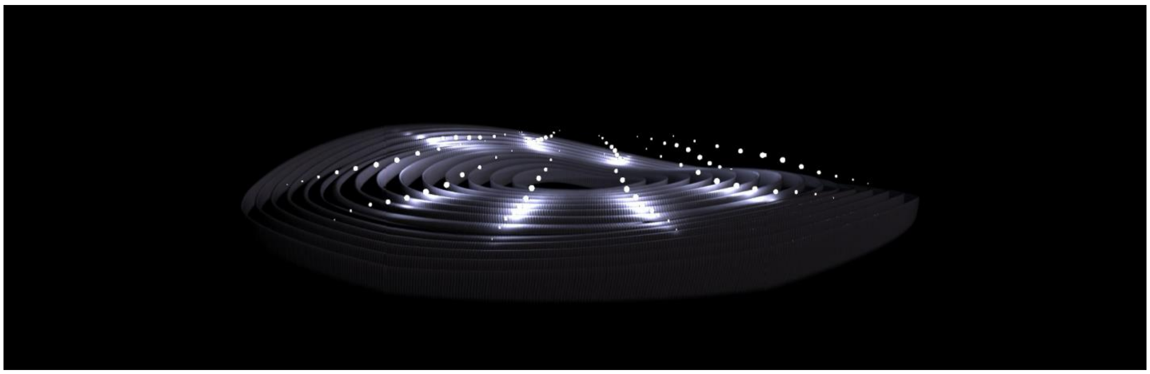

Figure 28: Still from movement 7 of Bright Shadows.

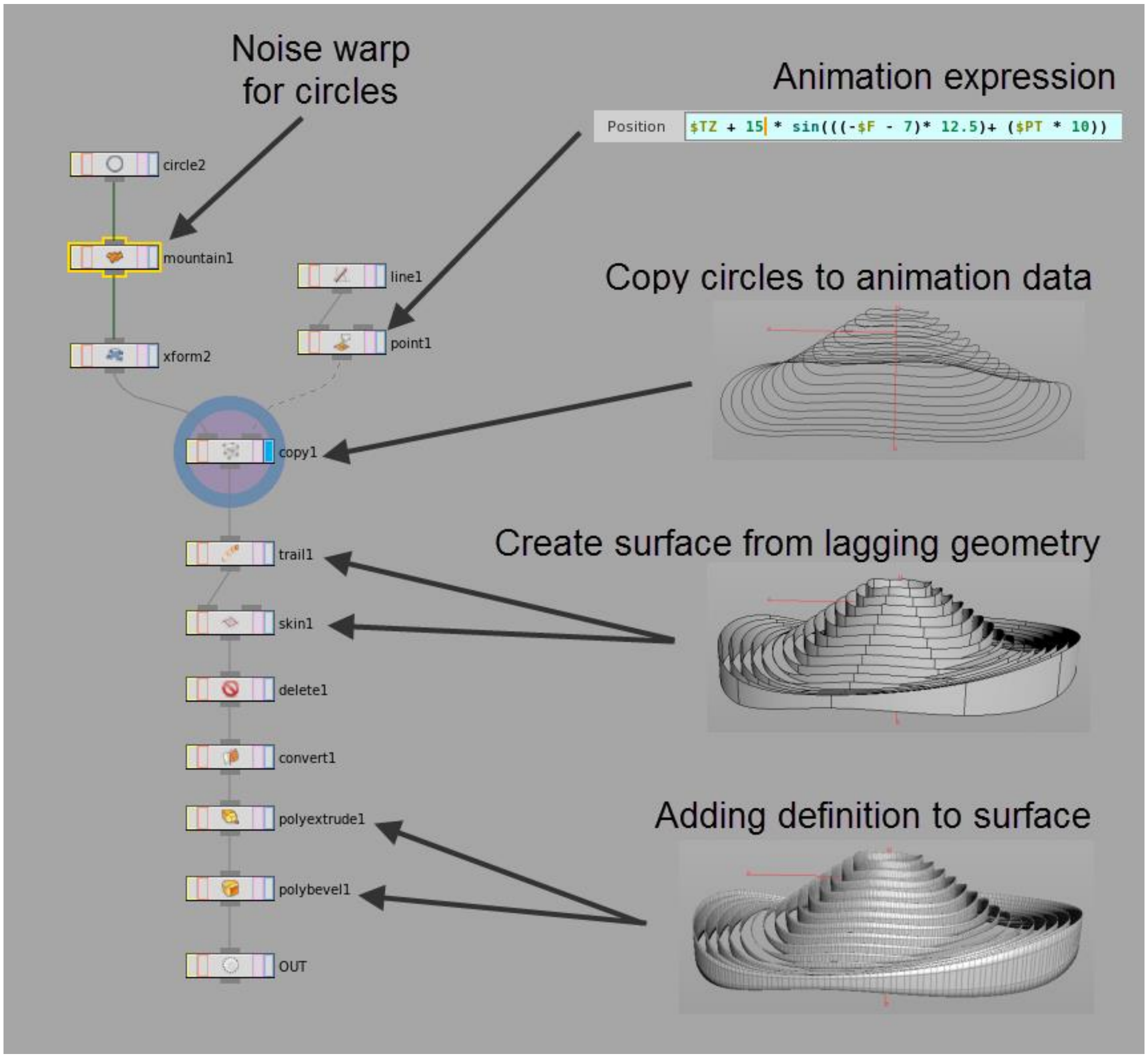

Figure 29: Houdini node tree of oscillating form with corresponding visual examples.

The final prominent visual component of the finale is another kind of temporal sculptural form that appears in synchrony with a high-pitched bell-like sound. The use of this instrument is sparse but contrasts with the rest of the musical soundscape enough to draw attention. This form consists of long, triangular prisms that connect at a single point and elongate outward from this point over time. Each prisms slowly spins around the center of its own axis through the common connection point and is given a glass-like appearance to reinforce a feeling of delicacy evoked by the gentle triangle instrumentation.

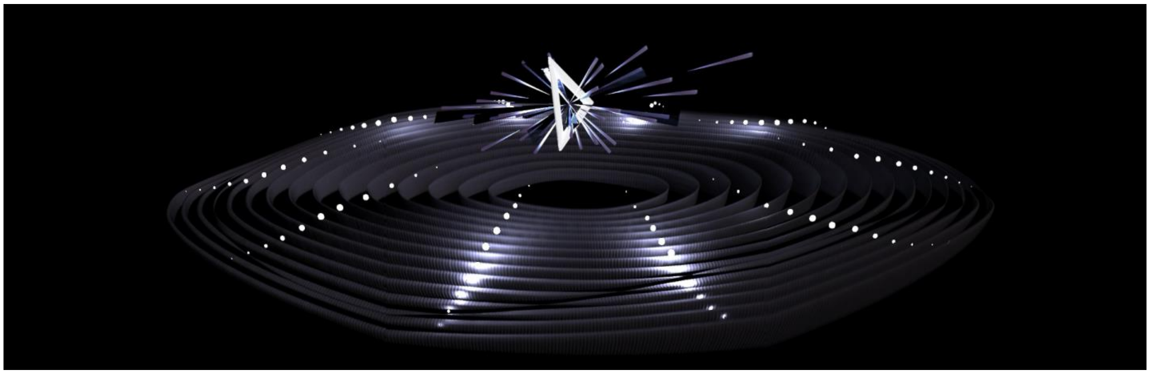

Figure 30: Still from movement 7 of Bright Shadows.

The growth and motion of each prism is defined by particle motion, as is done in movement five, in order to make its growth dynamic and non-uniform. The elegant dance of these elongating prisms is enclosed by a flat, triangular ring with a subtle wobbling motion that doubles as a light source which illuminates the form. This is achieved in using Renderman's color bleeding algorithm that uses point clouds to calculate an amount of illumination for surfaces based on its neighboring geometry.

Ombres Lumineuses ends with all audio components of the soundscape slowly fading out, leaving the wavering electroacoustic hum that has been keeping the tempo for most of the movement. As all other sounds exit the music, the concentric ring formation illustrating the hum slowly moves toward the audience in stereoscopic space, signifying its growing importance to the soundscape. The wavering then stops and the hum becomes a monotone drone. The oscillation motion from the concentric ring body evolves to a rapid spinning motion with each ring rotating at a slight lag behind its neighboring ring. This was done by offsetting matrix rotation values based on each rings distance to the center of the body.

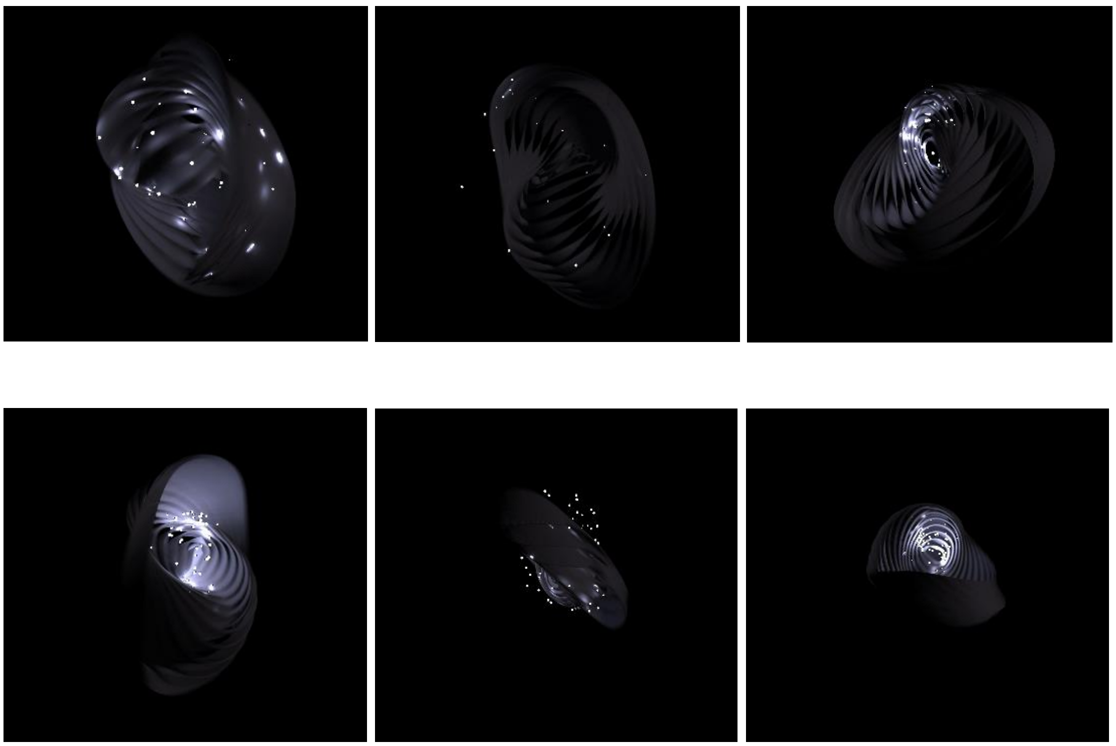

Figure 31: Still of oscillating, spinning rings at different stages.

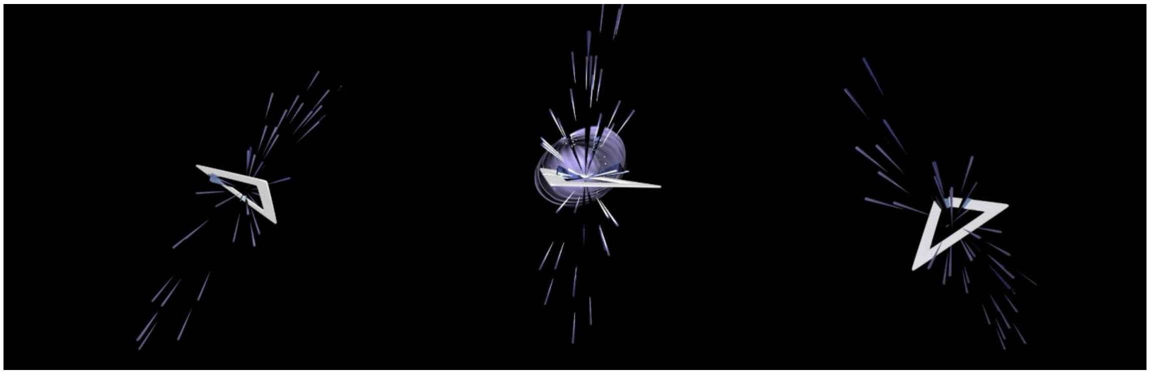

Figure 32: Final moments of Bright Shadows.

CHAPTER VI

CONCLUSION

Screening Bright Shadows

The first screening of Bright Shadows took place on December 22, 2014 in front of a small crowd of about twenty at the Immersive Visualization Center. Despite initial technical difficulties with the projectors, the screening was a tremendous success met with surprise and enthusiasm from the viewers. People talked about their favorite moments and the wide range of emotions they experienced during the piece such as angst and wonder. A variety of movements were chosen as favorites but perhaps the most common favorite was the final movement which helped to verify that accompanying visuals were successful in reinforcing the strong finale of Ombres Lumineuses.

People tended to discuss things that the visuals reminded them of, especially when trying to recall and describe particular movements. Their objective associations remained uniquely their own which affirmed that the visuals successfully avoided easy visual categorization and stayed true to a non-representational format. Some people realized that the visuals helped them find a greater appreciation for a style of music that they would normally consider unappealing. This was an exciting assessment as it demonstrated a value to this kind of work that could translate to pursuits outside of art and entertainment such as music education and appreciation.

Future Work

One of the greatest challenges of completing this project was the formidable length of the music. There are many instances of subtle instrumentation in Ombres Lumineuses that were not mapped to music due to the time constraints and scope of this project. It would be interesting to see what could be achieved with a shorter piece of music in a similarly scoped project. It would also be interesting to apply this immersive, spatially consistent approach to visual music with other types of absolute musical stylings such as classical and jazz.

Additionally, the introduction of affordable, high fidelity virtual reality systems has been a topic of increasing interest and would be a viable vessel for this work, eliminating its need to be shown in a specific type of theater. There is a shared communal experience in watching a ballet or theatrical film that Ombres Lumineuses invokes by being shown in a shared space. Viewing this piece on a virtual reality system would be an isolating experience compared to a theater but would help alleviate some of the technical shortcomings of the IVC and enhance the sense of immersion. It is an area that is worthy of exploration and should be evaluated as a possible platform for this type of visual music experience when these systems become available.

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