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A Vision of Sound
A 3D Visualization of Pipe Organ Music

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A thesis submitted to the Faculty of the College of Imaging Arts and Sciences in candidacy for the degree of Master of Fine Arts

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Abstract

My goal is to create a 3D animation that illustrates the movements and patterns produced in the air when Bach’s Chromatic Fugue is played on a pipe organ. By combining the visual element of swirling patterns inspired by pipe organ acoustics simulation with imagery that the music evokes in the mind, I aim to present a surrealistic soundscape that visually depicts the boundless creative energy and freedom of music and mind combined. I hope to create an animation that is aesthetically interesting and to inspire imagination in viewer.

Background

When we hear music, the effect of traveling vibrations on surrounding air molecules creates what we perceive as sound. In some cases, invisible patterns are formed by the disturbance in the air that these moving vibrations create when musical instruments are played. When a pipe organ produces sound, swirling vortex patterns form in the air. This effect cannot be seen by the eye, but experiments using high speed film have captured the movements of black smoke from the pipes of an organ and reveal that visually interesting forms are produced. The physics of this phenomenon have also been visualized in scientific simulations with the use of fluid dynamics. Research shows a possible connection between the appearance of scientific visualizations of musical acoustics and the results of music visualization studies based on a synesthetic association of sounds with visual forms.
Process

Choosing a topic

When choosing a topic for my thesis project, I looked at different sources of inspiration for ideas. I came across a book on the science behind music, and some imagery of swirling patterns caught my eye. I read that these patterns are created by sound vibrations when a pipe organ is played. (Jeans, 2009). I felt that this would be an interesting idea to illustrate in a 3D animation.

My initial idea was to create an animation that was aesthetically interesting as well as informative to people with an interest in musical acoustics. After presenting my thesis proposal and receiving feedback from my advisors, I made a change to the informational aspect of my proposal. I chose to create an artistic interpretation of the idea of sound visualization rather than a scientifically accurate representation.

A study involving musical graphics, a method of creating abstract visual compositions by painting and drawing audio-visual associations, reveals “the relationships between the results of these experiments with drawing music and the other physical methods of visualizing music...seem very similar to relationships between psychology and musical acoustics and between audio perception processes and the physics of sound processes.” (Vanechkina, 1994, p. 2) I took this idea into account when planning the design of my animation. I thought it would be interesting to combine imagery inspired by physical simulations of sound with images that the music evoked in my mind.
Planning & Design Ideation

I determined that I would create a 3D animation that was two minutes in length. To select the music that I would visualize in my animation, I browsed organ music in a royalty-free music library. According to an article on light painting, a form of music visualization, “The selected musical work is the same as a view of nature is for the landscape artist. The painter does not copy what is seen, but rather reflects his or her attitude toward it. The light-painter relies on imitation even less than does the painter because the material substance of what we hear and what we see are so different.” (Pravdyuk, 1994, p. 381) I kept this idea in mind when selecting music for my animation. I chose Bach’s Chromatic Fugue because I felt it was a song that could be illustrated visually. The tempo and mood of the music changes during the song, and I felt that these aspects of the music could be reflected in an animation.

I looked at different examples of sound visualization to gather inspiration for my project. Scientific images of organ acoustics simulations inspired the look of the effects that I would create for the animation. An article on organ jet physics featured images taken by a high-speed camera to illustrate the vortex movements of air from an organ jet. (Yoshikawa, 1996, p. 4). This inspired the design of the swirling smoke emerging from the organ pipes in my 3D animation.

Computer simulations of an air jet deflected by sound also served as helpful reference images. The article “Numerical and Experimental Study on the Sound Generation in the Flue Organ Pipe” features diagrams and colored images simulating sound generation in the flue organ pipe. (Angster, 2008). These images inspired the use of color in the smoke effect I created. I also looked at informational graphics in which
concentric rings were used to illustrate the movement of sound waves. I experimented with incorporating this visual element in my animation.

Another method of sound visualization I researched was a study of visualizing sound waves through the idea of sonoluminiscence. In a project called Camera Lucida, an ultrasonic signal was passed through a liquid in order to translate the behaviors of sound into light. (Domnitch, 2004). I found it helpful to look at examples of sound visualization during the process of forming ideas for my animation.

I also studied a project involving the creation of a series of works of art in which musical pieces were transformed into colorful designs. (Burgmer, 2008). The artist used a color-tone system to translate different notes into color. She took into account both the synesthetic perception of sound as well as the contrast between warm and cool colors when choosing her color palette to assign to the notes. I found this to be an interesting method and experimented with the idea of using color to convey changes in sound.

The idea of changing tune resulting in changing color was also utilized in the process of musical light painting. (Pravdyuk, 1994). In light painting, an artist uses moving lights of varying color and brightness to create a visualization of music. Crescendos and diminuendos in music result in growing and lowering of light. This idea inspired me to try varying the brightness and intensity of the smoke emitted from the organ pipes in my animation according to the amplitude of the music.

I also found inspiration in paintings. I thought Charles Burchfield’s painting “Autumnal Fantasy” created an interesting depiction of sound vibrations in the forest. In the painting, Burchfield uses a repeated ring pattern that reflects the patterns seen within the texture of the environment. The patterns appear to move through the space of the
scene and interact with the trees and other objects in the forest. I hoped to illustrate this idea of sound vibrations interacting with a surrounding three-dimensional environment in my project.

For the visual style of my animation, I looked at surrealist paintings for inspiration. I have an interest in surrealist art and wanted to incorporate the style in my project. I was especially inspired by the use of lighting and the metaphorical combinations of objects in paintings by Vladimir Kush. I brainstormed ideas for objects in the 3d environment that could resemble symbols related to music, such as islands in the shape of musical notes and a tree in the shape of a treble clef. [Figure 1] Through animation I had the ability to change the perspective of objects over time so that the secondary objects they formed became apparent over the course of the animation.

Figure 1: Treble clef tree and musical note islands
Figure 2: Storyboard
After forming ideas for the visual look of my project, I created a storyboard to visualize the subject matter and sequence of events in my animation. [Figure 2] I also created a list of the different 3D elements that would be involved in the project. I found that creating a storyboard and figuring out the components involved in the animation ahead of time was very helpful when implementing the project.

**Software**

I chose to use Maya for modeling, shading, lighting, animating, and rendering the 3D scenes in my project. I used Photoshop to create textures and After Effects for compositing scenes and creating visual effects.

**Implementation**

I began executing the project by modeling 3D assets in Maya. I first created a model of a pipe organ, looking at photographs for reference. [Figure 3] The main reference I looked at was the pipe organ from Disney’s 1954 film *20,000 Leagues Under the Sea*. This organ had a whimsical appearance that I found interesting. I then mapped textures to the surface of the model. I found most images for surface textures in a free texture library and edited these images in Photoshop.

*Figure 3: Pipe organ model*
The most challenging part of creating the pipe organ was figuring out how to model the baroque decorations and deciding on the level of detail to include. I used a combination of modeling techniques in creating the ornaments. I simplified some of the decorations because the complexity of the model slowed down the performance of the software.

Next, I began modeling an exterior landscape for the outdoor scene in my animation. [Figure 4] I created models of musical notes, which would form islands in the landscape. I added imperfections in the surface of the notes and created grass and dirt textures for the models to give them the appearance of landforms. I experimented with using Maya fur to create the grass, but decided to use a mapped image texture instead to reduce rendering time. It was a challenge to make the grass and dirt appear seamless. I tried different techniques to create the appearance of a natural transition between grass and dirt ground.

Figure 4: Outdoor scene
I then created models of trees for the outdoor scene. I experimented with using Paint FX in Maya to create trees, but found that I better achieved the look that I desired by modeling the trees. I had a similar problem with the tree models as I did with the pipe organ, where the model’s complexity caused problems in Maya. Because of this, I decided to only include a small number of trees in the landscape. I added raised areas and dents in the ground around the base of the trees to make their intersection with the ground appear more realistic. Influenced by the lighting in paintings of landscapes, I chose warm tones for the sky and lighting in the scene. I adjusted the direction of the lights as well as their color to create the appearance of dusk. I feel that natural lighting late in the day and early in the morning creates a more aesthetically interesting visual effect than mid-day direct sunlight.

I then began modeling the interior scene of the animation. [Figure 5] I referred to pictures of church interiors for creating the walls, ceiling, and columns in the interior space. I made adjustments to the size of the room and the objects within it to create a more accurate scale. I created a stained-glass window that resembled the outdoor scene of the animation. To create a texture for the window, I used Photoshop to assemble pictures of colored glass into a landscape that matched a rendered view of the exterior scene. [Figure 6] I made some changes to the scene to match the elements of the room with the style of the architecture. I changed the shape and design of the stained glass windows and changed the texture of the floor from flat boards to a more intricate design. I then added lighting to the scene. I modeled sconces in which I placed each light, and positioned the sconces around the columns in the interior scene. I experimented with
Figure 5: Interior scene

Figure 6: Stained glass window and exterior landscape
adjusting the number of lights in the scene to create a balance between rendering time and a realistic appearance to the scene.

To create a swirling smoke effect for the animation, I used fluid effects in Maya. [Figure 7] I adjusted parameters of the fluid to affect the movement and color of the smoke. I created an effect where the smoke transitioned through a series of colors over time. I experimented with the idea of adjusting the color of the smoke to change according to the amplitude of the music, but found the idea difficult to implement. I later created an animation with shorter bursts of the swirling smoke to better sync the effect to the notes played on the organ.

![Figure 7: Colored smoke effect](image)

Next, I created an animatic to determine the different camera views in the animation and the length of each shot. I first created a sequence of still images set to the music I chose for the project. I then created an animatic with animated camera movements to better visualize the pacing of the animation. It was helpful to refer to the animatic when putting together the final composition of the animation.

I then began animating individual elements in the scenes. I animated the keys of
the organ to play the opening notes of Chromatic Fugue. [Figure 8] It was challenging to accurately sync the movement of the keys to the music. I made timing adjustments in After Effects to make the striking of the keys match up to the music more believably.

In the exterior scene, I used particles to cover a tree in butterflies, creating the illusion of leaves. [Figure 9] I hoped to add an element of surprise to the animation by making the butterflies initially appear to be leaves on a tree. I used forces to affect the particles and animate the butterflies flying off of the tree. I made some changes to the butterflies, adjusting their placement and size and varying their color to add visual interest.

I created movement of the water in the scene and faced a challenge attempting to make the water react with the landforms. I tried several different methods of animating
the water, including deformers and animated displacement maps. I eventually decided on using fluid effects to create the water. This allowed for the appearance of a realistic movement of waves. I used shading effects to create a more believable intersection between land and water.

I rendered each shot in the order they appeared in the animation. The numerous lights casting shadows in the interior scene slowed down the rendering process. I rendered the swirling smoke effect separately from the environment and used After Effects to composite the smoke into the scenes. [Figure 10] In the outdoor scene, I rendered a layer of ambient occlusion, which I overlayed on the on the original render to create a more realistic shading effect on the landforms.

In After Effects I created transitions between the individual shots in the
Figure 10: Smoke emerging from organ pipes

animation. [Figure 11] Most shots faded from one to another to create a smooth transition. I created a morphing effect on the stained glass window to transition from the indoor scene to the outdoor scene. I coordinated this effect with the position of the colored smoke moving through the scene. I hoped to create the illusion of the movements and vibrations of the music affecting the environment.

Figure 11: Transition from interior to exterior scene
I used After Effects to create a waveform effect that reacted to the music in the animation. [Figure 12] It was a challenge integrating the effect into the scenes so that it did not appear to be a 2D layer on top of a 3D scene. I experimented with animating the placement of the sound waves to match up with the location of different objects in the scene, such as the musical notes.

![Figure 12: Waveform effect in exterior scene](image)

I rendered the final composition in After Effects and presented the animation as a QuickTime movie. During the thesis defense and thesis show, I displayed the animation on a projector screen. Throughout the implementation and revision process, I received helpful feedback from my advisors and peers.

**Conclusion**

The final outcome of the animation was close to my initial vision of the project. I feel that I accomplished the goals that I set out to achieve. There were several new things that I learned during the completion of the project. By solving the problem of illustrating sound, I gained experience thinking abstractly in order to find a visual solution. Through research, I gained knowledge about methods of music visualization and pipe organ
acoustics. I gained skills in planning and executing a project. I learned the importance of planning ahead, creating storyboards and animatics, and following a schedule. I was able to experience the different components involved in the process of making an animation. I also gained technical software knowledge in both Maya and After Effects.
Resources

After Effects CS4 (9.0.3.8) [Computer Software]. San Jose, CA: Adobe


Photoshop CS4 (11.0.2) [Computer Software]. San Jose, CA: Adobe


Appendix
Thesis Proposal for the Master of Fine Arts Degree

Rochester Institute of Technology
College of Imaging Arts and Sciences
School of Design
Computer Graphics Design

Title: A Vision of Sound: A 3D Visualization of Pipe Organ Music
Submitted by: Donna Schichler
Date: October 3, 2010

Thesis Committee Approval

Chief Adviser: Dan DeLuna, Associate Professor, Computer Graphics Design

______________________________    ______________________________
Signature of Chief Adviser    Date

Associate Adviser: Marla Schweppe, Professor, Computer Graphics Design

______________________________    ______________________________
Signature of Associate Adviser    Date

Associate Adviser: Shaun Foster, Assistant Professor, Computer Graphics Design

______________________________    ______________________________
Signature of Associate Adviser    Date

School of Design Administrative Chair Approval

Administrative Chair, School of Design: Patti Lachance

______________________________    ______________________________
Signature of Administrative Chair    Date
Situation Analysis

When we hear music, the effect of traveling vibrations on surrounding air molecules creates what we perceive as sound. In some cases, invisible patterns are formed by the disturbance in the air that these moving vibrations create when musical instruments are played. When a pipe organ produces sound, swirling vortex patterns form in the air. This effect cannot be seen by the eye, but experiments using high speed film have captured the movements of black smoke from the pipes of an organ and reveal that visually interesting forms are produced. The physics of this phenomenon have also been visualized in scientific simulations with the use of fluid dynamics.

Research shows a possible connection between scientific visualizations of musical acoustics and the results of studies of music visualization based on a synesthetic association of sounds with visual forms. A study involving musical graphics, a method of painting and drawing audio-visual associations, reveals “the relationships between the results of these experiments with drawing music and the other physical methods of visualizing music...seem very similar to relationships between psychology and musical acoustics and between audio perception processes and the physics of sound processes.” (Musical Graphics as an Instrument for Musicologists and Educators)

Problem Statement

Through 3D animation, I will create a visualization that illustrates the movements and patterns produced in the air when Bach’s Chromatic Fugue is played on a pipe organ. By combining the visual element of swirling patterns inspired by pipe organ acoustics simulation with imagery that the music evokes in the mind, I will present a surrealistic soundscape that depicts visually the boundless creative energy and freedom of music and mind combined. The digital medium enables me to express my vision to inspire and uplift the viewer, just as dynamic compositions, musicians and pipe organs have lifted hearts and minds for generations in the great cathedrals and concert halls of the world. My goal is to create an animation that is aesthetically interesting and to inspire imagination in viewer.
Survey of Literature

Numerical and Experimental Study on the Sound Generation in the Flue Organ Pipe  
Dr. Judit Angster  
Fraunhofer Institute for Building Physics, 2008

This article discusses a study on the sound mechanism of the flue organ pipe. It is geared toward researchers as well as organ builders. The article explains that the purpose of the project was to create an accurate simulation of sound generation in the flue organ pipe in order to further understanding. The study combines flow visualization with a numerical method of computational fluid dynamics to simulate an air jet deflected by sound. The article includes diagrams and color images from the simulation, which could be helpful reference material for my thesis.

A Pictorial Understanding of Organ Jet Physics  
Shigeru Yoshikawa  
Acoustical Society of America, 1996

This article discusses the physics of the organ pipe sounding mechanism. It is directed toward those interested in studying acoustics. The article explains that a pipe organ creates an air jet that moves in a wavy motion and creates a vortex. To visualize this movement, a high-speed video camera was used to capture and record the shapes of a smoked jet. Photos from the experiment are included in the article. These images along with the article’s description of the jet motion would be helpful for creating a visualization of sound movement.

Camera Lucida: A Three-Dimensional Sonochemical Observatory  
Evelina Domnitch and Dmitry Gelfand  
Leonardo, Vol. 37, No. 5, 2004

This article discusses a project called Camera Lucida, involving the creation of an interactive sonic observatory that translates the behaviors of sound into light. It is aimed toward people interested in art and science. To visualize sound waves, the project uses the idea of sonoluminescence, where a gas becomes illuminated when an ultrasonic signal is passed through a liquid. It was created as both a scientific tool and a work of art. The article details some interesting conclusions drawn from the experiment, which could be helpful in developing my thesis.

Chromatic Notation of Music: Transforming Bach and Webern into Color and Light  
Brigitte Burgmer  

In this article, the author describes works of art that she has created, in which she transformed musical pieces into colorful designs. The article is geared mainly toward artists. It explains the color-tone system that she uses to translate different notes into color. The artist took into account both the synesthetic perception of sound as well as the contrast between warm and cool colors and the blending of those colors when choosing her color palette to assign to the notes. I could use this article as an inspiration to choose colors that vary based on the tone of music in my thesis.

Musical Light-Painting and the Phenomenon of Form-Movement  
Yury Alekseyevich Pravdyuk  
Leonardo, Vol. 27, No. 5, 1994

This article explains the process of musical light-painting, where the artist uses moving lights of varying color and brightness to create a visualization of music. The article is geared toward people interested in art and performance. The artist uses musical speed to determine the movement of light forms and rhythm to paint clear elements of form movement. Tune change results in a color change and crescendos and diminuendos result in the growing and lowering of light. I could take these factors into account when creating a visual depiction of of music for my thesis.
Music Graphics as an Instrument for Musicologists and Educators
Irina L. Vanechkina
Leonardo, Vol. 27, No. 5, 1994

In this article, the author makes a comparison between the physical scientific visualization of musical acoustics and hand-drawn methods of music visualization that take into account the psychological and aesthetic aspects of music. The article is aimed toward people interested in psychology, education, and music. The author discusses the idea of musical graphics, which involves methods of painting and drawing audio-visual associations and results in abstract visual compositions. Experiments where children created musical graphics revealed a strong similarity between these graphics and the scientific visualization of musical acoustics. I would be interested to incorporate this idea in my thesis.

Fusion CI Studios adopts Prime Focus Software’s Krakatoa for SeaWorld TVC VFX
Natasha Wang
CGSociety Production Focus, 2010

This article describes the making of a SeaWorld commercial, which makes use of fluid simulations to achieve an ink-in-water ripple effect. It is geared toward people interested in 3D computer graphics. The article describes the process of creating the visual effects as well as the challenges faced by the studio. I am interested in creating swirling particle effects in my thesis project, so some of the information in this article could be useful to me.

Lovely Bones, Lovely Landscapes
Renee Dunlop
CGSociety Production Focus, 2010

This article discusses the creation of surrealistic concept art for the film The Lovely Bones. It is aimed toward people interested in computer graphics and visual effects. In the article, the art director for the film explains the methods he used to create the concept imagery along with some of the problems he solved to make the images appear surreal. I would like incorporate an element of surrealism in my thesis project, and the graphics in this article could be a source of inspiration for the design of the setting for my animation.

Six Degrees of Simulation
Jerry Laiserin
Computer Graphics World
Volume: 24, Issue: 6, 2001

This article discusses the importance of creating simulations to analyze and visualize elements such as sound, light, and wind flow. It is geared toward architects and engineers interested in designing buildings and interior spaces. The author explains how visualizations of acoustics can have an important impact on the way buildings are designed. Images from 3D animated sound visualizations are included in the article and could be helpful reference visuals for my thesis.

Fluid Motion in Focus
Diana Phillips
Computer Graphics World
Volume: 24, Issue: 1, 2001

This article explains how scientists and engineers use computer visualization to gain a better understanding of the flow of substances such as air and liquid. It discusses the limitations of using 2D graphics to visualize fluid motion and points out the benefits of creating 3D visualizations. The technology described in this article is likely outdated; however, the article’s explanation of the flow-visualization process could be useful for my thesis.
The animation begins with a close-up shot of organ pipes. As the music begins to play, swirling patterns emerge from the pipes. The patterns move according to the tempo of the music and expand through the space in a circular wave motion.

The tone of the music becomes more upbeat, and the interior room begins to transition into an outdoor scene. The sound patterns come in contact with a stained glass window on the wall, causing it to morph into a 3D landscape.

Baroque decorations on organ twist and move with the music, turning into colorful floral vines. The environment surrounding the organ continues to become more vibrant.

As the music builds, the surrounding room becomes brighter and fills with the swirling patterns that the organ is emitting. The sound waves interact with the surrounding environment when they come in contact, causing the surroundings to warp and vibrate.

The sound waves reach the wooden floorboards, which dissolve into moving water. Ripples in the water coincide with the music and interact with the patterns that continue to fill the air.

A long shot shows the sound patterns moving throughout the landscape. Plants and water move as they interact with the patterns. The sun moves lower in the sky as the song comes to an end.
Methodological Design

Methodological Approach
3D animation, 2 minutes in length

Software
Maya
Photoshop
After Effects
Music editing software

3D Assets
Pipe organ
Organ seat
Interior Room
  Walls, ceiling, floor
  Stained glass window
Exterior Landscape
  Landforms/mountains
  Rocks and boulders
  Trees and plants
  Flowing water
  Swirling air effect

Target Audience
Age - teen through adult
Sex - male or female
Occupation - any
Interests - music, art

Implementation Strategy
- Research and evaluate different methods and artistic styles of sound visualization
- Develop storyboards and create concept artwork
- Gather feedback, evaluate and make adjustments
- Create model of pipe organ using Maya
- Model surrounding environment
- Create visualization of sound movement using particles and dynamics
- Keyframe transformations and dynamic effects to create animation
- Apply textures to objects in the scene
- Add lighting to the scene
- Render animation from varying camera angles
- Composite animation in After Effects
- Show to others and obtain feedback
- Analyze feedback and make improvements to final project
Dissemination

Upload animation to video sharing web sites - YouTube, Vimeo
Share project on social networking sites - Facebook, Twitter
Submit project to computer graphics competitions
  SIGGRAPH 2011 Student Competition and Exhibition
  Computer Graphics Student Awards 2011

Evaluation Plan

Develop a questionnaire to obtain both qualitative and quantitative feedback from others
Show project to other students, friends, and family, and ask them to share opinions and complete questionnaire
Analyze feedback and implement changes to improve project

Expenses

Purchasing royalty-free music for project  $50
Printing cost for promotional materials  $50
Printing cost for documentation  $50
Entrance fee for competitions  $80
Cost of DVDs for competition entry  $10