School of Design & Art
Department of Design

Using generative techniques to visualize music in a meaningful way

Helen Kwok

This Dissertation is presented for the Degree of
Bachelor of Arts (Design) (Honours)
of
Curtin University of Technology

November 2010

Declaration

This Dissertation contains no material which has been accepted for the award of any other degree or diploma in any university.

To the best of my knowledge and belief this Dissertation contains no material previously published by any other person except where due acknowledgement has been made.

Signature: ________________
Helen Kwok

Date: / /

helen@helenkwok.net

Abstract

The concept of visualizing music is nothing new. Over the past century, artists had strived to create artworks that attain the nonrepresentational aspects of music through the use of different media and techniques. Furthermore, technology had also brought about a change in the accessibility of visual music – from the high art gallery setting to the everyday music visualizer. However, this venture into digital media had seen a shift in the artist's focus from the perceptual-emotional impact of visual music to the search for algorithms to translate sound into images. Digitally generated music visualizations lacked the 'wonderfully evocative metaphor' often found in past visual music works. The aim of this project was to explore the different ways music can be visualized using generative techniques, while still retaining the meaning of the music to the viewer. Using mixed methods as a strategy, this study first provided a visual and documentary analysis into the works of past visual music artists; the findings from this analysis were then used to form the hypotheses in a series of pre-experiments to test whether the theories established by these artists could be applied in a generative context. The research into each phase was broken down into five musical modules: Pitch, Timbre, Form & Structure, Harmony and Dynamics. The results showed that generative techniques can be used to create meaningful music visualizations; however, the process to make this happen can range from simple to complex, depending on the musical characteristic in question.

Acknowledgements

In completing this Honours research project, there are many people to whom I am immensely grateful. A big thank you to:

Gonni Bruekers, my supervisor in the first half of Semester One; she encouraged me to take risks with my project and to strive for something I didn't think I could do.

Jeff Alcroft, my other supervisor for the remaining of the year; he stepped in to help out when Gonni left on sick leave, and helped me realize my project.

All the Art and Design Honours staff at Curtin University, including Annette Seeman, John Teschendorff, Alana McVeigh, Ric Spencer, Trigg Craig, Stephanie Hampson and many more, for getting this new course together and to continually endow us with research knowledge and skills.

My fellow Honours classmates of 2010, who stuck with me during this tough time of adapting to a new Honours course; we survived the year through each other's encouragement and advice.

And last but not least my family, and in particular my Mum, who supported me the whole way through. She brightened my day when things looked bleak, showered me with love and care when I was sick, and just stayed by my side when I most needed her.

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Chapter 1: Introduction

1.1 The Problem

The concept of visualizing music is nothing new. Over the past century, artists had strived to create artworks that attain the nonrepresentational aspects of music through the use of different media and techniques, including abstract paintings, light projections, experimental films, computer animations and multimedia installations. Furthermore, technology had also brought about a change in the accessibility of visual music – from high art gallery settings, to performance venues available to the general public, and eventually to the desktop computer where everyone can experience music visualizations through the use of an everyday music visualizer.

However, this venture into digital and electronic media had seen a shift in the artist's focus from the perceptual-emotional impact of visual music to the search for algorithms to physically translate sound into images (Campen 1999). In comparison to the psychologically oriented works of Scriabin or Kandinsky, digitally generated music visualizations lacked the 'wonderfully evocative metaphor' often found in past visual music works (Strick 2005, 20). As Dawes (2007) argued, these sound-and-light displays created by today's media players do not communicate the music or the artist in any way, shape or form.

As we consume music increasingly through digital channels (IFPI 2010), this lack of meaning in music visualizations is ever more apparent; this is because the visual side of music also becomes increasingly available to the user through portable devices. Furthermore, with the individual track reassuming its importance through online downloads (Sexton 2009), it would be a more cost-effective solution if the artist, designer or composer could automatically generate *meaningful* music visualizations for each song.

Although various prototypes had been developed by researchers to generate something more than what the average media player could do, very few had adopted the theories of past visual music artists to generate a more meaningful visualization. Therefore, I had decided to explore this gap in the area of music visualization, and to find out if it is still possible to generate *meaningful* visualizations that were based on the work of these artists.

1.2 Aim & Scope

The aim of this project was to explore the different ways music can be visualized, and how this can be applied in a generative context to create music visualizations that enhance the meaning of the music to the viewer.

Starting with a literature review of the histories and technologies of visual music, this background research helped design the framework of my research project. Using sequential mixed methods as my strategy of inquiry, I split my research into two phases: first, to analyze the theories and meanings found in past visual music works; and second, to investigate whether these theories and meanings could be applied to music visualizations using generative techniques. It is through the qualitative findings found in the first phase which helped me better understand how I could implement and test these theories in the second phase of my research.

As the focus of the project was on visualizing the abstract quality of music, I had limited the scope of my project to mainly abstract and non-representational works. As a result, research areas such as music videos and motion graphics with representational graphics were not covered in the scope of this investigation.

1.3 Dissertation Overview

To achieve the above aim, I started off with a general historical overview of visual music in Chapter 2. The chapter will provide some definitions of the terminology used and take a brief look at the history of visual music in order to place my own work in context. I continued with my background research in Chapter 3, where I reviewed some of the current technologies being used to analyze and visualize music. Chapter 4 outlines the whole framework of my research design, including my strategy of inquiry and research methods. Chapter 5 describes the first phase of my research, where I conducted a visual and documentary analysis into the works of past visual music artists; while Chapter 6 outlines the second phase of my research, an experimental phase where I split my work into five modules based on the musical qualities under investigation. The design process, results and evaluation of each experiment are discussed in this chapter. Finally, conclusions and future considerations will be drawn in Chapter 7.

Chapter 2: History of Visual Music

2.1 Definitions

There are often misconceptions between the key terms that are used in my research field. Before I start to delve into my research, I would like to clarify the different terms used in this dissertation, and what I mean when I use them.

2.1.1 Music Visualization vs. Visual Music

"Music visualization" and "visual music" are sometimes used interchangeably in the literature on visual arts and music, and this was a cause of confusion during the initial stages of my project. Upon more research into the different terminology, I had found that "music visualization" is a more specific term used to refer to the animated imagery generated by media player software based on a piece of recorded music (*Music visualization* 2010):

> *The imagery is usually generated and rendered in real time and synchronized with the music as it is played. Visualization techniques range from simple ones (e.g., a simulation of an oscilloscope display) to elaborate ones, which often include a plurality of composited effects. The changes in the music's loudness and frequency spectrum are among the properties used as input to the visualization.*

On the other hand, "visual music" is a broader term used to refer to the application of musical structures in visual imagery (*Visual music* 2010). This could include paintings, light art, films and animations. "Music visualizations" can be considered under the "visual music" umbrella. My experimental modules were *music visualizations* that incorporated the theories and practices of *visual music* artists.

2.1.2 Synesthesia vs. Metaphorical Associations

"Synesthesia" is also a term which is often incorrectly or overused in visual music literature. Many art historians who had written about the interrelationships of music and art had appropriated the term "synesthesia" as a label for these connections, but what they actually meant was "metaphorical associations" (Berman 1999).

Synesthesia can be defined as: 'the involuntary physical experience of a cross-modal association' (Cytwoic 1995). It is very different to the musical analogies, sound symbolism and metaphorical associations employed by the majority of visual music artists. True synesthetes may involuntarily experience colors flashing before their eyes upon hearing music, and these synesthetic perceptions are usually consistent and unique to the individual. I am not synesthetic, so my music visualizations were based on my own *metaphorical associations* and those of the artists under investigation.

2.1.3 Generative Art & Techniques

The nature of my experimental modules could be considered a type of generative art. Galanter (2003) gives a succinct definition of the term:

> *Generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art.*

Essentially, I had used the generative techniques as outlined in the above definition to create my music visualizations. The visualizations I created were based on a set of code I'd written in a computer program, which would generate the whole visualization from beginning to end once I ran the code.

2.2 Background Context

In order to place my work in the context of visual music, I had to first review the history of this topic. Over the years, music had inspired many artists to push the boundaries of traditional media to more effectively emulate musical forms in their artworks. Artists embraced technology to transcend from static paintings to light projections, experimental films to computer animations; and finally to the contemporary multimedia installations so common today.

2.2.1 Abstract Paintings

The idea of musical analogy in painting originated in the late nineteenth century; however, it was not until the early twentieth century when European and American artists began to "compose" abstract paintings inspired by music where musical paintings reached their full potential (Brougher et al. 2005). These artists were particularly drawn to mysticism and based their work on metaphysical aspirations (Berman 1999). Conversely, a group of international artists in Paris strived for a more rationalized approach to musical representation in painting; this involved a combination of modern physics wave theory, and laws of color and musical harmony (Zilczer 2005). However, painting fell short in one important aspect: music is a time-based medium. As Strick (2005) discussed, a complex painted composition is more similar to a single musical chord than it is to a musical composition. It is therefore no surprise when visual music artists turned to light projection and abstract film in order to further their aspirations.

2.2.2 Light Projections

Light art, also known as “color music”, evolved as a result of artists trying to create visual music that incorporated the dimension of time. Instruments were developed to allow projected light to be “played” in conjunction with recorded and performed music. These included Louis-Bertrand Castel’s color harpsichord, Alexander Wallace Rimington’s color organ, Alexander Scriabin’s *Chromola* and Thomas Wilfred’s *Clavilux* (Peacock 1988).

2.2.3 Experimental Films

Experimental film was anticipated by the experiments of color organs and developed as a direct response to abstract painting’s shortcomings (Brougher et al. 2005). Through film, artists could elaborate sequences of geometric forms spatially and temporally. Fluid movements, rhythmic schemes, repetitive motifs and shape transformations were now all available to the abstract filmmaker.

2.2.4 Computer Animations

In paintings, light art and films, music and visual art were treated as separate but related entities; it was the role of the artist to bring together the two for the audience. But with the advent of digital media, sound and image could at last be united as they are created by the exact same bits of electronic information (Strick 2005). A new type of electronic visual music had emerged through computer animations, where images and sound were so inextricably linked that ‘one is not a result of the other; rather, sound is image, and image sound’ (Brougher 2005, 125). The Whitney brothers were at the forefront in experimenting with the simultaneous composition of sound and image via electronic devices.

2.2.5 Contemporary Installations

With the development of computer technology, hardware and software could now be used to create a mixture of real-time controllers that enabled live performances of visual music (McDonnell 2007). Multimedia installations and performances provided a new dimension to the visual music experience, breaking free from the fixed, frontal view of paintings and film (Wiseman 2005). Space could be utilized to envelope and immerse the viewer and to give an overall richer experience.

2.3 Contemporary Context

2.3.1 Current Issues

So what are the current issues in the field of visual music today? As technology advanced, artists started exploring the “physics” of visual music, delving into electronics and computer programming to create digital devices that simulated visual music (Campen 1999). The change in this production of visual music meant we could now use the everyday media player, such as Windows Media Player, iTunes or Winamp, to visualize music.

But this endeavor into digital media as a medium saw a shift in the artist's focus. Instead of striving to create a psychologically impactful piece of work as seen through abstract paintings, light art and films, artists experimented with the physical or electronic translation of sound into images through digital devices (Campen 1999). As Dawes (2007, 146) explained, these sound-and-light displays churned out of today's media players 'don't really communicate the music or the artist in any way, shape or form'.

2.3.2 Significance of the Problem

This lack of meaning in music visualizations poses a significant problem in today's digital era. The growth of mp3 as a popular music format had revolutionized the way we produced, distributed and consumed music. In 2009 globally for the first time, more than one quarter of record companies' revenues came from digital channels (IFPI 2010). This had meant consumers are increasingly buying digital music through download stores and services. The convergence of music services also meant it was easier to transfer and use music across multiple screens and platforms. As a result, there was also an increase in the use of digital portable devices, like the iPod and iPhone, where the visual side of music is also available to the user (Sexton 2009). The rise in digital music had brought about an increase in the importance of the music video.

Sexton (2009, 97) also argued that the 'individual single, as opposed to the long-playing "album", reassumes importance' as online downloads are sold in the form of individual tracks. Rather than having record companies design a visual representation of the music for each track, it would be a more *cost-effective* solution if the artist, designer or composer could design and automatically generate *meaningful* music visualizations for each of these songs.

2.3.3 Own Work in Context

Therefore, what I hoped to do for my research project was to test whether I could take the theories, meaning systems and techniques developed by past visual music artists and place them into a digital context. Was it technically feasible to digitally generate a music visualization via code, yet still retaining those meaningful and innovative approaches of past artists in the visualization? To explore this question further, I had to first review some of the current technologies in the field of music visualization.

Chapter 3: Current Technologies

3.1 Content-based Music Analysis Research

In order to investigate what kind of technologies could be used to generate more meaningful visualizations compared to the average media player, I had to first understand the complexity of music. As Downie (2004, 15) described, music information is ‘a multifaceted amalgam of pitch, tempo, rhythmic, harmonic, timbral, textual..., editorial, praxis, and bibliographic elements’. These elements seem to be lacking in the visualizations generated by current media players, which analyze the music based on its raw sound data.

This led me to the field of content-based music analysis. It is a process of analyzing and extracting music content beyond just its basic sound data, like amplitude and frequency. This is a growing area of research especially in the field of music information retrieval, where researchers are looking into systems that retrieve music based on musical concepts such as pitch and rhythmic information (Downie 2004).

There are three categories to content-based music analysis based on the degree of semantic meaning derived from analysis (Brandenburg et al. 2009):

- Low-level audio features, which are extracted from audio signals via basic signal processing operations;
- Mid-level audio features, which combines signal processing techniques with a priori musical knowledge; and
- High-level music features, which carry a high degree of semantic information so that even the human listener can understand their meaning. They bear close relations to musical vocabulary such as rhythm, harmony, melody, etc.

Borrowing this term from Brandenburg et al. (2009), I believed that if visualizations could be generated based on these ‘high-level music features’, it would result in a more meaningful visualization.

3.2 More Meaningful Music Analyzers

3.2.1 Research Prototypes

A number of music visualizers had been developed by researchers who wanted to create something more than just the average media player. These are the visualizers that dealt with high-level music features or musical characteristics like volume, pitch, melody, instruments, tempo, etc. However, there are only a few which had drawn from the theories and practices of past visual music artists and applied them in a generative context. These include the work of Bill Alves (2005), who worked with John Whitney on developing composition software based on Whitney's differential dynamics, and Lynn Pocock-Williams (1992), who used rule-system technology to automatically generate visual music inspired by key artists based on the music's pitch and duration.

Other attempts in developing visual music software had been documented in journals like the *Leonardo*, *Leonardo Music Journal* and the *Computer Music Journal*. Some examples include: TEMPER, a prototypical system for music synthesis from animated tessellations (Haus and Morini 1992); Sound Mosaics, a prototype graphical user interface for sound synthesis based on a set of sensory auditory-visual mappings (Giannakis 2006); and Jitter, a commercial software package first made available in 2002 by Cycling '74 to create music and multimedia (Jones and Nevile 2005). As technology advanced, researchers and programmers had greater flexibility in developing the "perfect" image-sound synthesis software.

The following list of software is by no means complete in covering the area of music visualization technologies. I had come to know about them as a result of my research into this area, and other artists/designers mentioning the use of them for visualizing music. They had been listed in detail mainly because I had access to these programs free of charge via the Web, and also because I had the chance to personally interact with each of them.

3.2.2 MP3-based Music Analyzers

3.2.2.1 Processing

Processing is an open-source programming language used by artists and designers to program images, animations and interactivity. It targets computer-savvy individuals who are interested in creating works through writing software, but have little or no prior experience in coding (Reas and Fry 2007). Numerous contemporary visual music artists have used *Processing* to create their artworks due to the program's flexibility. Additional sound libraries will have to be added in order to analyze sound input real time.

Although *Processing* allows for great customization of the visual imagery to be generated in the music visualization, its analysis of music is based on general sound spectral analysis such as amplitude and frequency data.

3.2.2.2 Echo Nest

Echo Nest is an application which analyzes songs and outputs an XML 'musical score for computers'. It takes an MP3 file as input, and generates an XML file which describes the track's structure and musical content (including rhythm, pitch and timbre) (The Echo Nest Corporation 2010). However, a good knowledge in programming such as Python is needed to use it effectively, and artists/designers who have no programming background may find the application hard to use.

3.2.3 MIDI-based Music Analyzers

3.2.3.1 Music Animation Machine

The *Music Animation Machine* is a very "resolved" program in terms of visualizing the many qualities of music real-time. It was created by Stephen Malinowski and developed from a "scrolling score project". The program deals with only MIDI files and displays a musical score on a black background. Information about the music's structure is conveyed with bars of color representing the notes. Their position on the screen indicates their pitch and their timing in relation to each other. Different colors denote different instruments, voices, thematic material, or tonality (Malinowski n.d.).

The software is extremely easy to use, but offers little customization of own imagery although there are preset visualizations schemes available. The acceptance of MIDI files as the sole input is one of the main limitations of the program, as MIDI music detracts the musical experience from the viewer (the musical sounds in a MIDI file are electronically generated by the computer, and therefore lacks the luscious sounds of real instruments).

Chapter 4: Research Design

4.1 Mini Experimental Modules

My background research into the history and technologies of visual music had shown that there was a need to explore the area of music visualization based on high-level music features, the same musical features which past visual music artists had also focused on in their work. These are the features which I believe would add meaning to generative music visualizations.

Therefore, I had opted to break down my research project into small experimental modules, with each module focusing on one musical quality at a time. The modules were:

- Pitch
- Timbre
- Form & Structure
- Harmony
- Dynamics

In each module, I would first investigate the theories of past visual music artists who had based their work on that particular musical quality; this *first* phase would look at how music can be visualized in a meaningful way. I would then follow that up with a mini experiment to test these theories in practice. This *second* phase would test whether I could replicate my findings from the first phase using generative techniques. The combination of the two phases would help answer my research question. As a result of this two-phased approach, I had chosen mixed methods as my strategy of inquiry.

4.2 Mixed Methods Strategy

Mixed methods research is a strategy of inquiry that combines or associates both qualitative and quantitative forms (Creswell 2009). The purpose for mixing is for the researcher to better understand the research problem by using one approach to explain or build on the results from another approach. Mixed method designs are usually used because one method alone will not prove a comprehensive answer to the research question (Richards and Morse 2007).

As Creswell (2009) explained, there are many different types of mixed methods strategies for the researcher to choose from, and the one that I had chosen is **sequential exploratory design**. This strategy of inquiry involves a first phase of *qualitative* data collection and analysis, followed by a second phase of *quantitative* data collection and analysis that builds on the results of the first phase. The overall weight or priority is placed on the *qualitative* phase.

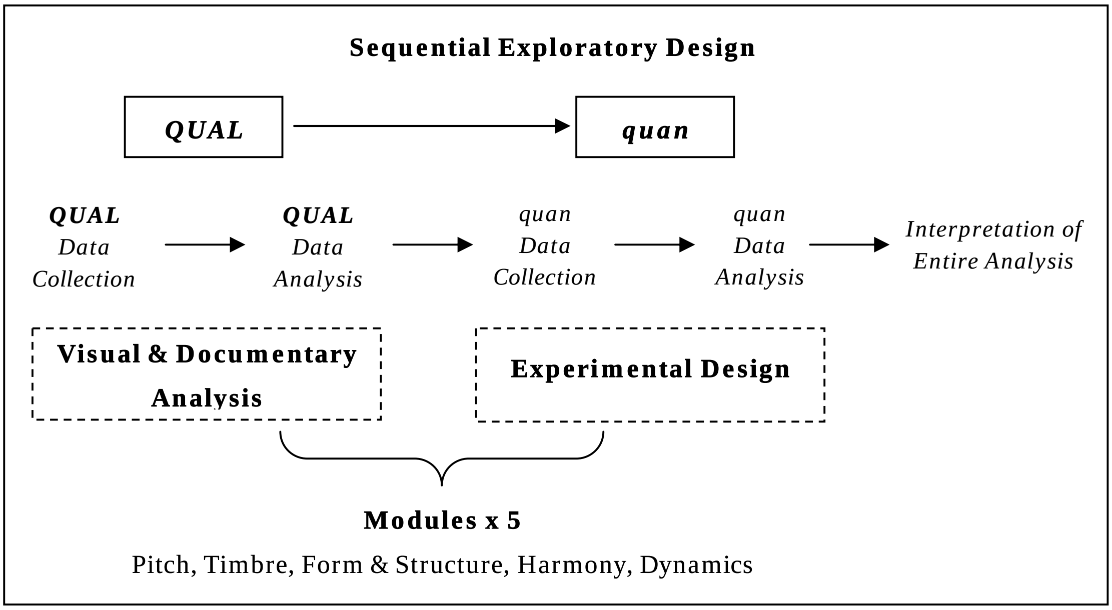

Figure 4.1: Sequential Exploratory Design: A visual model showing how sequential exploratory design is incorporated into this study (Creswell et al. 2003, 225)

Sequential exploratory design is a useful strategy for researchers to explore a phenomenon while also expanding on their qualitative findings through the use of quantitative methods. Likewise for my research project, I would first need to explore the phenomenon of visualizing music through a detailed analysis of past visual music artists' works (**Visual & Documentary Analysis**). It is through these qualitative findings which would help me better understand and define the hypotheses of my experiments (**Experimental Design**).

One of the challenges in using this research design was the substantial length of time required to complete both phases. Therefore, effective time management was essential. I had tried to make this project easier to handle by breaking it down into five modules. As I would be focusing on one musical quality at a time, this would make both qualitative and quantitative phases easier and quicker to complete.

Although my research involved both qualitative and quantitative phases, my project was still a qualitatively driven project. Consequently, I had approached this study through an **interpretive** worldview or paradigm. Interpretations were shaped by my own perceptions, backgrounds and prior understandings. Sites, individuals, documents or visual material for the project were *purposefully selected* to best help me understand the research problem. This purposeful sampling of individuals allowed me to select only those that had experienced the central phenomenon – the visualization of music – and had made subjective meanings of their experiences. The main focus of the research was on the participants' views of the situation being studied (Mackenzie and Knipe 2006).

4.3 Visual & Documentary Analysis

In the first phase of my research, I conducted a visual and documentary analysis of works created by past visual music artists. I had purposefully chosen specific documents and artworks which suited each of my modules. The rationale for this analysis was to explore and understand the meanings these individuals had made from their experiences of music and how their subjective meanings were negotiated socially and historically due to the context or setting of the artists. The outcome of this phase was a set of general themes or patterns which could be used as a testing system for my experiments.

4.3.1 Identification of Sources

Creswell (2009) and Denscombe (2003) listed some of the different types of documents and audio-visual materials that could be examined. Documents could include public documents such as books, journals, reports, websites, autobiographies, biographies, newspapers, magazines, records, archival material, government publications and official statistics; they could also be private documents such as diaries, letters and memos. While some examples of audio-visual materials could include photographs, videotapes, art objects, computer software, film, sound and music.

The main advantages of visual and documentary analysis are its unobtrusive method of collecting data, and for the participants to directly share their reality through their writings and artwork. However, a major drawback to this research method is the potential for incomplete, unauthentic or inaccurate materials. Therefore, after the identification of my visual and documentary sources for each of my modules, it was important for me to thoroughly evaluate them.

4.3.2 Evaluation of Sources

As Denscombe (2003, 220) described, good documentary research can use four basic criteria to evaluate documents: authenticity, credibility, representativeness and meaning.

Authenticity is used to assess whether a source is genuine or fake. *Credibility* is used to evaluate the accuracy of the source and whether it is free from bias and errors. This will depend on factors such as the purpose, author and date of the source, whether it was a first hand account, and in what social context and climate were the source produced. *Representativeness* looks at how the source fits in with similar sources, and whether it is completed, edited or extracted 'in context'. Finally, *meaning* is used to review the clarity and ambiguity of the meaning the author is trying to convey.

4.3.3 Analysis of Sources

After evaluation, the documents and audio-visual material could then be analyzed for any common themes or perspectives. The general procedure in qualitative data analysis is to start off with the raw data, review it, make sense of it and organize it into patterns, categories or themes (Creswell 2009). The researcher's own backgrounds would influence their analysis and interpretation of the data.

For each module, I examined a variety of documents and images of artworks in order to draw out the emergent themes and theories that these visual music artists had established in their works. Why are the components of the image arranged this way? What are the relationships between these components? What do the different components signify? Why are certain colors used? These were some of the questions that were asked in the analysis of the works. A full list of questions that could be used to examine visual images was developed by Gillian Rose (2007, 258) in her book *Visual Methodologies*.

Rose (2007) emphasized on the need for a critical visual methodology when interpreting visual materials. She outlined three sites which meanings of an image could be made: site(s) of the *production* of an image, site of the *image* itself, and site(s) where it is seen by various *audiences*. Within each of these sites, there are also three modalities to look at: technological, compositional and social. Different research methods would focus on different sites and modalities for analysis.

The research method which I had chosen to analyse the images collected was **compositional interpretation**. This method focuses on the site of the image, and places most attention on its compositional modality, i.e. looking at the image's content, color (hue, saturation and value), spatial organization, light and expressive content. It also looks at the technological modality in the site of production to investigate the type of materials and techniques used to make the image (Rose 2007). The reason why I had chosen this method was because it provided a detailed vocabulary for expressing the appearance of an image. It was a useful way of looking very carefully at the content, form and visual impact of images, and thus allowed me to analyse the themes and patterns that emerged from the visual material, which I could then use for my experiments.

4.4 Experimental Design

The findings from the visual and documentary analysis were then used to mark out the parameters of each of my experimental modules. The purpose of these experiments was to test whether the systems established by these visual music artists and designers could be generated autonomously via code, and whether they could effectively convey the meaning of the music to the viewer when put in practice. Each module resulted in a music visualization based around the musical quality for that module. The results of each module were then compared, analyzed and discussed.

4.4.1 Experiment Type

The purpose of experimental design is 'to test the impact of a treatment (or an intervention) on an outcome, controlling for all other factors that might influence that outcome' (Creswell 2009, 146). In the case of my research project, each experimental module was designed to be tested for its effectiveness in conveying the meaning of the music to the viewer, based on its assigned musical quality and the visual systems established by past artists.

However, I must emphasize that these experimental modules were based *loosely* on the structure of experimental design; they were not true experiments. Due to time limitations and other resource factors, there were no random selection of participants, no random assignment, no pretest, and no control group. Each module simply consisted of an intervention (adjusting the parameters in the code to create the music visualization), followed by an observation of the results. The type of experimental design these modules belonged to were in fact **pre-experimental designs** (Riddick and Russell 2008).

Pre-experiments can be thought of as the simplest form of experimental research design. In a pre-experiment, either a single group or multiple groups are observed subsequent to some treatment presumed to cause change (Research Connections n.d.). They act like pilot studies conducted before a full-scale experiment is carried out in order to check the feasibility of hypotheses and potential for further investigation. As exploratory approaches, pre-experiments are a cost-effective solution. However, any conclusions reached from this type of design should be viewed as suggestive at best (Abrahams, n.d.).

Here is a diagram to illustrate the specific pre-experimental design used, based on the classic notation system provided by Campbell and Stanley (1963):

Alternative Treatment Post-Test-Only with Nonequivalent Groups

Group A	X1 -------------- O	(Pitch Module)
Group B	X2 -------------- O	(Timbre Module)
Group C	X3 -------------- O	(Form & Structure Module)
Group D	X4 -------------- O	(Harmony Module)
Group E	X5 -------------- O	(Dynamics Module)

Figure 4.2: Alternative Treatment Post-Test-Only with Nonequivalent Groups (Creswell 2009, 160)

What this diagram illustrates is the way I had structured my experimental modules. X represents the intervention I had made when altering the code for each module to generate the music visualization based on the module's musical quality. O represents an observation or measurement recorded after the visualization. The separation of parallel rows by a horizontal line indicates that comparison groups are not equal by random assignment (Creswell 2009). So in other words, the music used for each module is not the same, and had been purposefully chosen to best highlight the assigned musical quality.

4.4.2 Participants

The participants for my experiments were the musical pieces I had chosen for each module. The selection was *nonrandom* and based on my own knowledge of classical musical pieces. Since different pieces might highlight a musical quality more than others, I had chosen ones which best suited the module under investigation.

4.4.3 Variables

The independent variable in this experimental design was the musical quality (Pitch, Timbre, Form & Structure, Harmony and Dynamics) assigned to each module. Music visualizations were generated based on this independent variable. While the dependent variables were: firstly, the ease in generating the music visualizations; and secondly, the effectiveness in conveying the meaning of the musical piece to the viewer.

4.4.4 Possible Software for Experimentation

As shown in Chapter 3, there are various music visualization software programs available, but very few that analyze music based on high-level audio features, and also allow for full customization of imagery and sound data. As a result, I had to resort to using a combination of software packages in order to conduct my experiments. They had been chosen for their ease of use, availability in my research environment, accessibility to a wider audience, and whether I had prior knowledge and skills in using these programs.

4.4.4.1 Adobe Flash

Adobe Flash is an application for developing rich content, user interfaces, and web applications. The *Adobe Flash Player* is installed on 99% of Internet-enabled desktops worldwide and on a wide range of popular devices (Adobe Systems Incorporated 2010). *ActionScript* is the scripting language used in *Flash* to make applications play in a nonlinear way. It adds complex functionality that cannot be represented in the timeline.

Adobe Flash was my main tool in developing each of the modules. Through *ActionScript*, I was able to generate and customize the movie clips I had designed for each module in terms of the timing and randomization of insertion, location, color, scale, opacity, movement, rotation and so on.

4.4.4.2 Adobe After Effects

In order to generate my music visualization, I needed the sound data of the music files as data arrays which I could copy into *ActionScript* in *Flash*. To do this, I used *Adobe After Effects*'s Keyframe Assistant to convert the audio of the mp3 file into keyframes. I then exported the amplitude data from these keyframes into a text array, which I could then use in *Flash* for scripting. This technique was adopted from Lee Brimelow's (2008) tutorial on sound driven animations.

4.4.4.3 MIDI Analyzer

However, amplitude data alone was not sufficient in generating more complex music visualizations such as ones based on Pitch or Harmony. This meant I needed another program which could analyze and output exact musical pitches. As melody extraction in polyphonic audio is still a developing area of research (Paiva, Mendes, and Cardoso 2006), and the lack of access to software which could analyze for pitch meant I had to resort to the use of a combination of MIDI and mp3 files for analysis.

MIDI is a representation of 'different categories of musical *events* (notes, continuous changes, tempo and synchronization information) as abstract numerical values' (DuBois 2007, 589). This meant exact pitches of each musical note can be extracted from MIDI files. *MIDI Analyzer* is a freeware which gives a detailed analysis of any standard MIDI file in a readable format (Sirulnikoff 2009). I had used *MIDI Analyzer* to extract the musical pitches in MIDI files into a data array for use in *Flash*.

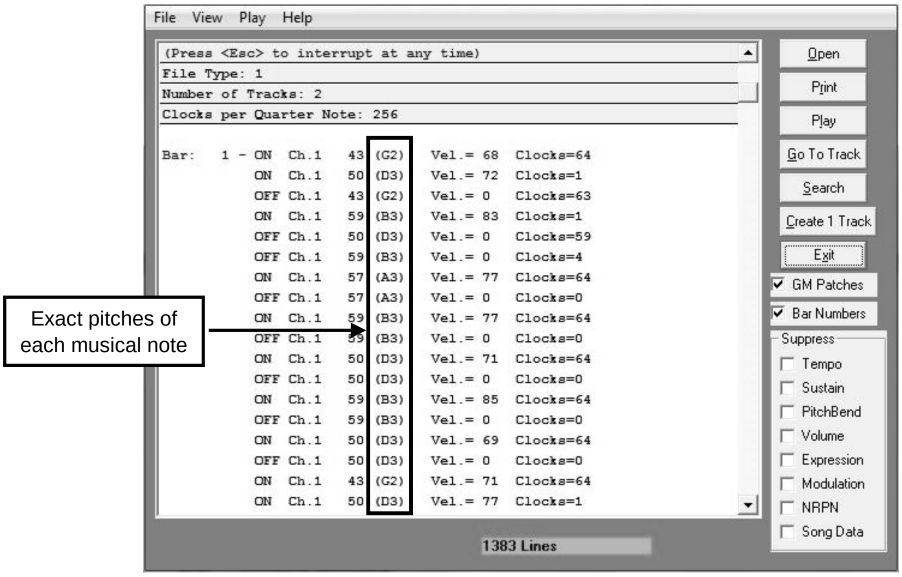

Figure 4.3: *MIDI Analyzer II* screenshot: Analyzing Bach's *Prelude*

4.4.4.4 Reason & Soundtrack Pro

The final two programs needed to generate these music visualizations were *Reason* and *Soundtrack Pro*. *Reason* is a music software program which allows me to import MIDI files and separate each instrumental track for export. This way, I could analyze the amplitude of each instrument when dealing with musical pieces that had multiple instruments or voices. While *Soundtrack Pro* is an audio editing application which I had used to synchronize the outputs from the MIDI file with the mp3 file.

4.4.5 The Procedure

As shown in the flowchart below, a complex procedure is needed to generate the music visualizations for each module. Starting with an mp3 file (and an optional MIDI file) as input, the audio is converted into numerous data formats before it is output as a Flash-generated music visualization.

Flowchart legend:

- Rectangles are used to denote *software*:
- Multidocument symbols are used to signify *data*:
- Arrows indicate *data flow*:

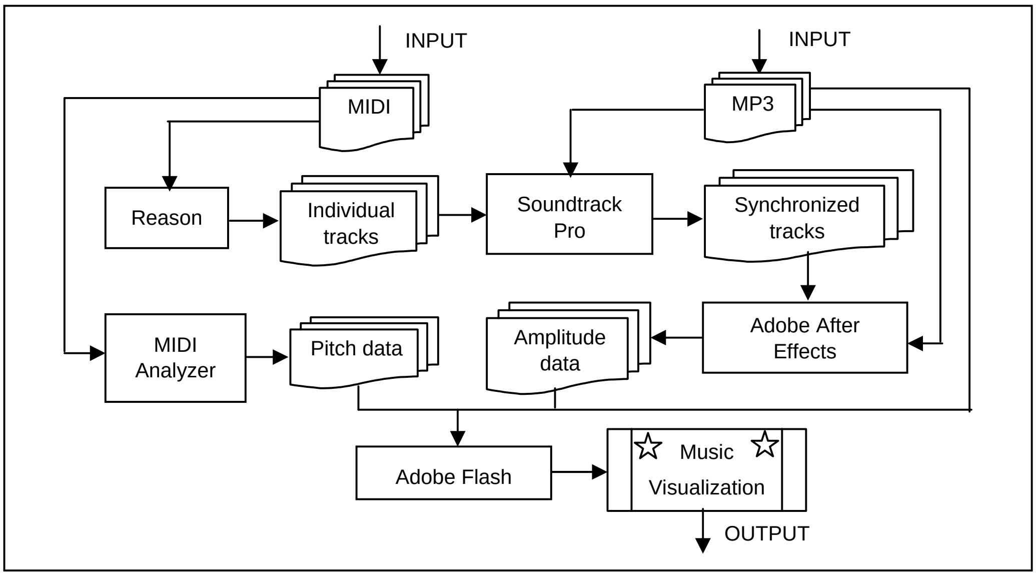

Figure 4.4: The Experimental Procedure for Each Module

4.4.6 Data Analysis & Interpretation

After completing each of the experimental modules, I would evaluate the music visualizations based on the dependent variables under investigation. The variables are: the ease in generating the music visualizations, and the effectiveness in conveying the meaning of the musical piece to the viewer. These interpretations were contingent upon my own musical background and personal connection to the music. Was the music visualization more meaningful due to its assigned musical quality and visual music system? What could be improved and altered if I could repeat the module again?

4.4.7 Final CD Package

The music visualizations generated from the five musical modules have been put together into an interactive Flash CD package. The CD can be played on any computer (PC or Mac) for private home use only.

Chapter 5: Visual & Documentary Analysis

5.1 Fundamentals of Music

Before I describe my findings from my visual and documentary analysis, it is necessary that I clearly define the musical terminology I'll be using. The table below outlines some of the descriptions of the terms I had used in my analysis (*Music theory* 2010).

Musical Attribute	**Description**
Pitch	The lowness and highness of a sound. It is closely connected with the fundamental frequency of a musical note. The higher the frequency, the higher the perceived pitch.
Melody	A melody is a series of notes sounding in succession.
Timbre	The quality or sound of a voice or instrument.
Form & Structure	The musical genre or style of the music, e.g. fugue, canon, theme and variations, rondo, etc.
Harmony	The relationships between pitches that occur together; usually this means at the same time, although harmony can also be implied by a melody that outlines a harmonic structure.
Consonance & Dissonance	Consonance can be roughly defined as harmonies whose tones complement each other and are more "pleasant" sounding, while dissonance is the quality of sounds that sound "unstable" and more "unpleasant".
Dynamics	The softness or loudness of a sound or note.
Texture	The overall sound of a piece of music depending on the number of instruments used, e.g. polyphonic – multiple independent melodies.
Rhythm	The arrangement of sounds and silence in time. It is closely connected with the time signature and beats of a musical piece.
Scales & Modes	Closely related to the key of a musical piece.

Table 5.1: Musical Attribute Descriptions

5.2 Pitch

Attempts to associate color with pitch could be dated back to the classical Greece period, where people like Pythagoras tried to link color with sound based on mathematical principles (Campen 1999). This led to the development of numerous color scales over the past three centuries, with Isaac Newton being the first to invent a correspondence scheme to integrate the color harmony system to a musical harmony system. Collopy (2004) collated the numerous color scales adopted by artists, scientists and musicians over the years into the chart below:

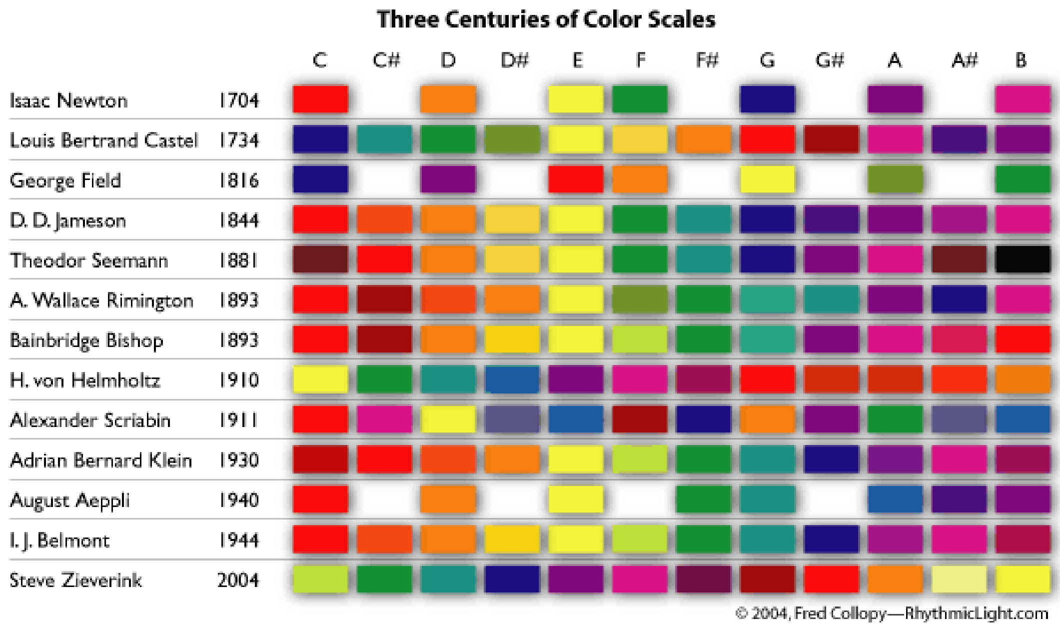

Figure 5.1: Three Centuries of Color Scales

Fred Collopy, a designer, scientist and researcher, created an extensive online resource on visual music at *RhythmicLight.com* that included texts, timelines, biographies and an annotated bibliography. However, Collopy believed there were many problems with the proposed mapping of pitch to hue. In his various writings (Collopy 2000; Collopy 2004; Collopy 2009), Collopy argued that Newton's division of the visible spectrum into seven distinct colors was arbitrary, deliberately doing this to match them to the seven natural tones of the musical scale. There were also a range of physical and aesthetical limitations to tone-hue correspondences. Nevertheless, it was Newton's color scale that inspired an entire movement of color music and light art.

Many painters were also heavily influenced by the use of color scales in their works. One such example was Roy De Maistre, a musician turned painter who devised a system of color-music codes based on Newton's theories of color and the correlation of colors to the seven pitches of the musical scale (McDonnell 2007). He used these color codes to compose his paintings, such as his *Rhythmic Composition in Yellow Green Minor* (1919):

Figure 5.2: Roy De Maistre, *Rhythmic Composition in Yellow Green Minor*, 1919. (Hutchison 2009)

However, unlike Newton, De Maistre moved the colors on the scale three semitones down so that his color-music code started at A. The seven musical notes (A, B, C, D, E, F and G) were now assigned the colors red, orange, yellow, green, blue, indigo and violet. As a result, we might expect the range of colors in a scale of yellow green minor to be like so:

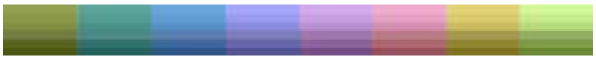

Figure 5.3: De Maistre's color-music code in C sharp/D flat minor (Hutchison 2009)

Another painter, Frantisek Kupka, also paid homage to Newton's color wheel in his music-inspired paintings:

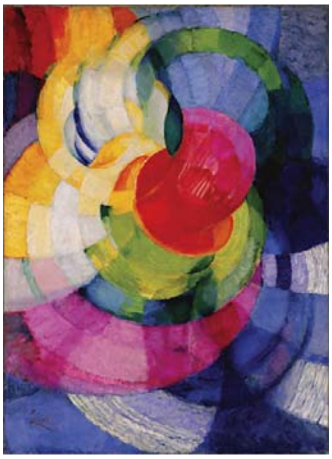

Figure 5.4: Frantisek Kupka, *Disks of Newton (Study for "Fugue in Two Colors")*, 1912 (Zilczer 2005).

As shown in Collopy's (2004) color scale table and the various paintings studied, it seemed that there was little consistency among the numerous color scales developed, with artists creating their own color codes and mappings based on their own perceptions. However, as it was Newton's color scale which had sparked this whole new era of color-music theory, I had decided to base my Pitch module on Newton's color scale (**Section 6.1**) and test it in practice.

5.3 Timbre

Over the years, visual music artists had also been interested in how to visually depict the different timbres produced by musical instruments. One key artist in this field was Wassily Kandinsky, who studied the psychological effects of color and assigned musical timbres to them. Kandinsky wrote about these theories in his book, *Concerning the Spiritual in Art* in 1910, and the book was first published in 1912.

The original edition was in German, and was translated by Michael Sadleir into English in 1914. I was able to get access to a complete copy of Kandinsky's *Concerning the Spiritual in Art* (republished in 1947) to study in detail these color-timbre associations. This edition was a version of the Sadleir translation, however with considerable re-translation by Francis Golffing, Michael Harrison and Ferdinand Ostertag (Kandinsky 1947). It should be noted that although the book provided a genuine, first-hand account of Kandinsky's thoughts and processes through his writing, some of his original ideas may have been lost in translation.

Kandinsky was an artist and musician who passionately loved colors, and would distinguish the particular smell and musical sound of each color (Kandinsky 1947). He compared the psychological effect of color to that of resonance in music, and believed colors were able to produce "spiritual vibrations" to sensitive viewers. Kandinsky (1947, 45) expressed: 'The sound of colors is so definite that it would be hard to find anyone who would express bright yellow with bass notes, or dark lake with the treble.'

He dedicated a section of his book to the analysis of forms and colors - 'Section VI: The Language of Form and Color' - that were based on his inner experience as an abstract painter. It was in this section where he wrote about his color-timbre associations based on his own emotional connections and understandings of color and music.

For example, 'keen lemon-yellow hurts the eye as does a prolonged and shrill bugle note the ear' (Kandinsky 1947, 44). He thought absolute green was a restful color, lacking any undertone of joy, grief or passion, and therefore represented the placid, middle notes of the violin. While 'light warm red has a certain similarity to medium yellow, alike in texture and appeal, and gives a feeling of strength, vigor, determination, triumph... it is a sound of trumpets, strong, harsh and ringing' (Kandinsky 1947, 61).

A full summary of Kandinsky's color-timbre associations is listed below (1947, 44-63):

Timbre or Musical Instrument	**Color**
Bugle	
Cello	
Cello (middle tones)	
Church-bell, contralto voice or largo of an old violin	
Double bass	
Drums or great trumpet	
English horn or bassoon	
Flute	
Organ	
Trumpet	
Violin	
Violin (middle notes)	
Silence, pauses in melody	
Final pause	

Table 5.2: Kandinsky's Color-Timbre Associations

I was fascinated that some of my own color associations with timbre were very similar to Kandinsky's views, in particular the brass and woodwind instruments. I had decided to put Kandinsky's theory into practice, by testing it in my Timbre module (**Section 6.2**).

5.4 Form & Structure

One of Kandinsky's close friends at the Bauhaus was Paul Klee. Klee was heavily influenced by Bach's music, and often drew direct inspiration from the complex musical form of Bach's fugues (Webster 2007). While Kandinsky drew comparisons between color and sound, Klee looked at the relationship between structure and composition of his paintings through musical metaphor.

The work that I had focused on in my analysis was Klee's *Fugue in Red*. Klee painted this watercolor in 1921, inspired by the musical fugue. The painting was 24.5 x 37cm (Kagan 1983). Despite the image being only a reproduction of the original painting, a lot of the color and nuances were still visible.

Figure 5.5: Paul Klee, *Fugue in Red*, 1921 (Webster 2007)

In music, a fugue is 'a contrapuntal composition in two or more voices, built on a subject (theme) that is introduced at the beginning in imitation and recurs frequently in the course of the composition' (*Fugue* 2010). In simpler terms, there are various voices or instruments which would play the same musical motif over and over again throughout the musical piece.

It could be seen that Klee was trying to show the fugue's musical motif by painting a series of repeated forms, with each group of forms taking on a different shape to represent the different musical voices in the fugue. The gradual overlays and muted shades of red expressed the idea of polyphony and resonance in the fugue. These flat colored forms faded in value and enlarged in size from front-to-back, giving the feeling of left-right movement and a temporality to the painting. Through this work, Klee was able to visually show the fugal texture and continuous ebbing and flowing of energy by filling the canvas with these organic, red colored forms. The random positioning of these forms seemed to indicate the intermittent entering and exiting of the different musical voices during the fugue, much like a musical score unfolding horizontally but still displaying the vertical interrelationships between each voice.

In summary, the above analysis of *Fugue in Red* displayed several compositional techniques which I had adapted in my Form & Structure module (**Section 6.3**), in particular Klee's use of shapes, color, space and gradual overlays in his painting.

5.5 Harmony

John Whitney was a computer animation pioneer who applied musical concepts of harmony into his visual work. Whitney believed that the Pythagorean laws of harmony found in music can also operate in a graphic context, so that 'the attractive and repulsive forces of harmony's consonant/dissonant patterns [are]... matched, part for part, in a world of visual design' (Whitney 1980, 5).

Whitney's research into "visual harmony" was documented in his book, *Digital Harmony: On the Complementarity of Music and Visual Art*, published in 1980. He wrote the book as a record of how his explorations into this area of visual music had evolved as the basis for his life work. I was privileged enough to get hold of *Digital Harmony* from the library, and to read Whitney's personal and detailed account of his visual music work into harmony.

Whitney defined harmony as the 'physical fact of orderly ratio in both its horizontal and vertical [linear and simultaneous] meaning' (Whitney 1980, 5). The ratio is the mathematical relationship between two pitches, and is often called the "interval" in musical terms. All music is derived entirely of intervals of audio harmonic relationships, and they define how musical instruments should be tuned. Intervals with whole number ratios, such as octaves, fifths and fourths are usually considered more "resolved" and "pleasant-sounding".

As Whitney (1980) discussed in his "Concept" chapter, he needed a generative building block, such as an alphabet or scale, which would connect the art of harmonic structures to a visual pattern. He found the answer to his problem through computer graphics, where he had the power to generate complex visual patterns based on mathematical algorithms. Using a motion function that advanced each visual element differentially, the result was a type of visual pattern that formed and reformed like the harmonic resonance found in musical harmony.

From this, Whitney (1980, 40) was able to develop the relationship between the terms *differential*, *resonance* and *harmony*, which later on formed the guiding principles to his work:

> *First, motion becomes pattern if objects move differentially. Second, a resolution to order in patterns of motion occurs at points of resonance. And third, this resolution at resonant events, especially at whole number ratios, characterizes the differential resonant phenomena of visual harmony.*

So in other words, at points of *consonance* in music, the corresponding visual pattern should also be "resolved" so that the pattern generated is relatively simple. In contrast, *dissonant* harmonic structures in music would generate visual pattern that is more complex and chaotic. There were two major differential parameters which Whitney used to determine event patterns and had employed in his instrument: (1) **RD**, the radius differential factor; and (2) **TD** (theta), an angular differential factor.

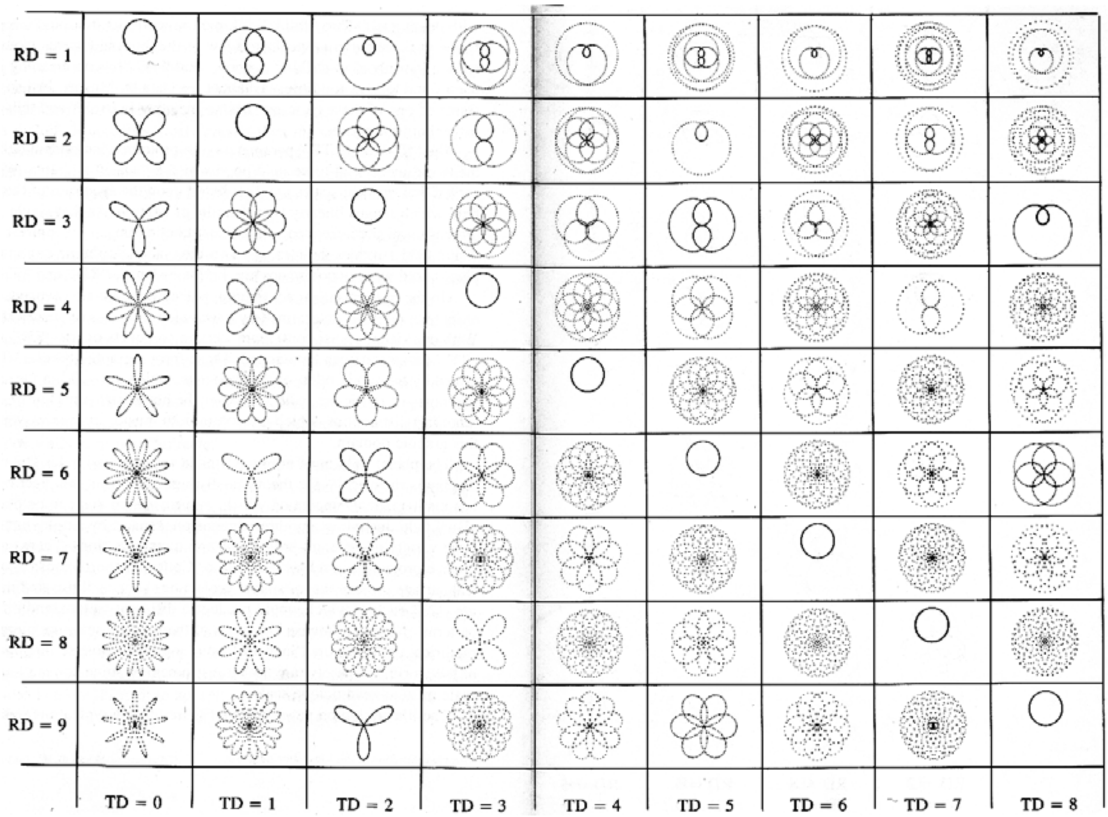

Figure 5.6: RD/TD Mappings in John Whitney's *Digital Harmony* (1980, 56-7)

Both factors control how the visual pattern is generated on the computer, such as the radius, angle of motion and X/Y coordinates. Depending on what kind of visual field they are applied to, there is a potential for great variations in patterns, such as circles, Lissajous curves, and other geometrical formations.

This documentary analysis into Whitney's work allowed me to see the potential in linking musical harmony with visual harmony. I had decided to test Whitney's digital harmony theories in my Harmony module (**Section 6.4**).

5.6 Dynamics

The visual and documentary analysis for my last module involved a shift in focus towards the psychological effects of visual music. Under investigation were the various psychological studies that had been conducted in the area of synesthesia and cross-modal association. These were used to draw out the synesthesia-like mappings between the dynamics of sound and visual dimensions.

The main document examined was Lawrence Marks' book *The Unity of the Senses*, published in 1978. Marks is a leading researcher in the field of cross-modal research, and *The Unity of the Senses* provided a detailed summary of the numerous studies he had conducted in this area. I mainly focused on analysing his chapter on 'The Doctrine of Analogous Sensory Attributes and Qualities".

He categorized his research into four sensory dimensions: extension, intensity, brightness and quality. In the first three dimensions, he associated the loudness of a sound to that domain. Marks (1978) defined "extension" as the apparent spatial magnitude of sensations; "intensity" as the apparent strength of sensations; and "brightness" as the apparent piquancy of sensations.

In the *Extension* section, Marks (1978, 53) wrote:

> *Sounds differ not just in their subjective intensity, or loudness, but also in the degree to which they appear to fill up space. Loud, low pitched sounds appear most massive and seem to fill up large volume, whereas soft, high pitched sounds appear most thin, small, and seem to take up only small volume.*

He further associated the deep, rich music from the organ as sounds which would 'encompass all the listener's subjective space'. Loud, low pitched sounds seemed to be the most voluminous. Similarly in the *Intensity* section, Marks noted that loud sounds such as 'the din of an argument' seemed more intense, while soft sounds such as 'the muted whisper' were less intense.

Finally in the *Brightness* section, associations between loudness and brightness were not as clear cut. However, Marks did mention that 'a dim light more closely resembles a whisper than a jackhammer' (Marks 1978, 62). It seemed that brightness is a factor that was closely connected with both loudness and pitch. He emphasized that loud, high pitched sounds seemed most bright. Below is a diagram which Marks (1978, 68) had drawn to show the relationships among the four perceptual dimensions of pure tones:

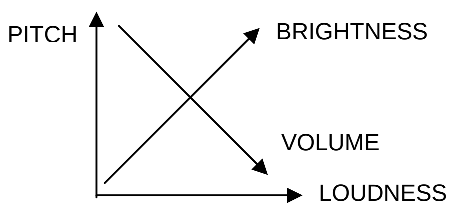

Figure 5.7: Relationships among four perceptual dimensions

Reading into Marks's studies allowed me to determine some of the visual parameters that could be used to relate to the dynamics of music. This will be further discussed in **Section 6.5** in my Dynamics Module.

Chapter 6: Experiment Results & Discussion

6.1 Pitch Module

The aim of this module was to test whether Newton's color scale (as analyzed in **Section 5.2**) could be applied to a music visualization generated by *ActionScript* in *Flash*. My hypothesis was that by assigning specific colors to each note of the musical scale, it would result in a more meaningful visualization.

For this experimental module, I had chosen "Prelude" from J. S. Bach's Cello Suite No. 1. I had purposely selected this song because I had played this musical piece before on the cello, so I was very familiar with the overall pitches of the music. This would make it easier for me to evaluate the module during the design process and on completion.

6.1.1 Design Process

To create this music visualization, I created twelve different colored balls and assigned each ball to the pitches of the musical scale according to Newton's theory:

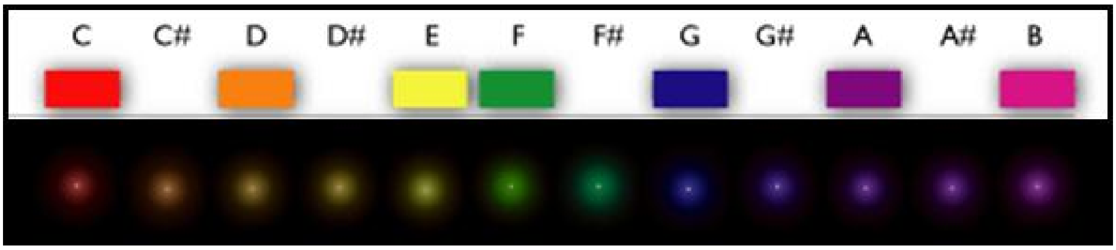

Figure 6.1: Pitch Module Design based on Newton's Color Scale

As each musical pitch is played during the visualization, the corresponding colored ball would be recalled and attached onto the screen.

6.1.2 Results

Below are some screenshots of the Pitch Module after completion. The left screenshot is taken after the first measure (the first bar in music), the middle screenshot taken after the second measure, and right screenshot taken after the third measure.

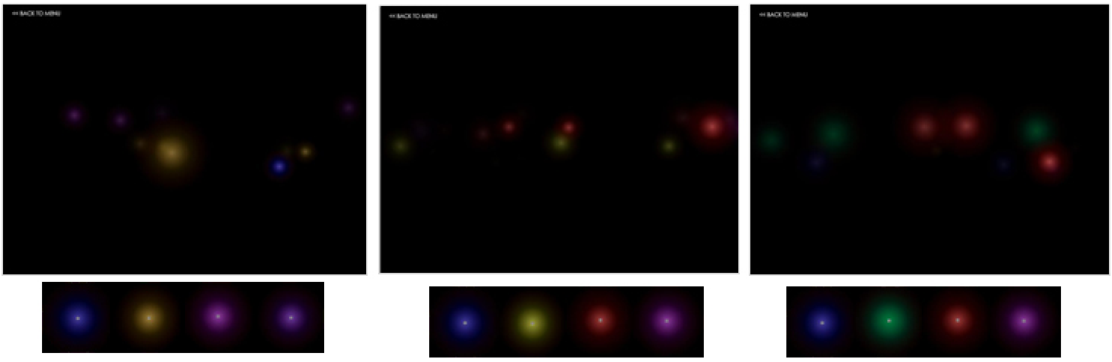

Figure 6.2: Screenshots of the Pitch Module

6.1.3 Evaluation

As shown in the screenshots above, although the correct coloured balls were recalled for each measure, they were not exactly synchronized with each of the pitches in the musical piece. It was extremely hard to synchronize the pitch array data with the mp3 file because of the musical nuances in the performance that were not present in the MIDI file. I also had problems with the generation of the pitch data through MIDI Analyzer due to the long duration of the piece. The Pitch module was one of the hardest modules to generate using the experimental procedure in this research project. Consequently, it was not very effective in generating a meaningful music visualization based on Newton's color-pitch system.

The outcomes of this module wasn't very successful, however further testing is needed before we can come to a conclusion in regards to pitch-hue mappings. Could a better song choice that contained "scales" of pitches in the form of musical phrases provide a more meaningful solution? Could another pitch system such as the placement of low/high notes as opposed to color be of a more effective solution too? These are some of the questions that could be looked into in future studies.

6.2 Timbre Module

The aim of this module was to test whether Wassily Kandinsky's color-timbre theory (as analyzed in **Section 5.3**) could be used in the generation of a music visualization via code. My hypothesis was that by assigning specific colors to different musical instruments, it would result in a more meaningful visualization.

To carry out this experimental module, I had chosen "Rondo", the 3rd Movement of Mozart's *Horn Concerto No. 4* (K. 495). This was because throughout the musical piece, there is a constant dialogue between two groups of instruments: the French horn and the strings (plus two oboes that play a minor part). This would be an effective way to highlight the interplay between different timbres.

6.2.1 Design Process

Although Kandinsky did not specify a color for the French horn, I had associated it with the colors orange-red, the general colours of *brass* instruments according to Kandinsky's theory. Likewise, Kandinsky had also linked *string* instruments to colors blue-green. This resulted in the design of the visual elements like so:

Figure 6.3: Design of the Movie Clip for Horn in *Adobe Flash*

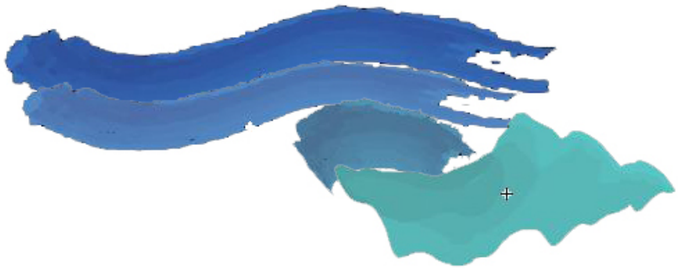

Figure 6.4: Design of the Movie Clip for Strings in *Adobe Flash*

Each of these movie clips would be recalled and attached to the screen via *ActionScript* in *Adobe Flash* in accordance to the music. Whenever the horn instrument sounds, the Horn Movie Clip would be "painted" onto the screen canvas, and whenever the strings play, the Strings Movie Clip would do the same.

6.2.2 Results

Here are some screenshots of the Timbre Module after completion:

Figure 6.5: Horn and Strings Movie Clips in Action

Figure 6.6: Kandinsky's Color-Timbre Theory applied to Mozart's Horn Concerto

6.2.3 Evaluation

Overall, the Timbre module was pretty effective in producing a meaningful music visualization through the use of Kandinsky's color-timbre theory. The contrast in hues made it easier for the viewer to identify with the different instruments. The constant exchanges between the horn and strings timbre were also clearly visible to the viewer. Most steps in the generative procedure had been quite successful; the only step which took longer than expected was the synchronization of the MIDI and mp3 files. It would be interesting to see this module further developed with music that involved more than two timbres.

6.3 Form & Structure Module

The aim of this module was to test whether Paul Klee's techniques in translating the fugal qualities of music into visual forms (as analyzed in **Section 5.4**) were still feasible if generated via code. My hypothesis was that by using the successful qualities of Klee's *Fugue in Red* painting, it would result in a more meaningful visualization.

To carry out this experimental module, I had chosen J. S. Bach's "Little Fugue" in G Minor in order to link back to Klee's original influence to his paintings: Bach's fugal music.

6.3.1 Design Process

“Little Fugue” had four distinct voices that ranged from high to low. Each voice entered and exited the fugue at different times during the musical piece. For each voice, I had designed a separate movie clip that had a similar style, but a different color and shape:

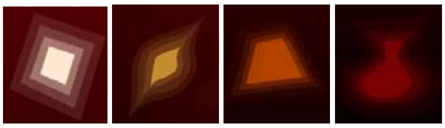

Figure 6.7: Designs of the Movie Clips for the Four Voices in Little Fugue

As each voice entered the fugue, the corresponding movie clip would randomly appear on the screen along its assigned horizontal line, with the highest voice at the top, and the lowest voice at the bottom.

6.3.2 Results

The results of the Form & Structure Module are shown below:

Figure 6.8: Screenshot of the Form & Structure Module

6.3.3 Evaluation

Results of the Form & Structure module showed that Klee’s visual techniques in representing the musical fugue were effective in making the music visualization more meaningful to the viewer. Each of the four voices was easily recognizable due to its distinct organic shape, and the colors and overlay technique inspired by Klee gave the visualization a certain resonance and energy. The visualization was also relatively easy to generate; in fact, the procedure used was very similar to that of the Timbre module. Overall, Klee’s techniques were successfully used to show the fugal texture and interrelationships between each of the voices in the module.

6.4 Harmony Module

The aim of this module was to test whether I could use John Whitney's digital harmony theories (as analyzed in **Section 5.5**) to generate a meaningful music visualization based on harmony. My hypothesis was that if I followed Whitney's differential, resonance and harmony principles, I could create a visual pattern that was analogous with harmonic structures.

I had chosen "Prelude in C Major" from J. S. Bach's *Well Tempered Clavier* as my song choice for this module. The reason for this was because the harmonic structures in the Prelude was easy for harmonic analysis, with the musical notes in the form of broken chords that repeated for 32 of the 35 measures (Burgmer 1995).

6.4.1 Design Process

To recreate the differential visual patterns like Whitney did, I first had to choose a geometric form to base my patterns on. After much consideration, I had chosen the Rose curve, which had the shape of a petalled flower (Weisstein n.d.). The polar equation of a rose curve is written as follows (*Rose (mathematics)* 2010):

$$r = \cos(k\theta)$$

In this case, RD (the radius differential factor), would determine how big the rose would look. I had assigned this factor to the amplitude of the music. TD (the angular differential factor) would represent *k* in the equation. I had assigned this factor to the musical ratios established by Pythagoras in musical tuning, hoping to link this back to the Pythagorean laws of harmony Whitney also looked into.

Note	G♭	D♭	A♭	E♭	B♭	F	C	G	D	A	E	B	F♯
Ratio	$\frac{1024}{729}$	$\frac{256}{243}$	$\frac{128}{81}$	$\frac{32}{27}$	$\frac{16}{9}$	$\frac{4}{3}$	$\frac{1}{1}$	$\frac{3}{2}$	$\frac{9}{8}$	$\frac{27}{16}$	$\frac{81}{64}$	$\frac{243}{128}$	$\frac{729}{512}$

Figure 6.9: Pythagorean Tuning for a Twelve Tone Scale

This combination of factors allowed me to generate a set of rose curve patterns for each musical note in *Flash*:

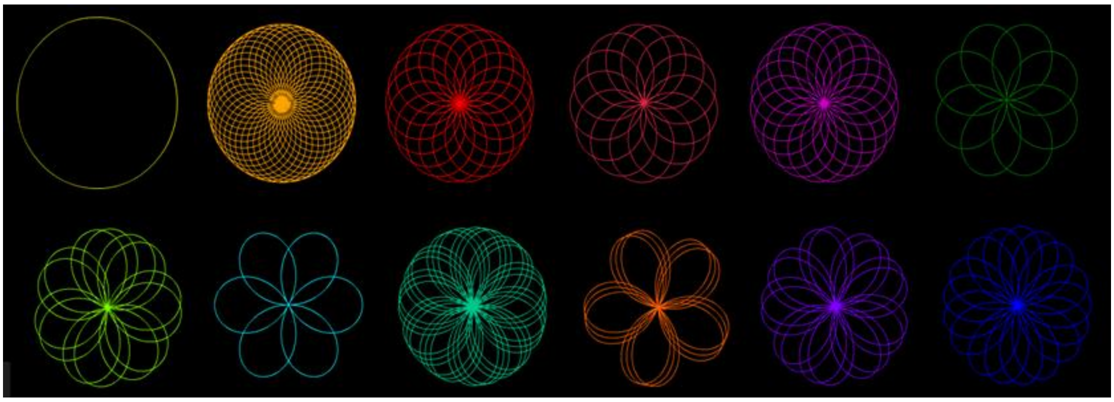

Figure 6.10: Rose Curve Patterns created in *Adobe Flash* (Top: C-F; Bottom: F#-B)

When each of the musical notes is played, the corresponding rose curve would be generated and placed onto the screen. Likewise, when Prelude was set to run during the music visualization, a combination of rose curves would be generated based on the harmonic structures of Bach's piece.

6.4.2 Results

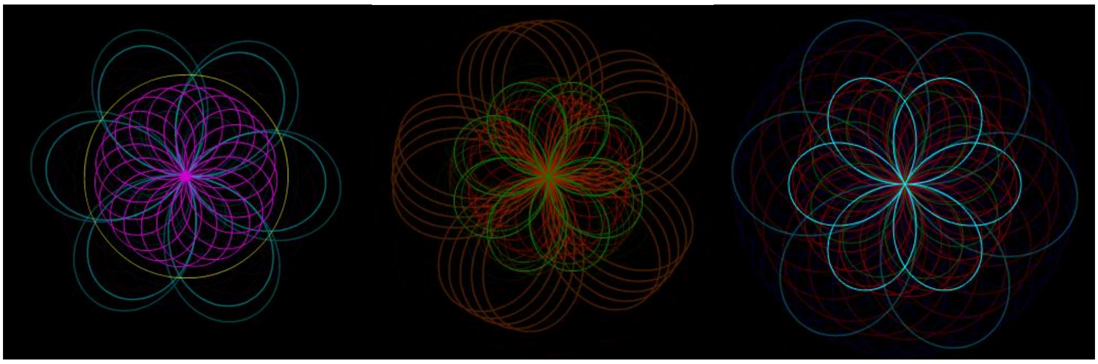

Figure 6.11: Combinations of Rose Curves for Bach's Prelude

The pictures above are a few screenshots taken from the Harmony Module. The first rose curve was from the first bar of the Prelude, where the tonic (CEG) is played (Burgmer 1995). The second rose curve was from the second bar, the subdominant (CDAF); while the third rose curve was from the third bar of the piece, the dominant (BDGF).

6.4.3 Evaluation

The results of the Harmony module showed that the different harmonies from a musical piece could be visually depicted in the form of graphic system. In this case, I had chosen the rose curve as my visual system. It had resulted in a more meaningful visualization based on Harmony.

This module was my most complex module yet for this research project, as it involved the generation of complex patterns and the use of mathematical equations. A lot of time had been spent trying to generate the rose patterns in *Flash*. Luckily, there wasn't much synchronization needed on the MIDI and mp3 files.

An aspect which could be looked into in future studies would be the implementation of fluid visual patterns that allowed for a continuous transformation between the different rose curves. Whitney's theory offers great potential for a wide range of geometric patterns. It would be interesting to see what other visual patterns could work well in *Flash*. Another visual aspect that could also be further explored is use of color in relation to musical harmony (Lubar 2004).

6.5 Dynamics Module

The aim of this module was to test whether Lawrence Marks's findings on cross-modal associations with loudness (as analyzed in **Section 5.6**) could be used as parameters for a music visualization based on Dynamics. My hypothesis was that if I was to utilize these associations with the dynamics of a musical piece, it would result in a more meaningful visualization.

To conduct this experimental module, I had chosen a variety of musical excerpts for testing. Each excerpt was around 30 seconds in duration. They were: (1) "March" from Gustav Holst's *Suite No. 1* in E Flat, 3rd Movement (measures 1-36); (2) "Bydlo" from Modest Moussorgsky's *Pictures at an Exhibition*, 4th Movement (measures 1-20); and (3) "Bourree" from George Frideric Handel's *Music for the Royal Fireworks* (measures 11-26). These three examples were chosen based on a previous study on color-music association where they used these excerpts because of their unique and contrasting musical qualities (Cutietta and Haggerty 1987). This would allow me to sufficiently test whether Marks's cross-modal associations could be applied over a range of musical works.

6.5.1 Design Process

The following table shows the parameters (based on Marks's findings) I had followed while designing the visual elements for my music visualization:

Dynamics	**Amplitude**	**Brightness**	**Size**
Very soft (pp)	1-3	Dark ↑	Small ↑
Soft (p)	4-6		
Medium soft (mp)	7-9		
Medium (m)	10-12		
Medium loud (mf)	13-15		
Loud (f)	16-18		
Very loud (ff)	19+	↓ Bright	↓ Large

Table 6.1: Dynamics Associations with Brightness and Size

6.5.2 Results

The following screenshots show how the different soft-loud systems were put in place visually for each musical excerpt:

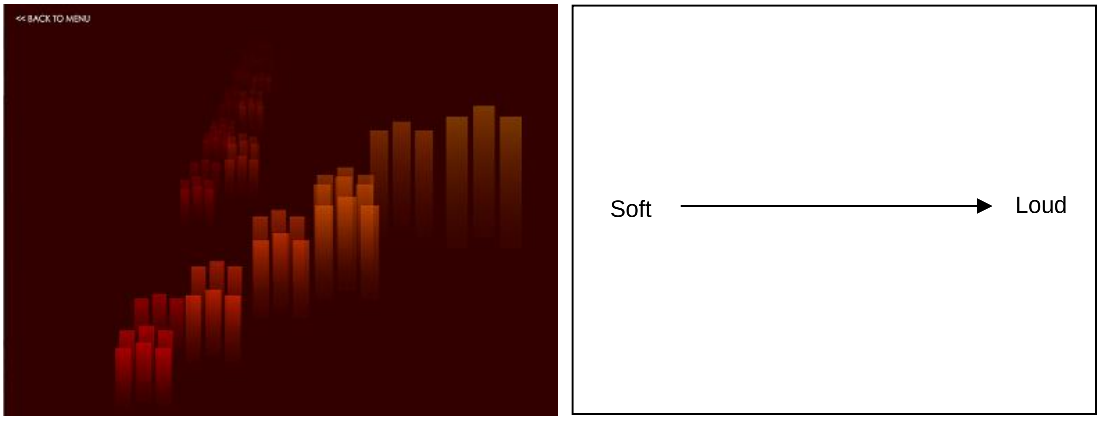

Figure 6.12: Screenshot of “March” from the Dynamics Module

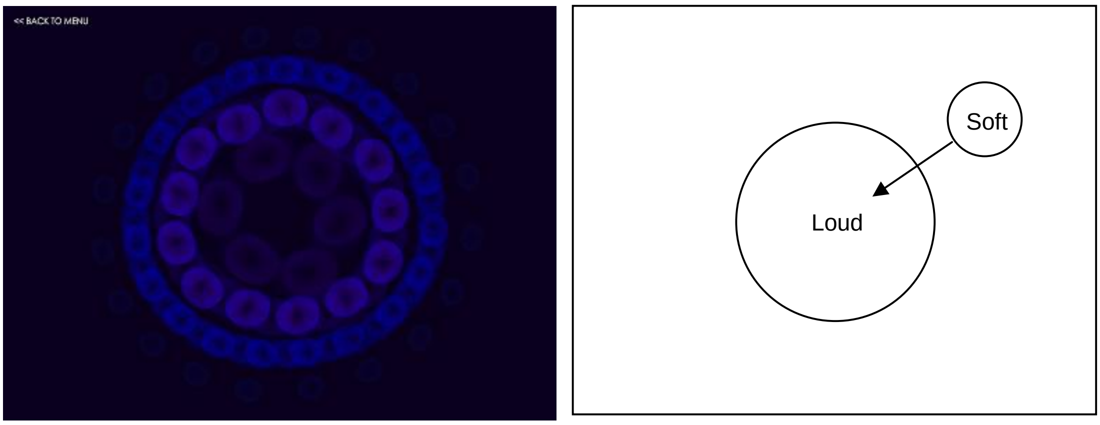

Figure 6.13: Screenshot of “Bydlo” from the Dynamics Module

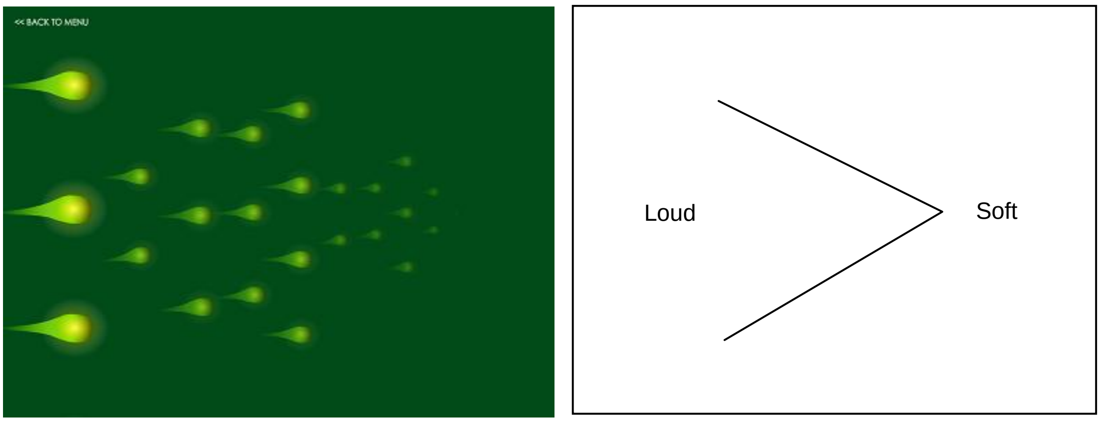

Figure 6.14: Screenshot of “Bourree” from the Dynamics Module

6.5.3 Evaluation

The results of the Dynamics module showed three very successful music visualizations that effectively conveyed the variations in the dynamics to the viewer (based on cross-modal association of brightness and size to music dynamics). These results were to be expected, as Marks's psychological studies were the results of tests conducted on large groups of people; in contrast to the earlier modules, their testing systems were based on individual artists' and designers' subjective meanings.

To finish off this research project, the Dynamics module was the easiest one to generate, as it involved only one set of Amplitude data, and no synchronization was needed. I was also able to test the feasibility of automatically generating different colored backgrounds and color schemes in the middle of the music visualization. This proved to be successful, and the use of multiple visual music systems in one single piece of music is definitely another aspect that could be further looked into in the future. In addition, other cross-modal associations could also be tested in relation to dynamics.

Chapter 7: Conclusions

7.1 Conclusion

On completion of the research project, I have found that more meaningful music visualizations can be created using generative techniques such as coding. However, the process to make this happen can range from simple to complex, depending on the musical quality that the artist/designer is dealing with.

As shown in Chapter 6, the *Dynamics* module was the easiest to generate and also the one that was easiest to understand upon viewing. There is great potential in mapping cross-modal associations to musical attributes. What this module demonstrated was that minor adjustments to color, shape, opacity and other simple parameters by the artist, designer or composer could result in a much more meaningful visualization as long as the associations “match up”. This personalization of the visualization is what makes it unique and meaningful to the viewer.

On the other hand, the *Pitch* module was the hardest to generate, and the least effective in conveying the meaning of pitch to the viewer. There were a lot of problems involved in the synchronization of the exact musical pitches with the colors on screen, and subsequently I was only able to generate the colors according to each of the measures in the music via code. However, even with the correct recall of the colors for each musical phrase, the visualization still didn’t seem very effective in conveying the meaning of the music compared to other modules.

Timbre, Form & Structure and Harmony modules sat in the middle of the generative and meaningfulness scales. The *Timbre* module was very effective in allowing the viewer to identify with the different musical instruments based on their assigned colors. It would be interesting to see how this color-timbre system fares when dealing with a multitude of timbres, such as a symphony orchestra. Likewise, the *Form & Structure* module performed with similar results to the Timbre module. Musical genres other than the fugue, such as a canon or a rondo, could be investigated in the same manner in future studies.

Despite the *Harmony* module being slightly harder to generate compared to Timbre and Form & Structure, it was successful in showing the complex nature of musical harmony. Due to the difficult procedures involved in the programming of the visual system, I wasn’t able to fully implement Whitney’s vision of fluid visual patterns that transformed continuously between points of resolution and tension (consonance and dissonance). This could be further looked into in future studies through collaboration with software engineers or programmers.

On the whole, these experimental modules were quite successful in showing some of the possibilities and limitations in generating a meaningful music visualization based on the systems established by past visual music artists. Through a detailed visual and documentary analysis of these artists' works, I was able to test their visual systems and theories in practice via generative techniques. However, it must be emphasized that these modules were not true experiments; therefore, further research and testing must be conducted before generalizations could be made.

7.2 Future Directions

The prospective to further this research project is enormous. Future research could involve the testing of other musical qualities (not already addressed in this dissertation) that could be carried out in the same manner. Or instead, a particular musical module could be chosen and expanded upon in a research project that involved true experimentation and user testing. Researchers could also try applying these theories to a full scale music visualization that incorporates a *combination* of musical qualities.

There are also many areas where the outcomes of this project can be developed in, such as commercial, performance, and educational applications. In collaboration with computer programmers, a single piece of software to generate these visuals could be developed to replace the combination of programs that was needed in the experimental procedure. This software could be used in the development of commercial applications.

The prospect of this research project could also be relevant in the area of live performance visuals, where real-time generation of *meaningful* music visualizations could be made in concert settings and performance venues. The visualization of the different musical characteristics may also prove to be useful in educating children about music. Likewise, the promise of generating these meaningful music visualizations based on musical attributes may even allow deaf people to finally have the opportunity to fully appreciate music in sensory domains other than hearing.

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