Visual Music Composition with Electronic Sound and Video

Mr David Payling

A thesis submitted in partial fulfilment of the requirement of Staffordshire University for the Degree of Doctor of Philosophy

August 2014

Acknowledgements

I would like to thank my PhD supervisors for their invaluable support throughout the entire research project.

They are:

Professor Stella Mills of Staffordshire University and

Professor Tim Howle of the University of Kent

Contents

Contents

CONTENTS IV

LIST OF TABLES VII

LIST OF FIGURES VIII

DVD CONTENTS X

DVD 1. HUE MUSIC PROGRAM. THESIS ELECTRONIC COPY X
DVD 2. THE COMPOSITION PORTFOLIO X

ABSTRACT XII

1. INTRODUCTION 2

THE PROBLEM AND MOTIVATION 4
AIMS OF THE INVESTIGATION 6
OBJECTIVES OF THE INVESTIGATION 6
CONTRIBUTIONS TO KNOWLEDGE 7
MULTIMEDIA COMPOSERS AND ARTISTS THAT HAVE INFLUENCED THE COMPOSITION PORTFOLIO 8
THESIS STRUCTURE 10

2. CONTEXT AND HISTORICAL BACKGROUND 12

COLOUR 12
SOUND 13
ACOUSMATIC SOUND AND ELECTROACOUSTIC MUSIC 14
HISTORICAL DEVELOPMENTS IN VISUAL MUSIC 15
COLOUR ORGANS 18
THOMAS WILFRED AND LUMIA 20
ANIMATED VISUAL MUSIC 22
HAND DRAWN SOUND AND OPTICAL SOUNDTRACKS 23
SONIFICATION 27
SYNAESTHESIA 28

3. PORTFOLIO OVERVIEW AND COMPOSITIONAL STRATEGIES 32

MUSIC COMPOSITION 34
THE AUDIO-VISUAL PRODUCTION WORKFLOW 36
TECHNOLOGY PLATFORMS FOR COMPOSITION 38

Considerations in Video Production 40
Chroma-Keying 42
Symmetry in Video Production 43

4. HUE MUSIC 46

Colour Analysis and Sound Mapping 46
Scanning and Focus 51
Audio Timbre Mixer 52
Compositions 54
Improvements on the Algorithm 55
Summary 55

5. COLOUR MIRROR AND SONI-CHROME 59

Visual Development 59
Visual Compositional Forms 64
Algorithmic Sound Design for Colour Mirror 64
Soni-Chrome Musical Composition 69
A Critique of Algorithmic versus Traditional Composition Techniques in these Pieces 69

6. THERAVADA COLOUR MORPH AND SUNSET 74

Theravada Colour Morph 75
Synchronisation in Theravada Colour Morph 76
Sunset 79
Sound Textures and Time Dilation 80

7. SPACE MOVEMENT SOUND 85

Form in Visual Music 85
Colour in Visual Music 87
Motion in Visual Music 88
Combinations of Form, Colour and Motion 90
Sonic Equivalents of Lumia 92
Space Movement Sound 96
Motion Shifts 96
Colour Blends 97
Space Movement Sound Summary 99

8. DIFFRACTION 103

REFRACTION, DIFFRACTION AND RAINBOWS 103
THE COMPOSITION PROCESS 105
CREATING REFRACTION IN SOUND 106
OTHER USES OF NOISE IN THE COMPOSITION 111
CONCLUSION 113

9. EVALUATION, CONCLUSIONS AND FUTURE WORK 116

MEETING THE AIMS AND OBJECTIVES 116
DISCUSSION 120
FUTURE WORK 121
CONCLUSION 123

SELECTED PERFORMANCES AND PRESENTATIONS 126

REFERENCES 128

List of Tables

TABLE 1	**COLOURS AND MUSICAL INSTRUMENT ASSOCIATIONS**	**16**
TABLE 2	**HUE VALUES USED FOR TIMBRAL ASSOCIATION**	**47**
TABLE 3	**QUANTISED HUE VALUES FROM RGB VALUES**	**49**

List of Figures

FIGURE 1	ADDITIVE AND SUBTRACTIVE COLOUR MIXING	12
FIGURE 2	RAINBOW KEYBOARD BASED ON NEWTON'S IDEAS	15
FIGURE 3	COLOUR AND PITCH ASSOCIATIONS	15
FIGURE 4	DETAIL OF BISHOP'S COLOUR ORGAN	19
FIGURE 5	THOMAS WILFRED'S 'GRAPHIC EQUATION' OF THE FACTORS AND SUB-FACTORS OF LUMIA	21
FIGURE 6	STILL FROM SYNHROMY NO. 4: ESCAPE, BY MARY ELLEN BUTE	23
FIGURE 7	EXAMPLES OF HAND-DRAWN ORNAMENTAL SOUNDTRACKS	24
FIGURE 8	COMPOSITION METHODS USED IN THE EARLY PORTFOLIO PIECES	32
FIGURE 9	DIRECTION OF INFLUENCE FROM ONE MEDIUM TO THE OTHER IN THE LATER COMPOSITIONS	33
FIGURE 10	AN EXAMPLE OF EFFECTS ROUTING IN REAPER	39
FIGURE 11	COMBINING IMAGES USING TRANSPARENCY ADJUSTMENTS AND CHROMA-KEYING	41
FIGURE 12	REFLECTING ONE HALF OF AN IMAGE IN A PLANE TO CREATE BILATERAL SYMMETRY	43
FIGURE 13	CREATING ROTATIONAL SYMMETRY	44
FIGURE 14	BLUE-YELLOW IMAGE	47
FIGURE 15	BLUE-YELLOW MATRIX	47
FIGURE 16	AQUARIUM PHOTOGRAPH	48
FIGURE 17	AQUARIUM DOWN-SAMPLED INTO AN 8X8 MATRIX	49
FIGURE 18	8X8 MATRIX OF QUANTISED HUE VALUES	50
FIGURE 19	HUE HISTOGRAM FOR THE AQUARIUM PICTURE	50
FIGURE 20	FOCUSING ON AN IMAGE AREA	51
FIGURE 21	TIMBRAL 'HUE' MIXING	53
FIGURE 22	WEDDING DANCE PHOTOGRAPH	54
FIGURE 23	TREE BARK PHOTOGRAPH	54
FIGURE 24	FLOWERS PHOTOGRAPH	54
FIGURE 25	PHOTOGRAPHIC IMAGES SLICED AND RECOMBINED	60
FIGURE 26	BOTTOM IMAGE OF FIGURE 25 FIRST RESAMPLED TO EMPHASISE THE COLOURS, THEN REFLECTED, THROUGH THE VERTICAL AND HORIZONTAL PLANES TO CREATE SYMMETRY	61
FIGURE 27	BLENDED PICTURES CREATING ADDITIONAL TEXTURE AND COLOUR EFFECTS	62

FIGURE 28	BLURRING THE IMAGE AND CREATING SYMMETRY FROM FIGURE 27	63
FIGURE 29	FILTER CHARACTERISTICS CREATED BY DIFFERENT AVERAGE COLOUR CONTENT	65
FIGURE 30	THE EQUAL LOUDNESS CONTOUR CURVES FORMULATED BY FLETCHER AND MUNSON	65
FIGURE 31	STILL FROM COLOUR MIRROR WITH A HIGH RED CONTENT. THE RED TIMBRE IS EMPHASISED AT THIS POINT	66
FIGURE 32	STILL FROM COLOUR MIRROR WITH LOW RGB VALUES. RESULTS IN LOW FREQUENCY DOMINANCE IN ALL AUDIO CHANNELS.	67
FIGURE 33	GARRO'S CONTINUUM OF GESTURAL AUDIO VS. VISUAL ASSOCIATION STRATEGIES	76
FIGURE 34	STILL FROM AERIAL BY HEGARTY AND HEGARTY	86
FIGURE 35	STILL FROM PHASE BY ANDREW HILL	88
FIGURE 36	STILL FROM HELIOCENTRIC BY SEMICONDUCTOR	89
FIGURE 37	DIAGRAMMATIC REPRESENTATION OF THE COMBINATIONS OF LUMIA FACTORS BASED ON WILFRED (1947)	91
FIGURE 38	SOME OF THE IMAGES USED TO EXTRACT THE COLOUR PALETTE FOR COLOUR BLENDS	98
FIGURE 39	CREATING TONES FROM FILTERED NOISE	107
FIGURE 40	SPECTROGRAMS OF THE INPUT NOISE SOURCE AND FILTERED SINE TONES CREATED BY THE FILTERING PROCESS	108
FIGURE 41	THE ATTACK AND SUSTAIN PHASE AND INCREASING SPECTRAL CONTENT	110
FIGURE 42	THE RELEASE PHASE AND DECREASING SPECTRAL CONTENT	110
FIGURE 43	SPECTROGRAM OF A NOISY DRONE PRODUCED FOR DIFFRACTION	111

DVD Contents

DVD 1. Hue Music Program. Thesis Electronic Copy

- **HUE MUSIC. STANDALONE PROGRAMME. PC AND MAC COMPATIBLE VERSIONS.**
- **PDF VERSION OF THIS THESIS**

DVD 2. The Composition Portfolio

QUICKTIME MOVIE FILES

• **SONI-CHROME**	**3' 29"**
• **COLOUR MIRROR**	**5' 13"**
• **THERAVADA COLOUR MORPH**	**9' 53"**
• **SUNSET**	**11' 19"**
• **SPACE MOVEMENT SOUND**	**6' 28"**
• **DIFFRACTION**	**9' 45"**
• *TOTAL RUNNING TIME:*	*46' 07"*

Thesis chapters 4 to 8 are preceded by textual mnemonics that describe the contents of each of these compositions. This is to inform readers who have not watched the DVD of the compositions contents and also to act as memory aids for those who have.

Abstract

Abstract

This research project investigated techniques for composing visual music and achieving balance in the relationship between sound and image. It comprises this thesis and a portfolio of compositions. The investigation began with an interest in the relationships between colour and sound and later expanded to include form and motion, the remaining factors of Thomas Wilfred's lumia (1947). Working with a cohesive theme, such as lumia, proved to be an effective way of creating a coherent aesthetic in portfolio pieces. Other themes were therefore investigated including composing with visual and audio materials recorded from the single source of Thailand, the wave phenomena of refraction and diffraction and a filmed natural sunset interpreted in electroacoustic music.

Two distinct compositional techniques were used, material transference, where qualities were transferred between sound and image, and compositional thinking, which assisted in creating audio-visual compositions that possessed musical qualities. Material transference proved to be the most productive technique during composing and it was discovered that effectuating it algorithmically created a strong bond between sound and image. Compositional thinking assisted in creating the form of the portfolio pieces and was found to apply to both video and music. Compositional thinking was found to be useful at the macro level, where structural form was designed, and material transference worked at a finer micro level, transferring individual qualities between sound and video objects.

1. Introduction

1. Introduction

This practice based PhD comprises the written thesis, software, media files and a visual music composition portfolio that can be found on the accompanying DVDs. The composition portfolio on DVD 2 contains a selection of creative visual music works that should be reviewed in conjunction with this thesis. This is a recognised format for practice based research projects as described by Frayling (1997).

Visual music will be the primary term used to describe the compositions and it can have different connotations dependent on context. For the purposes of this thesis, visual music *'can be defined as time-based visual imagery that establishes a temporal architecture in a way similar to absolute music. It is typically non-narrative and non-representational (although it need not be either). Visual music can be accompanied by sound but can also be silent'* (Evans, 2005, p.11). The composition portfolio predominantly includes time based visual imagery with underlying musical form. The pieces are also non-narrative and non-representational in nature and accompanied by sound; they therefore fit within Evans' definition of visual music. 'Audiovisual' is a similar term used to describe multimedia works but ones which are not necessarily visual music. In audiovisual works, the integration between sound and imagery may not be as tight as in visual music and there is no attempt to impart or reveal musical qualities in the video. The term 'audiovisual' may also relate to the equipment and practice used when reproducing or creating such works and will be used in this context in places throughout the thesis.

The portfolio of compositions is intended to contribute to on-going research in the digital arts in contrast to similar work being created by non-academic practitioners. Scrivener (2002) distinguished the researcher from the practitioner in two ways. First, the researcher attempts to generate culturally novel apprehensions, not just ones that are novel to the artist or observers. He describes apprehensions in this sense as, *'objects that must be grasped by the senses and the intellect'* (Scrivener, 2002, p.1). Secondly, within an academic framework, this is possible as *'the "researcher" would seek to comply with accepted ways of generating apprehensions and to meet discipline determined norms of original creation'* (Scrivener, 2002, p.1). These guidelines have been followed with the current portfolio. Based on existing working methods and by analysing and evaluating compositions of other academics and artists, the body of work presented here contributes to the emerging field of visual music composition. It also demonstrates several novel production methods, compositional strategies and extension of existing visual music themes. Although the composition portfolio is important in demonstrating a contribution to knowledge, this written thesis also needs consideration to appreciate its context and significance. As Candy suggested:

'Creative output can be produced, or practice undertaken, as an integral part of the research process. However, the outcomes of practice must be accompanied by documentation of the research process, as well as some form of textual analysis or explanation to support its position and to demonstrate critical reflection. A thesis arising from a practice-based research process, such as the one given above, is expected to both show evidence of original scholarship and to contain material that can be published or exhibited' (Candy, 2006, p.2).

In this thesis reflection upon, and analyses of, all the creative works are undertaken and original scholarship is demonstrated in Chapters 3 to 8. The creative works were produced with the intention of them being screened or performed and many have been accepted nationally or internationally at academic conferences and concerts. Details of these screenings and performances can be found in Appendix 1.

The Problem and Motivation

An interest in visual music composition was gained when living and composing separate music and visual material in Sheffield, UK. In the late 1980s and early 1990s, in and around Sheffield, there was a culture of experimental electronic composition and performance taking place in venues and clubs such as the City Hall Ballroom and later the Arches with performances and club nights often accompanied with video projections. A few acts typified this experimental approach such as Cabaret Voltaire and Clock DVA, whose engineer and composer, Robert Baker, was a strong influence and mentor in my early experiments with digital video animation. This influence seeped into later work when electronic video was produced to accompany live band performances, and was displayed on television sets either side of the stage. These were old and heavy cathode ray tube television sets mounted on top of speaker stacks! The videos in these productions were not intended to be of interest in their own right; they were more a way of enhancing the musical performance in a visual way. The videos were abstract and colourful and often behaved more in the manner of a light show rather than containing any kind of narrative or representation of the musical content. The audience seemed to accept the visuals and responded with positive comments about their inclusion in the performance. Some of the ideas concerning the use of abstract colour and light experienced in these shows have been carried forward into the compositions presented here. In contrary to this previous work, however, the visuals were intended to combine evenly with the music. In order to achieve this, the portfolio presented here explored the workflow and techniques used in creating visual music. The compositional approach was modified and refined to determine how the visual could influence the musical, and vice-versa, to achieve a more unified balance between the two. The technique of *'compositional thinking'* (Hyde, 2012, p.171) was used in part to achieve this. The compositional form of music influenced that of the visual, but this also occurred in the opposite direction. The primary technique that was employed, however, was that of *'material transference'* (Hyde, 2012, p.170). With this technique the attributes of one medium are transferred by some means to the other. In earlier pieces this was achieved through automated techniques and the mapping of parameters between domains. Chapters 4 and 5 examine these processes. There was also a more subtle transference exerted, through the composer's influence and interpretation between the media, which occurred in the later work.

During composition a bottom up approach was taken; audio and video materials were gradually pieced together and the evolving themes developed into completed pieces. Switching focus between audio and video during this process allowed qualities to flow between the media and the results of this will be described more thoroughly in Chapters 3 and 7. In relation to the light show nature of my early video experiments, Thomas Wilfred's lumia (1947, p.247) were used as inspiration for the final two compositions. Lumia performances were a light based art that demonstrated interaction between visual form, colour and motion. Since lumia existed without sound, methods are discussed as to how sound can be integrated with lighting based effects and rendered to fixed media video. The concepts related to lumia will be detailed further in Chapter 4.

Intended Audience

Although undertaken with existing visual music composers and academics in mind, this research project may also be useful to people who compose music but are considering adding a visual component to their work. There may also be 'video only' artists, who are interested in adding a musical dimension to their creations, who could derive pertinent information and techniques from this work. Both in the thesis and through the composition portfolio, a progressive development in the compositional output is demonstrated, in addition to how expertise was obtained through experimentation.

Aims of The Investigation

1. To explore the use of material transference to interpret between audio and visual domains to create visual music.
2. To explore the use of compositional thinking techniques to create visual music.
3. To create visual music compositions influenced by historical developments in musical and visual composition.

Objectives Of The Investigation

1. To explore the aesthetic links that exist between the visual and musical arts. *Aim 3*.

2. To investigate methods for recreating Thomas Wilfred's lumia in fixed media video. *Aims 2 and 3*.

3. To investigate algorithmic techniques to translate from visual to audio domains. *Aim 1*.

4. To explore the use of use synthesised and concrete found sounds or a combination of both to compose music for abstract video. *Aim 3*.

5. To explore the use of animated visuals and real footage or a combination of both to create abstract video with musical qualities. *Aim 3*.

Contributions to Knowledge

The main findings and contributions of this thesis are relevant to the following areas:

1. The role of algorithmic techniques in audiovisual composition and how they assist in material transference and audio-visual bonding. *Aim 1*.
2. The role of the composer in the creation of visual music. *Aims 1 and 2*.
3. The role of colour in visual music and its relationship to timbral music composition. *Aim 3*.
4. How the factors of lumia can be used in visual music composition. *Aim 3*.
5. How the factors of lumia can be separated and translated into music. *Aim 3*.
6. The advantages and disadvantages of composing one medium in isolation before pairing with the second. *Aims 1, 2 and 3*.
7. The issues related to, and results obtained by, pairing electroacoustic music with abstract visual imagery. *Aims 2 and 3*.

Each of the contributions is addressed in the relevant chapters as listed below.

- Point 1 in Chapters 4 and 5, describing Hue Music and *Colour Mirror and Soni-Chrome*.
- Point 2 in Chapters 4 and 7, Hue Music and *Space Movement Sound*.
- Point 3 in *Colour Mirror and Soni-Chrome* and *Diffraction*, Chapters 5 and 8.
- Points 4 and 5 in *Space Movement Sound*, Chapter 7.
- Points 6 and 7 are addressed in Chapter 6, *Theravada Colour Morph* and *Sunset*.

These and other points are also covered incidentally in other places throughout the thesis.

Multimedia Composers and Artists that have influenced the Composition Portfolio

Many artists and composers works have been viewed and reflected upon in the preparation of this thesis and portfolio. Their works have been used as inspiration for some of the techniques used in the pieces and to gain awareness of the style and aesthetics intrinsic to visual music. As well as viewing the works from the artists listed below, the annual NoiseFloor Festival[1], which has taken place at Staffordshire University since 2010, has screened many audiovisual and visual music compositions from a wide variety of composers. Curating the audiovisual section of the festival has given me the opportunity to further develop awareness of current trends and develop a sense of compositional forms and themes that are used. The experience of interacting with the audience and receiving feedback on the screenings has also been useful in informing the direction of future concerts and technical and aesthetic decisions when creating my own work. The artists introduced below are a small selection of currently active composers who produce a wide variety of audiovisual and visual music media. Dennis Miller's *Amorphisms* and Paul O'Donoghue's *Pretty in Pink* were screened at NoiseFloor.

Semiconductor

Ruth Jarman and Joe Gerhardt are a duo of artists who,

'Through moving image works they explore the material nature of our world and how we experience it, questioning our place in the physical universe' (Jarman & Gerhardt, 2012, p.1).

Semiconductor have created a wide variety of multimedia works ranging from fixed media to installations. They use film recordings and physical phenomena, landscapes and environments to which they add soundtracks that often have a minimal and low fidelity style. An example is *Black Rain* (Jarman & Gerhardt, 2009), a piece that makes use of images of space from NASA satellites with a soundtrack built from noise sources and other digital artefacts. There is generally a limited use of colour in their works and they portray the visual phenomena and setting in quite minimal ways.

---

[1] See http://www.noisefloor.co.uk/ for further information about the NoiseFloor Festival.

Jean Piché

Jean Piché is an electroacoustic composer from Canada who in recent times has begun to combine music with video. *'His practice meshes moving images and music in a new hybrid form he calls videomusic.'* (Piché, 2004). He has a produced a wide variety of videomusic using many techniques ranging from ambient synthesised pieces, such as *Océanes* (Piché, 2011), to tightly edited and synchronised found and processed material in *Munjikal (paNi intiyA)* (Piché, 1996).

Dennis Miller

Dennis Miller is an American composer based in Boston, USA. He works with animation and musical composition. For *Amorphisms* (Miller & Young Ha, 2008), he created a slowly evolving abstract colour animation to which Moon Young Ha composed the music. He has also created mixed media works entirely by himself such as Echoing Spaces, which *'explores a number of virtual environments in which the primary elements recur (echo) both in immediate succession and at different times throughout the piece, always in varied form'* (Miller, 2009).

Paul O'Donoghue (Ocusonic)

Ocusonic uses real time techniques to produce audio and video simultaneously. He *'explores a disparate collection of methods and techniques for the creation of visual music. Underpinning all of these disciplines is Ocusonics, the real-time generation of synchronous audio and visual material'* (O'Donoghue, 2012). His work includes live performance. For example, the performance of *Chasing Waves* (O'Donoghue, 2011), during the 'Seeing Sound 2' conference in 2011 at Bath Spa University, involved multiple videos being directed to different sections of the screen with accompanying music. All of this was under the real time control of O'Donoghue. He also records the outputs of his performances to allow fixed media presentation of his works. An example of this type is *A Diamond Forms Under Pressure* (O'Donoghue, 2010).

These are just a few currently active audiovisual artists. There are many more significant historical figures whose work will be discussed and compared with the compositions in this portfolio.

Thesis Structure

Chapter 1. Introduction. The aims objectives and motivation behind the investigation.

Chapter 2. Historical Background. Examines historical links between images and music in science and art and how they have been applied. It also examines issues related to this such as synaesthesia and introduces important concepts in visual and musical theory.

Chapter 3. This gives an overview of the portfolio structure and details the compositional methodologies used in creating it. Technical considerations are also addressed.

Chapters 4-8 comprise the main body of the thesis and discuss and analyse the methods used in creating each of the compositions. This is where the main contributions to knowledge can be found.

- Chapter 4 describes algorithmic techniques used to create Hue Music.
- Chapter 5 describes the creation of *Colour Mirror* and *Soni-Chrome* and compares the different strategies used in their production.
- Chapter 6 is a discussion of *Theravada Colour Morph* and *Sunset.* This chapter describes how the music composition was refined and the issues related to pairing electroacoustic sound with video.
- Chapter 7 analyses the lumia components of form, colour and motion in video and how they relate and translate to sound. This is the chapter for *Space Movement Sound.*
- Chapter 8 describes the final portfolio piece, *Diffraction*. It shows how a programmatic theme was used to create closely related audiovisual materials for compiling into a finished composition.

Chapters 4-8 are to be read in conjunction with the relevant composition on the DVDs. They are preceded with a short textual commentary on the content of each video.

Chapter 9. A reflective evaluation, conclusions and description of potential future work related to this study.

Note: When mentioned in the text, portfolio pieces are highlighted in italics, for example, *Diffraction*. This is to avoid confusion between composition titles and actual words and terminology.

2. Context and Historical Background

An introduction to colour, sound, animation, music and historical developments in visual music

2. Context and Historical Background

Some of the terminology used to describe colour, sound and music will now be discussed and defined as they are referred to in the thesis.

Colour

Colour can be classified in a number of different ways. Additive colour mixing uses the primary colours of red, green and blue (RGB). This type of mixing uses coloured lights, such as those used in the cathode ray tube televisions, which are added together to create other colours. Subtractive colour mixing, which is used in printing, uses the primary colours of cyan, magenta, yellow and black (CMYK). CMYK colour mixing uses pigments which subtract, by a filtering process, other colours from light. In both RGB and CMYK colour mixing, any other colour can be created from the three primary colours. In the CMYK system a purer black is created from a separate ink.

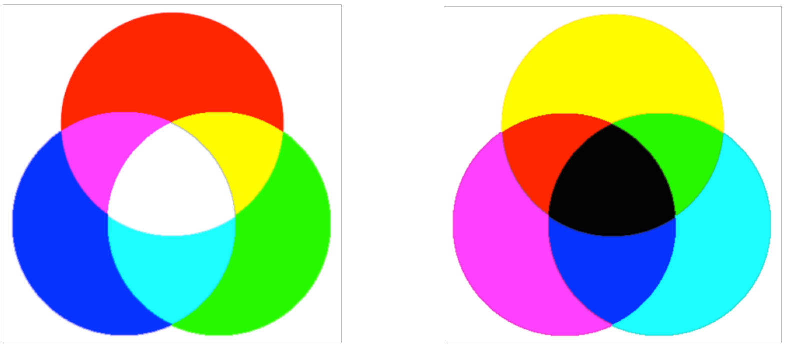


Figure 1 - Additive (Left) and Subtractive (Right) Colour Mixing

Although artists could mix two or more RGB or CMYK colours together to create a new one, it is more common to start with a wider palette of pigments that can be modified for purpose. This type of colour use is classified as the hue, saturation and lightness (HSL) colour model. There are similar systems that replace lightness with either 'value' or 'brightness'. These are known as the HSV and HSB colour models respectively. The three HSB parameters have been described as:

'Hue indicates a particular colour sensation which is dependent simply on the relevant wavelength; the inherent colour of a thing; the purest or brightest form of a colour having no white or black mixed with it. A particular colour or colour name. Each hue has an intrinsic tonal value on the chromatic scale' (Paterson, 2004, p.203).

'Saturation. The intensity or purity of a hue; the extent of its colourfulness; the strength or richness of a colour indicating whether it is vivid or dull. The colours of the greatest purity are those in the spectrum. A colour with a very low purity is on the verge of becoming grey' (Paterson, 2004, p.349).

'Brightness. The condition of being bright. The value or luminosity of a colour. Yellow has the highest value in the spectrum and violet is the darkest in the spectrum. The two extremes of brightness are, of course, black and white. The addition of black or white to a hue changes its brightness' (Paterson, 2004, p.68).

When using a palette of coloured paints a starting hue can be lightened by the addition of white paint or darkened by the addition of black paint. In watercolours, saturation would be reduced by the addition of more water to make the hue less vibrant. For an artist therefore, HSB is a more practical way of achieving a desirable colour quickly.

Sound

Just as the parameters relating to colour can be classified, there are four properties of sound that are commonly used. The first property is loudness, also referred to as sound volume, intensity or amplitude. Humans can perceive very large differences in amplitude and the logarithmic decibel scale is used to avoid unwieldy calculations and large numbers. The second property of a sound, in conventional musical instruments, is its frequency or pitch. In stringed instruments this relates to the speed at which the strings vibrate. Faster vibrations create a higher pitch. The third parameter associated with sound is that of its duration, or note length. A sound cannot exist without occupying a quantity of time. Over its duration a sound's volume will change dynamically and this is referred to as the amplitude envelope. As Roads described, *'if the amplitude of the sound changes over its duration, the curve that the amplitude follows is called the amplitude envelope'* (Roads, 1996, p.95). Percussion instruments often have a very loud and fast initial transient followed by a slower decay back to silence. The amplitude of a sound is therefore connected with its duration and described by its envelope.

The last, and perhaps least easy to quantify quality of a sound, is its timbre. Timbre is from the French word meaning stamp, in this case referring to the 'acoustic stamp' or quality of a sound. Another way timbre can be described, is that it is the property that distinguishes one instrument from another when playing a note at the same pitch. Middle C on a piano will sound different to middle C on a church organ for example.

Acousmatic Sound and Electroacoustic Music

The parameters above describe sound in basic terms. In electroacoustic music further concepts develop their own language, such as reduced listening:

'The acousmatic situation changes the way we hear. By isolating the sound from the "audiovisual complex" to which it initially belonged, it creates favourable conditions for reduced listening which concentrates on the sound for its own sake, as sound object, independently of its causes or its meaning' (Chion, 1983, p.11).

In reduced listening the cause of the sound is not considered when appreciating the music. The original sounds can even be transformed in ways that further remove them from their causal origins. This is undertaken to remove existing preconceptions and create interest in the qualities of the sound itself. Spectro-morphology (Smalley, 1986, p.61) is a means of describing sounds processed and used in this way in electroacoustic compositions:

'Spectro-morphology is an approach to sound materials and musical structures which concentrates on the spectrum of available pitches and their shaping in time. In embracing the total framework of pitch and time it implies that the vernacular language is confined to a small area of the musical universe.' He continues: *'it is sound recording, electronic technology, and most recently the computer, which have opened up a musical exploration not previously possible'* (Smalley, 1986, p.61).

Spectro-morphology therefore deals with the transformation of the pitch and timbral characteristics of a sound over time. The result of transformation can produce changes in pitch and amplitude producing complex sound objects of compositional interest. Although some of the traditional concepts of sound and music composition, such as the structural form of a piece, are still relevant, electroacoustic composition creates music of very different qualities to that created by traditional musical instruments. Electroacoustic music is well suited to the experimental nature of the videos composed for this investigation.

Historical Developments in Visual Music

'We may regard all these colours as analogous to the sounds that enter into music, and suppose that those involving simple numerical ratios, like the concords in music, may be those generally regarded as most agreeable; as, for example, purple, crimson, and some few such colours, their fewness being due to the same causes which render the concords few' (Aristotle, 350AD).

Visual perceptions have been equated to auditory ones in several ways. A common analogy is the one made between coloured hues and musical pitch. Isaac Newton touched on this in 'Opticks' (Newton, 1704). When he split white light into the familiar rainbow spectrum he equated his seven rainbow colours with the whole tone musical scale. Others extended this to the twelve-tone chromatic musical scale and a wider colour palette. Some of the correspondences favoured by artists, composers and scientists are shown in Figure 2. One thing to note about these is the similarity between some of the choices made. Rather than the allocations being completely arbitrary there are some distinct similarities, especially in the C, D, E and B notes possibly due to familiarity with the rainbow spectrum.

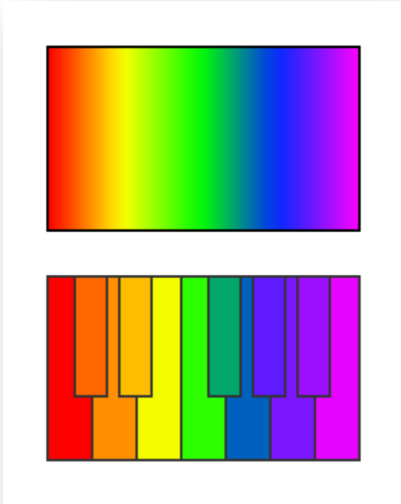


Figure 3 - Rainbow Keyboard Based on Newton's Ideas

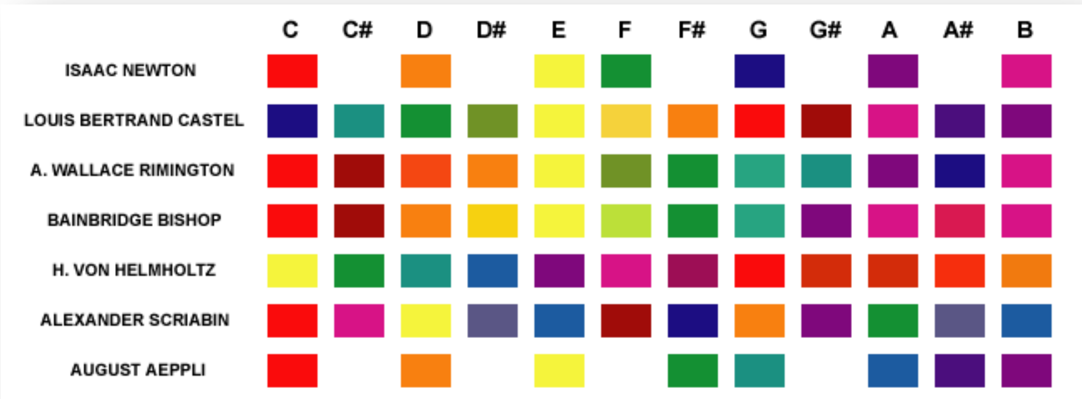


Figure 2 - Colour and Pitch Associations. Adapted from Collopy (2012)

Another relationship that exists between colour and music is the one between hue and musical timbre. Hue has been described as *'the principal way in which one colour is distinguished from another'* (Collopy, 2000, p.356) in a similar way that timbre has been defined as, *'the distinctive tone quality differentiating one vowel or sonant from another'* (Humberstone, 1991, p.1613). Furthermore, a common way of referring to instrumental timbre is as the 'colour' or 'tone' of the instrument and linguistically klangfarbe, or 'sound colour', is the German word for 'timbre'. A study by R. H. M. Bosanquet (Scholes, 1950) showed there was a general agreement between musicians for printing musical scores of different instruments in different colours. For example, a red score would be used for brass instruments and a blue one for woodwind. A similar suggestion by Albert Lavignac (Jones, 1973) resulted in a list of instruments and colour associations shown in table 1.

Instrument	**Analogous to**
Flute	Blue of the Sky
Oboe	A Crude Green Tint
Clarinet	Red-Brown, Vandyke Red, Garnet
Horn	A Brilliant Copper Yellow
Cor Anglais	Violet
Trumpets	Crimson or Orange
Clarions	Crimson or Orange
Trombones	Crimson or Orange
Cornet	Ordinary Red, Ox Blood
Bassoon	Grayish Dark Brown
Kettle Drums	Black
Side Drum	A Grayish Neutral
Triangle	A Silvery Blue
Violin (harmonics)	Blue
(IV String)	Grave Red-Brown
(Pizz)	Little Specs of Black

Table 1 - Colours and Musical Instrument Associations. (Jones, 1972, pg. 11)

Lavignac discussed these colour associations, explaining how a composer would use contrasting instruments to create a composite piece of music in a similar way an artist would use colours:

'I would add that the art of orchestration seems to me to have much similarity to the painter's art in the use of colour; the musician's palette is his orchestral list; here he finds all the tones necessary to clothe his thought, his melodic design, his harmonic tissue, to produce lights and shadows, and he mixes them almost as the painter mixes his colours' (Lavignac, 1899, p.184).

It is possible to map between specific colour and sound parameters in this way but artists have also attempted to interpret music in visual art in a broader sense. Wassily Kandinsky was part of a visual art movement based on the desire to express musical qualities in painting. Kandinsky's paintings have a free flowing style that omits representational features in favour of abstract visual strokes suggestive of musical gestures. Colours were used expressively and he went some way to explaining the link he considered to be present between colours and sounds in his classic text 'Concerning the Spiritual in Art' (Kandinsky, 1914).

'colour is a power which directly influences the soul. Colour is the keyboard, the eyes are the hammers, the soul is the piano with many strings. The artist is the hand which plays, touching one key or another, to cause vibrations in the soul' (Kandinsky, 1914, p.25).

The other major contribution of Kandinsky was his discussion on colour and form and the distinction between them (Kandinsky, 1914, pp.44–78). Colour and form are the two components available to a painter that are employed to produce the required effects.

'The value of certain colours are emphasised by certain forms and dulled by others. In any event, sharp colours sound stronger in sharp forms (for example, yellow in a triangle). Those inclined to be deep are intensified by round forms (for example blue in a circle). On the other hand, if a form does not fit the colour, the conjunction should not be considered "Inharmonious" but rather as a new possibility and, therefore, as harmony. As the number of colours or forms is endless, the combinations and effects are, also, infinite. This material is inexhaustible' (Kandinsky, 1914, pp.46–47).

Even though he was describing visual effects, Kandinsky's discussions often incorporated musical terms. The Swiss artist Karl Gerstner expanded on Kandinsky's ideas focusing more on the emotive and spiritual significance of colours. He stated:

'In our experience of colors and in our knowledge of the laws underlying them we penetrate to the ultimates that hold all life together from the origin, evolution, and structure of the cosmos to the moral category in which individual colors produce their ethical / aesthetic effect' (Gerstner, 1981, p.48).

Gerstner's artistic œuvre reflects these sentiments with many boldly coloured works. His writings also explored the relationships he believes exist between colours and sound in a similar way to Kandinsky.

Colour Organs

A more direct interaction between colour and sound was employed in the devices known as colour organs. Although colour organs could take on many forms, they commonly had a standard piano keyboard with additional apparatus that allowed the projection of coloured light. One intention was for the colour organ to play music and light simultaneously but some only produced light and required musical accompaniment. Colour organs have a long lineage, but the first assembled and documented one was by Louis Bertrand Castel (1740). He was a French monk with an interest in music and mathematics. His 'Ocular Harpsichord' (Franssen, 1991) generated some interest but did not appear to have any long term success. In 1893, Alexander Wallace Rimington patented an invention for 'Method and Means or Apparatus for Producing Colour Effects' (Rimington, 1895) which describes the workings of a device where:

'coloured light is projected on to a screen or other suitable body or surface in such a manner as to give effects in colour bearing a definite relationship to certain sound vibrations' (Rimington, 1895, p.1).

Photographic evidence (for example, Scholes (1950, p.181)) indicates that this organ was built although it did not produce music, only providing a colour accompaniment to a musical performance. After the turn of the century in 1915 Alexander Scriabin performed his piece 'Prometheus: The Poem of Fire' accompanied by a purposely commissioned colour organ in New York City. Although each revision and implementation of the colour organ was peculiar to its inventor, the ones built by Bainbridge Bishop are well documented via his book (Bishop, 1893) and can be described a little here. The diagram in Figure 4 shows the workings of one of Bishop's organs with specific components listed alongside.

'1. Ground glass tablet.

2. Ground glasses to diffuse light.

3. Reflectors.

4. White screen.

5. Upper sash.

6. Lower sash.

7. Electric light.

8. Keyboard.

A. Color-stop for keyboard.

B. Color-stop for pedals.' (Bishop, 1893, p.7)

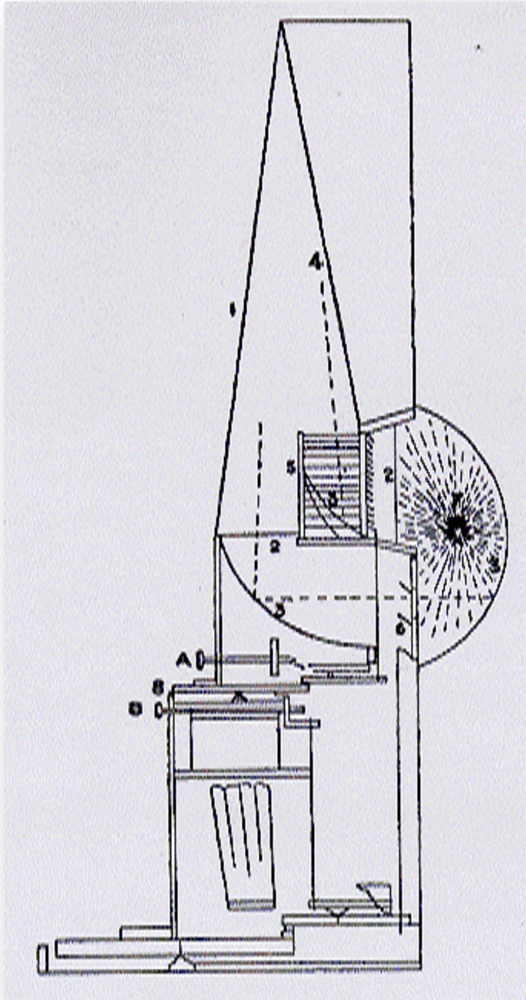


Figure 4 - Detail of Bishop's Colour Organ (Bishop, 1893, p.7)

The instrument comprised coloured glass filters through which light was projected and reflected onto the ground glass tablet above the keyboard. The mapping of colours to pitch was similar to Newton's ideas with the rainbow colour spectrum spanning across the keyboard.

'I had some trouble in deciding how to space the intervals of color, and what colors to use, but finally decided to employ red for C, and divide the prismatic spectrum of color into eleven semitones, adding crimson or violet-red for B, and a lighter red for the upper C of the octave, and doubling the depth and volume of color in each descending octave, the lower or pedalbass notes or colors being reflected evenly over the entire ground. The whole effect was to present to the eye the movement and harmony of the music, and also its sentiment' (Bishop, 1893, p.8).

It was also possible to combine colours, when playing a chord for example, and for the intensity of the lights to be adjusted. Bishop described how he believed these techniques could be used to represent music:

'I soon found that a simple color did not give the sensation of a musical tone, but a color softened by gradations into neutral shades or tinted grays did so; also, that combinations of colors softened by gradations into neutral shades or tinted grays, with the edges of the main colors blending together, or nearly together, rendered the sensation of musical chords very well indeed. The impression or sensation of the lower bass notes I could get only by low-toned or weak colors diffused over the whole field, the higher colors or chords showing smaller on this ground.' (Bishop, 1893, p.5).

There is no surviving evidence of the existence of Bishop's colour organs apart what has been written.

Thomas Wilfred and Lumia

The clavilux, (*'a name derived from the Latin, meaning light played by key'* (Stein, 1971, p.4)) invented by Thomas Wilfred, was another device that permitted performances with colours. Compared to colour organs, however, the clavilux had additional capabilities allowing the form and motion of the colours to be manipulated. These three factors together, form, colour and motion were used to create a new art form Wilfred called lumia (Wilfred, 1947, p.247), which were produced exclusively using light. There were several clavilux instruments, some of which were self-operating and internally programmed and designed for unique performances. The visual output of the instruments was a light projection of sometimes stationary and sometimes transforming coloured forms. The clavilux was capable of creating complex visual arrangements, as Stein (1971) described:

'A typical composition contains one principal motif with one or more subordinate themes. Once chosen, they vary infinitely in shape, color, texture, and intensity. The principles evident in plastic and graphic compositions—unity, harmony, and balance—function kinetically in lumia. When movement is temporarily suspended in a lumia composition, the result is a balanced picture. However, the static picture's ultimate meaning can only be seen in relation to what follows it' (Stein, 1971, p.3).

Wilfred described lumia in detail; the three principal lumia factors of form, colour and motion also had four sub-factors each and he grouped these into a 'graphic equation' as shown in Figure 5.

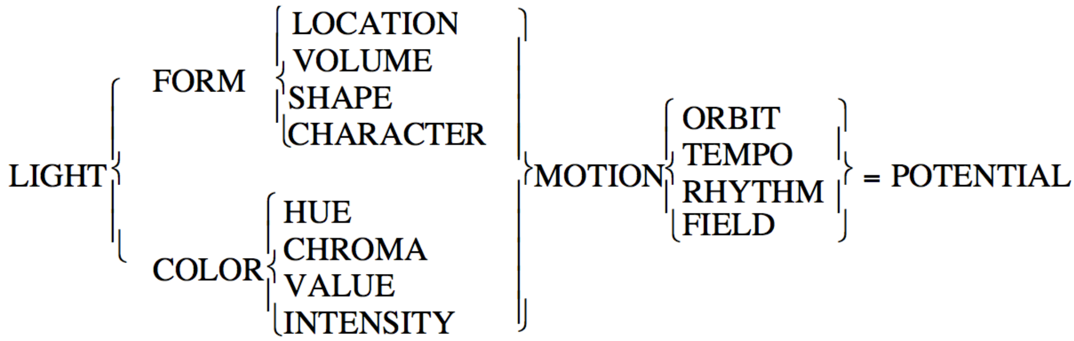


Figure 5 - Thomas Wilfred's 'Graphic Equation' of the Factors and Sub-Factors of Lumia. From Wilfred (1947, p254)

The combination of the lumia factors, to the left of the equation, produced the artistic potential on the right:

Place this inert potential in a creative artist's hand, supply him with a physical basis—screen, instrument and keyboard—and when his finished composition is performed, the last link in the chain has been forged and you have the eighth fine art, lumia, the art of light, which will open up a new aesthetic realm, as rich in promise as the seven older ones (Wilfred, 1947, p.254).

Wilfred believed he had laid the foundations for a new art that would continue to be studied and practised but there appears to be no work subsequently using lumia or the clavilux instruments.

Animated Visual Music

Film animation was progressing through its formative years during the early part of the 20th century and during the 1920s film with sound and synchronised sound also became possible. During this period a number of artists began animating musicality into a visual form; creating what Oskar Fischinger described as *'absolute, non-objective film'* (Fischinger, 1947, p.1). As physical film roll was the animation medium, it was viable to hand draw, or paint, individual frames directly onto the celluloid. William Moritz titled Fischinger's biography 'Optical Poetry' (Moritz, 2004), based on one of Fischinger's films, *Optical Poem* (Fischinger, 1937). This describes the poetic nature of the animations Fischinger created. Len Lye, an artist who was based in New Zealand created animations using similar direct film making techniques. *Colour Box* (Lye, 1935) was his first attempt at painting colour directly onto film and it was also the first film of this type to be viewed by a wider audience as it was actually an advertisement for the British Post Office. Fischinger and Lye's animations both conveyed musical qualities in their animations. To make her audience aware of this fact in her films, Mary Ellen Bute created a series of works she categorised as 'seeing sound'. In these films, Bute visualised music compositions, which in the case of her first colour film, *Synchromy No. 4* (Bute, 1938), was Bach's Toccata in D minor. In this film, orange triangles and blue squares interact, move and transform in unison with the musical dynamics and flourishes in Bach's composition. Interestingly, Bute also used the term 'visual music' on some of her title slides as shown in Figure 6.

Further developments in non-objective filmmaking continued throughout the 20th century. John and James Whitney used an analogue computer with a camera controlled by pendulums to animate colourful patterns. They were influenced, among other things, by their interest in Eastern metaphysical beliefs. Films such as *Lapis* (Whitney, 1966) contained evolving circular mandalic imagery akin to some of Jordan Belson's, similarly influenced, productions. Stan Brakhage also used various techniques such as painting onto film, scratching and baking film to produce many of his later works.

Figure 6 - Still From Synhromy No. 4: Escape, by Mary Ellen Bute

Hand Drawn Sound and Optical Soundtracks

Conventional music recordings often accompanied the above artists' animations, but novel methods of drawing sounds were also being experimented with. These 'direct' approaches to producing sounds were invented during the 1930s simultaneously by German and Russian pioneers. Andrey Smirnov (2005) listed the different techniques as:

1. hand drawn ornamental sound
2. hand made paper sound
3. automated paper sound - the Variophone as a sort of proto-wavetable synthesis
4. spectral analysis, decomposition and re-synthesis technique.

Ornamental sound was created by drawing shapes and curves directly onto cinematic film and, although used by others, it is associated with the work of Oskar Fischinger. Fischinger's drawings were 'ornamental' in that he used graphically appealing shapes that were repeated and modified to create a continuous soundtrack. He described how the shapes and colours influenced the quality of the sound:

'In reference to the general physical properties of drawn sounds, we can note that flat and shallow figures produce soft or distant-sounding tones, while moderate triangulation gives an ordinary volume, and sharply-pointed shapes with deep troughs create the loudest volume. Shades of grey can also play a significant role in drawn music-ornaments. High-contrast definition of the wave form decisively creates the prevalent sound effect, but as long as one places such a "positive" (well-defined) wave somewhere in

the foreground, one can simply overlay other wave patterns simultaneously by using grey shades for the secondary sound effects' (Fischinger, 1932, p.1).

Figure 7 is an example of the types of ornamental soundtracks also used and drawn by the Russian pioneer Arseny Avraamov in Moscow between 1930 and 1931. Norman McClaren created music in a similar way, with the results clearly demonstrated in *Synchromy* (McLaren, 1971) where the picture and sound are both made from the same hand-painted images.

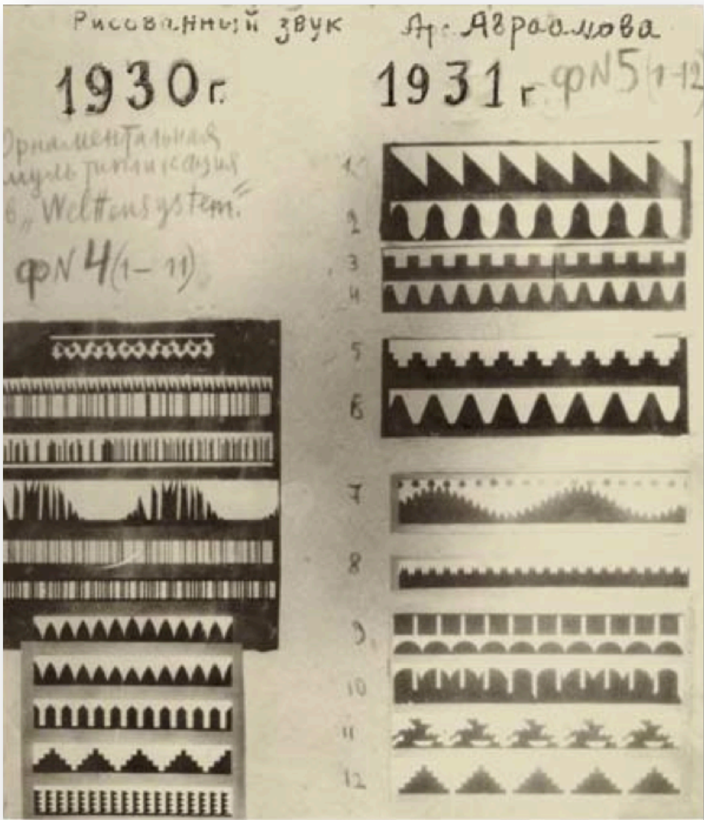


Figure 7 - Examples of Hand-Drawn Ornamental Soundtracks.
From (Smirnov & Liubov, 2011, p.11)

Hand made paper sound was essentially the same technique as ornamental sound but the sound shapes were first drawn onto paper. This was the approach taken by Rudolf Pfenninger in his early direct sound experiments. Pfenninger developed a technique he called *'Tönende Handschrift (Sounding Handwriting)'* (Levin, 2003, p.53). By analysing the shapes produced by real sounds recorded onto film he was able to recreate his own soundtracks. He drew waveforms onto paper that were similar to the ones he had analysed and afterwards transferred them to film either by scanning or by recording with a film camera.

The third method, automated paper sound, involved a mechanical device known as the Variophone optical synthesiser. The Variophone was actually used to produce synthesised music rather than to create soundtracks to accompany animations. It comprised a camera and number of paper disks into which waveforms were cut. The disks were combined and rotated at varying speeds and the moving shapes captured on the camera to produce an optical soundtrack. The variophone was used to help recreate synthesised versions of compositions such as Nikolai Timofeev's Waltz, Richard Wagner's Ride of the Valkyries and Franz Liszt's Rhapsody No. 6.

Finally, the spectral analysis techniques of Yankovsky sought to analyse the content of various waveforms and reproduce them graphically so they could later be combined and resynthesised. This was similar to Pfenninger's method but was made through observation of the spectral characteristics of sounds rather than their time varying qualities.

'Yankovsky firmly believed in the possibility of creating a universal library of sound elements based on the model of Mendeleev's periodic table of elements. Its graphic curves, the 'spectrostandards', were semiotic units which, when combined, formed new hybrid sounds. He also developed several sound processing methods including pitch shifting and time stretching based on the separation of spectral content and formants, resembling recent computer music techniques of cross synthesis and the phase vocoder' (Smirnov & Liubov, 2011, p.11).

Such classification of sounds allowed Yankovsky to create any sound he desired and also permitted manipulation of the individual sound elements through processes such as time stretching, for example.

Oramics and UPIC

Other methods of optical sound production involved technologies emerging in the second half of the 20th century. Oramics, discussed by Hutton (2003) and invented by Daphne Oram in the 1950s, was a technique where drawings made on 35mm camera film were processed to manipulate a hardware sound synthesiser. The Oramics machine shone light over the moving film and the light's intensity was modulated by the drawings as it passed through. The light modulation was measured and converted into control information that drove oscillators and other sound synthesis parameters present in the device. The Oramics machine was therefore using the film drawings as control information rather than to produce sound directly. Similarly, Iannis Xenakis, used dedicated apparatus that utilised drawn control and synthesis data, and compositional information. The Unite Polyagogique Informatique du CEMAMu[2] (UPIC), completed in the late 1970s, enabled the user to draw sound waveforms and envelopes on a digitizer tablet. The musician would compose music from these waveforms by drawing the desired pitch information over time across the x-axis on the UPIC tablet. A computer would then reproduce the entire composition.

[2] CEMAMu, the Centre d'Etudes de Mathématique et Automatique Musicales. Xenakis' arts and science research centre in France, later renamed CCMIX (Center for the Composition of Music Iannis Xenakis).

Sonification

Whereas the preceding discussion highlights artistic interpretation between musical and visual material, similar techniques have been investigated for scientific purposes. Sonification is a technique that uses '*audio to convey information*' (Bonebright et al., 1999) about the data being sonified. It can also be compared with Chion's causal listening mode (Chion, 1994), where a sound is auditioned to gather information about its cause. An example of sonification is Thomas Hermann's 'Tweetscape' (Hermann et al., 2012) experiment. In this study, Twitter posts were mapped to audio recordings of typewriters and followers' replies were mapped to samples of whispers. The resultant Tweetscapes permitted listeners to determine how many followers the tweet authors had and the number of replies each post received simply by listening to the sonification.

A number of sonification studies have also been undertaken to create sound from visual data. Firstly, Giannakis (2001) investigated a system whereby small square picture mosaics could be linked together to create combined tones and timbres. This was an experimental synthesis technique that used visual metaphors and interpreted them in sound. The studies from Meijer (1992) and Yeo and Berger (2005) both used pixel scanning techniques to drive synthesis programmes that gave information about pictures. In the case of Meijer's vOICe (Meijer, 1992) system, the intention was to aid blind people 'see' the environment purely with sound. Another experiment by Margounakis and Politis (2006), used 'Chromatic Synthesis' to convert the colour information in a picture to pitch and melody. An image was scanned left to right and top to bottom, as one would read a book, and coloured 'blocks' with contiguous pixels of the same colour were converted into different musical melodies.

Although sonification is not primarily intended to produce music, there have been attempts to assign greater importance to the aesthetic qualities of sonified sound. One of the first sonification concerts took place in Sydney in 2004 and was titled the 'Listening to the Mind Listening', curated by Stephen Barrass (2004). Ten pieces were performed, each created from the same data that was taken from a set of electroencephalograph (EEG) traces of a person listening to a piece of music. Composers were invited to use the recorded EEG data to produce music that would be performed in a concert setting. An example of the type of music performed is David Payling's piece 'Listen (Awakening)' (Payling, 2004) that used the data to drive a number of different synthesis techniques, the results of which were mixed and panned to a large array of spatialised monitor speakers. The audiovisual composition, 'Patterns of Organic Energy' by Sylvia Pengilly (2004), used sonification techniques to produce sound from video information. Pengilly described how the piece *'is a music/video work in which the sounds used for the music were derived directly from the keyframes of the video, thus creating an intimate link between video and audio'* (Pengilly, 2004, p.118).

Synaesthesia

Another topic related to the connection between sound and vision is the 'condition' known as Synaesthesia. Synaesthesia (syn for united, joined and aisthesia – sensation, or union of the senses) occurs when:

'stimulation of one sensory modality automatically triggers a perception in a second modality, in the absence of any direct stimulation to this second modality' (Harrison & Baron-Cohen, 1996, p.3).

An example is when a person hears or reads a word, they perceive colours that they associate with its vowels and consonants. The word 'associate' is used cautiously here as the cross-modal perception is not a learned one, it is an innate predisposition that the synaesthete has no control over. Since there are five human senses, there are several possible connections between them. For example, a smell could be perceived by the sense of touch. Interestingly for this study, however, is that the most common manifestation of synaesthesia has been shown by Baron-Cohen (1996) to be coloured-hearing. This is where the person perceives sounds as colours or vice-versa. Although this appears to validate Newton's and others colour-sound correspondences, the associations cannot be generalised between all people with the same cross-modalities. For example one synaesthete may perceive the colour yellow as one sound, and a second synaesthete as another. An example by Motluk (1996) of two synaesthetes discussing their individual perceptions highlights these differences...

'If you asked me the colour of a "horse", I'd rather think of an actual brown horse... H as a letter is dark red. But it doesn't affect a word like "horse". Well I point out it does for me. 'Horse' is orangey, much like the letter H. The word 'milk' is green because M is green; 'water' is a yellow word, 'bread' blue, 'olive' white and 'snow' red' (Motluk, 1996, p.277).

One theory of how synaesthesia is developed is that the link between the corresponding stimuli could be physiological or emotional. For example, when two stimuli excite two different senses but produce the same physiological response those stimuli could become linked. A sudden change in pitch or loudness in music could create a physiological reaction similar to one experienced when exposed to flashing colours for example. Subtler stimuli and reactions could also be experienced and it is possible that many people have some degree of developmental synaesthesia. Cohen showed a greater prevalence of synaesthetic response among children, indicating that it is a trait many people share but gradually lose as the learned, culturally ingrained, associations become more dominant. Some of the artists and musicians described in the preceding paragraphs either claimed to have had synaesthesia, or exhibited traits that could class them as synaesthetes. It could also be speculated that artistic inspiration can come from many sources that interact to produce ideas and insight.

Summary

This concludes a review of important people, innovations and concepts in the development of visual music composition and some of the relationships that exist between sound and image. These have been influential in the production of the creative works and the development and refinement of the composition techniques.

This page included for formatting purposes

3. Portfolio Overview and Compositional Strategies

This chapter gives an overview of the content of the composition portfolio. It summarises the workflow, technologies and techniques used in its creation and describes how the compositional approach changed as the portfolio progressed.

3. Portfolio Overview and Compositional Strategies

One of the first areas under investigation in the portfolio was the relationships that exist between colours and sounds. Algorithmic techniques were employed, as it was believed there might have been one way to map from a colour to a sound that was applicable to all images and all people. This approach worked, in the sense that colours were represented by sounds, but it produced repetitive music with little variation that was largely the same regardless of the colours being used. As further compositions were created, the dependency on algorithms reduced. The composer was able to develop freely the interplay between colours and sounds and take into account other visual and musical relationships. The result of this was more sophisticated compositions with greater audiovisual interaction and structural intricacy. Figure 8 shows how algorithmic processing was gradually replaced by composer arrangement during the first three portfolio pieces.

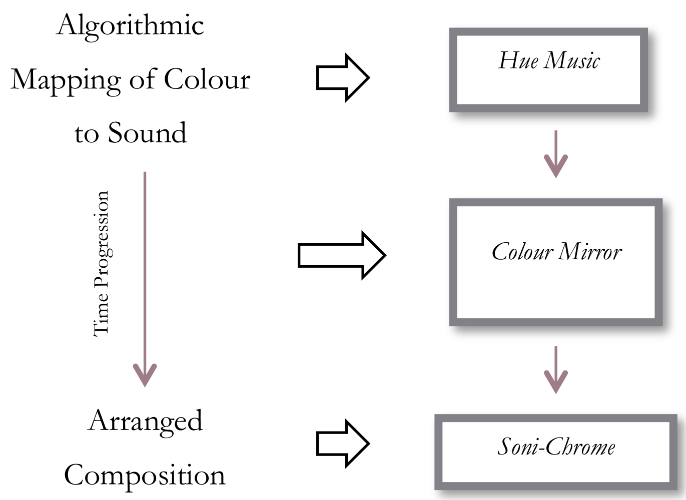


Figure 8 - Composition Methods used in the Early Portfolio Pieces

Hue Music was created entirely algorithmically and *Soni-Chrome* was arranged entirely by the composer. Between these two sits *Colour Mirror*, which used a combination of both techniques and allowed transition from one method to the other. This was a formative period and using contrasting production techniques here meant experience was gained in the results that could be achieved by using the different approaches. Further work was attempted to refine the Hue Music algorithm but was abandoned as it was felt the process was becoming more of a programming exercise than a musical composing one. With the author already having an engineering and technological background, the development of compositional abilities was deemed more desirable than a further refinement of coding skills.

After this initial investigatory stage, more emphasis was placed on how the audio-visual relationships could be explored without algorithms. The composer improvised with the techniques of material transference and compositional thinking. This was a process of continual experimentation and interpretation between musical and visual content and was more gradual, as the content of one medium had to be at least partly completed before the other could be started. This led, in some pieces, to one medium being dominant and producing differing results depending on the nature of this balance. In the first of these later pieces, *Theravada Colour Morph*, the music influenced the content of the visual form completely; the solid arrow pointing from music to visuals in Figure 9 indicates this. This musical dominance progressively weakened in later pieces and a more fluid relationship was established between media as indicated with the bi-directional arrows.

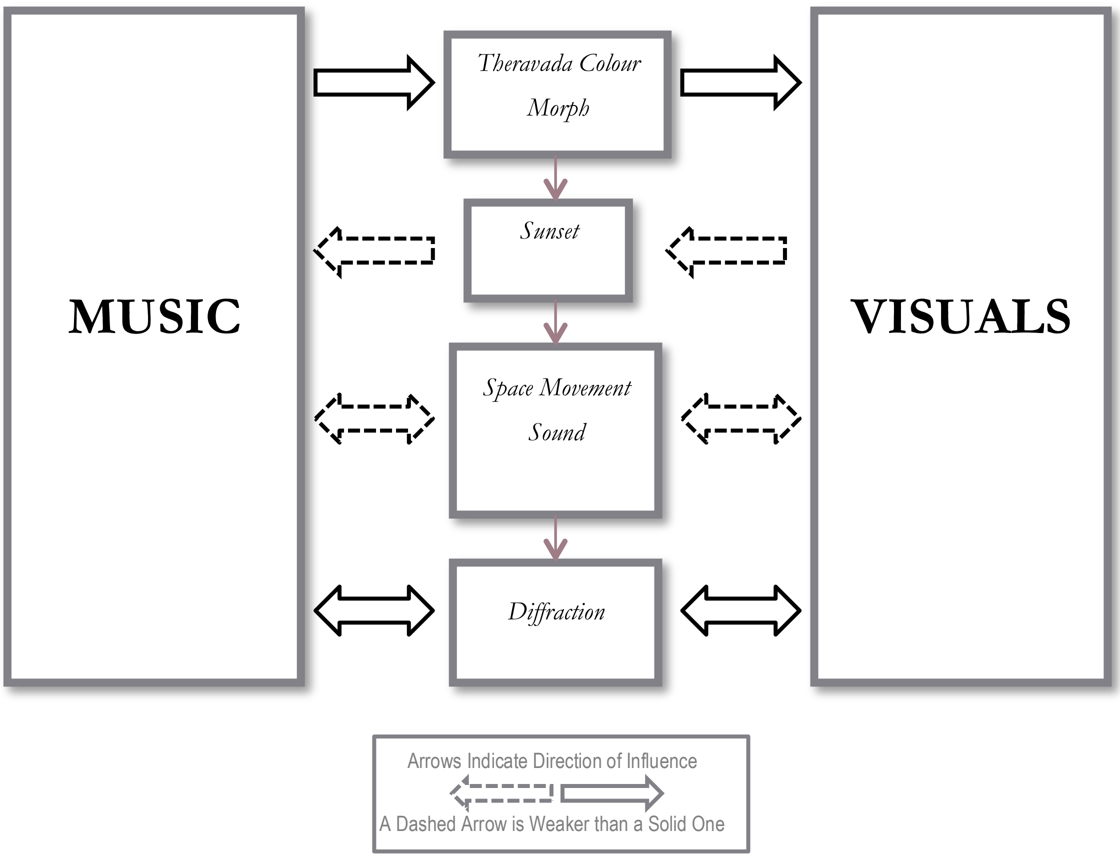


Figure 9 - The Direction of Influence from One Medium to the Other in the Later Compositions

Theravada Colour Morph was musically dominant and *Sunset* visually dominant. This was more in relation to the overall design concept of *Sunset*. The slowly evolving nature of the video was expressed by similar characteristics in the music. The video was completed before the music, but after watching it several times the musical composition progressed largely independently without having to refer back to it continually. The final two pieces, *Space Movement Sound* and *Diffraction*, were produced by an increasingly more fluid process and transference between media. Attention was switched from one medium to the other more frequently and the results of this are most strongly evidenced in *Diffraction*. In these final pieces the relationship between music and visuals is considered to be more evenly balanced than in the earlier compositions and is possibly due to their being created at a finer resolution. Although the portfolio ends with a stronger bi-directional influence between media, it was felt that successful work can still be produced by the uni-directional approach employed in earlier works.

Music Composition

One challenge in composing music is to create a sense that the sounds and structure have a shared musical purpose. Although sounds can be combined easily, and even randomly, this may not necessarily produce a piece of music with a coherent theme throughout. In the electroacoustic realm one way of describing this coherence is as a '*sonic- landscape*' (Field, 2000, p.44). Field's landscape morphologies consist of four types:

- *'hyper-real*
- *real*
- *virtual*
- *non-real'* (Field, 2000, p.45).

The first type, hyper-real landscapes, contain material that is recognised as real, but has been treated in some way to exaggerate or enhance the sound to make it appear *'more than real'* (Field, 2000, p.45). Real landscapes use non-destructive audio processing and simply reproduce the recording without modification. Neither of these types of landscapes was used extensively in the portfolio. There are brief moments where untreated sounds appear, but they are within predominantly virtual and non-real landscapes as described next.

Virtual landscapes are created by pure simulation. Describing the piece *'Red Bird'* by Trevor Wishart, Field stated, *'Although the spaces that Wishart creates are highly plausible, tiny details in the sounds suggest that we might not be listening to a recording of reality'* (2000, p.46). Finally, heavily processed or synthesised sound can create a non-real landscape that *'does not contain any real world gestures or naturally occurring sounds'* (Field, 2000, p.47). These four morphologies are created through appropriate treatment and presentation of audio materials, as Field explained:

'For maximum credibility, the contextual information exposed by all sounds within a particular sonic landscape must match. If the sounds within a simulated environment possess similar spectral types the perception of reality will be strengthened. In such a situation, it is clear to see that if a sound possesses an unexpected timbre, even though its gestural and contextual information are consistent with spatial information, the whole soundscape might no longer be trusted to be an authentic representation of reality' (Field, 2000, p.44).

A coherent piece will give the impression of all the individual elements belonging together in the same environment, rather than simply being a collection of unrelated sound objects and conflicting environments. This is not to say the landscapes cannot be combined to create different effects. Creating the impression of a real world recording moving through a virtual acoustic space, for example, can create an intersection between a real environment and a virtual one. In Field's (2000) taxonomy then, the resulting portfolio pieces presented here are predominantly virtual and non-real type landscapes with real world environments included in places. *Soni-Chrome*, *Theravada Colour Morph*, *Sunset* and *Diffraction* are virtual landscapes. *Sunset* and *Diffraction* contain elements of real environments blended with virtual ones. Hue Music and *Colour Mirror* are non-real sonic landscapes; created entirely from synthetic sound sources. *Space Movement Sound* is a hybrid combination between a virtual and non-real environment. The music made use of synthetic timbres, natural sounds and heavily transformed ones to create interaction between the two types.

The Audio-Visual Production Workflow

The composition of the audio-visual works primarily involved the stages of:

1. Recording and preparation,
2. Arrangement and composition,
3. Mixing, mastering and rendering for delivery format.

These stages applied to both music and video composition individually, and also in some part to the combined media. The phases were not strictly linear, as quite frequently a composition seemed to be complete but on viewing it became apparent that something was out of place or missing. If this was the case it was sometimes necessary to go right back to the first stage and prepare new material that was placed where needed in the composition. The work could then proceed again through arrangement, mastering and rendering.

1. Recording and Preparation

In cases where found sounds were used, these were mainly captured on a portable field-recorder. The use of a field-recorder allowed an immediacy to capture sounds that may have suddenly occured, like a person running past, opening a gate and running off into the distance, for example. Being able to capture sounds in an opportunistic way made for some unique recordings, ones that could not be recorded in a studio. There was also an inherent spatial quality contributed by the environment and it was possible to move the position of the recorder in real time to track movement or change the spatial positioning of sounds. Once recorded, all the files were taken from the field recorder memory, auditioned in an audio editor and interesting sections trimmed out for later use. The decision on which sections were useful was based partly on reflection on the visual imagery that had also been captured and partly on the sounds own individual spectral and dynamic qualities. When scanning through a long recording the majority would usually consist of noises from traffic and people talking and other everyday sounds that did not possess anything distinctive or unique. There would be times, however, where a sound would appear briefly, such as a bell being hit, that was interesting within an otherwise mundane sound collage. These were the sections that were trimmed out and transformed with various spectromorphological processes to enhance further their musical qualities and identification with the desired sonic and audiovisual landscapes. The sound library was also constructed to contain different categories of 'instrument' that may typically be found in musical compositions. This meant producing short percussive elements, longer evolving textural sounds and others designed to inhabit specific frequency ranges such as bass parts.

A similar approach was taken when creating synthetic sounds. A major difference with these types of sounds was that it was possible to predetermine their qualities before recording and rendering. Their duration and dynamic behaviour could be modelled with specific envelopes and their overall timbral character carefully tuned with filtering, modulation and other synthesis parameters that were available. There was, therefore, usually less time consumed in editing rendered synthesised sounds as the programming before rendering was designed to produce a completely finished sound.

2. Arrangement and Composition

The structural phase of the compositions began when the sound library contained enough contrasting and related sounds and sound objects to allow the music to begin taking shape. The primary technological process taking place here consisted of compiling sounds horizontally in time and vertically as a layered montage inside the digital audio workstation (DAW). Layering multiple sound objects together as a montage permitted a complete spectral picture to be created, and arranging them across a timeline produced the structural form of each composition. This method of working has been described as a bottom up approach: *'works based on materials they (the composers) have assembled which they subsequently manipulate and place in sequences to form structures'* (Landy, 2007, p.34). This required an intuitive approach to composition; gradually expanding the structure as the compositions developed. A top down approach would require a predefined structure that dictated the placements of sound objects from the library. Top down structures were sometimes imposed and transferred between media; when the video or music were completed in entirety, as in *Theravada Colour Morph* and *Sunset* the structure of the other medium had to follow.

3. Mixing, Mastering and Rendering for Delivery Format

These were the final stages in the production process but they were often combined with the composition and production stages already described. The flexibility of the DAWs used meant the arrangements could be modified all the way until the final master was rendered. Mixing involved ensuring all the sounds occupied a specific frequency range and were not masked by other sounds. Their dynamic behaviour was also adjusted to ensure they were not too loud or too quiet at any point. Finally their positioning in the stereo field was adjusted to create an evenly balanced spread of sounds. Mastering involved using any equalisation, dynamic and enhancement type processes that were required to produce as clear and detailed a sound as possible before being rendered for later use with the video. To ensure a large dynamic range in the finished audio, all audio tracks were mastered using the K20 standard devised by Bob Katz (2007). K20 is designed to be used for, *'large theatre mixes, "daring home theatre" mixes, audiophile music, classical (symphonic) music, "audiophile" pop music mixed in 5.1 surround'* (Katz, 2007, p.190). Mastering to this standard therefore assures high quality reproduction over a good sound system such as a diffusion system[3] that may be used at concerts and conferences. All the portfolio compositions were created in 2-channel stereo. This means they can be presented on standard audiovisual playback devices but also scaled up to multichannel systems where available.

Technology Platforms for Composition

The decision of which technologies to use during the composition process was mainly made through familiarity with, and availability of, certain hardware and software with some investigation to consider alternatives. Nuendo (Steinberg, 2012) was the main DAW of choice. This was through familiarity and experience but also due to its technical capabilities with audio and video. It is possible to include video files on the same timeline as audio to allow synchronisation of video and audio material. The automation and audio editing features in Nuendo are also very flexible making the audiovisual workflow very intuitive. A secondary DAW, Reaper (Frankel, 2012), was used mainly for sound design purposes. Reaper has very good facilities for time stretching, methods for complex routing of audio and has a large bundled tool kit of signal processing effects. One classic analogue technique, which essentially developed from tape manipulation methods, is that of time stretching and time compacting, which in digital audio can be achieved in numerous ways. Reaper has several algorithms for adjusting the duration of existing audio recordings ranging from Fast Fourier

---

[3] *'A sound diffusion system is hardware, software, or a combination thereof, used to facilitate the presentation of electroacoustic works via loudspeakers in a live concert situation'* (Mooney, 2006, p.168). A typical layout of a diffusion system would be eight mid and high range monitors in a circle surrounding the audience with one or two subwoofers for the reproduction of low frequencies. There are therefore more channels for audio reproduction giving the artist more creative potential during composition. Audiovisual material is often presented over two channels, one speaker either side of a screen, as on a standard flat screen television, however. Production using only two channels will therefore accommodate these situations without having to down-mix or omit the extra channels.

Transform (FFT) techniques to granular processing. Each of these produces slightly different results allowing a large range of timbres to be created from a relatively simple process. The main transport can also cause the audio to be slowed down or speeded up, allowing a rapid manipulation of individual source materials or a full combined audio mix. The other area that Reaper excels in is its flexible audio routing system. It follows the typical structure of inserts, send and return busses, but these can be routed quite freely and even have feedback, if desired. It is possible, for example, to have a modulation effect on the original audio channel, send this separately to delay and reverb effects and have the reverb effect sent to a further chorusing effect set up as another insert on a different channel, as shown in Figure 10. These experimental routing arrangements may be possible in other workstations but Reaper handles it in a very intuitive way and can create unexpected and fortuitous results.

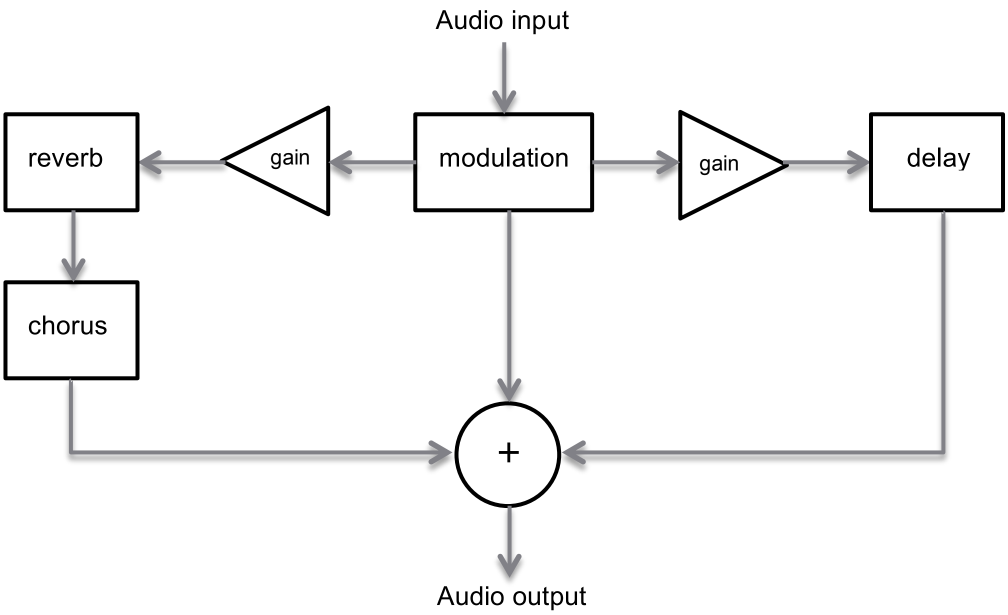


Figure 10 - An Example of Effects Routing in Reaper

Alongside these two primary audio workstations, a number of other programs were used at various stages for sound and video processing and synthesis. MAX/MSP (cycling '74, 2012) was used considerably when algorithmic processing was needed. MAX/MSP allows bespoke audiovisual systems to be programmed for specific tasks and was invaluable in this respect. Another audio program used regularly was Reaktor by Native Instruments (Instruments, 2012). This is similar in some respects to MAX/MSP but has an instrument and object library that is more suitable for generating synthesised sounds. For some of the later visual work, Quartz Composer (Apple, 2012) proved very useful for creating abstract animations. This allowed algorithmic and mathematical generation of coloured sequences for use in *Diffraction*. For the majority of the video work however, Sony Vegas (Sony, 2012) and Adobe After Effects (Adobe, 2012) were used each for their strengths, After Effects for rendering animations and visual effects and Vegas for compiling the finished work and preparing it for final render.

Considerations in Video Production

The technologies used to create the video and musical compositions had similar capabilities. Although this allowed the video to be treated in similar ways to sound, entirely different results could be produced. One example where this manifested itself was when mixing two video clips together by adjusting their transparencies. If two musical instruments were mixed, for example, by adjusting their relative amplitudes it could give the impression that they were playing in duet and forming a combined musical performance. This did not work in the anticipated way when two clips of video were mixed through blending. Each video scene maintained its own form and content, which could be identified, and even though blended together they still behaved independently in a visual sense. There were, for example, certain familiar combinations of objects, such as a horizon line dividing the sky and terrain across the horizontal. When another video with a similar setting was mixed with the first, both maintained their perceptual independence with two obvious horizon lines. This did not produce the desired effect of creating a new single unified scene from the two separate ones. This effect is demonstrated in the third image of Figure 11, where the two images are blended through transparency adjustments. This could in some part have been resolved by making sure the original footage was captured in a useable form, by ensuring the horizon lines were in the same position, for example. The primary method of video capture, however, mainly with the use of a handheld high definition (HD) video camera, meant there was inconsistency between framing and settings between each shot. Two such scenes blended together rarely produced useable material.

Landscape 1

Landscape 2

Landscapes 1 and 2 Blended by Adjusting their Transparencies. Each Landscape Maintains its Individual Identity

Landscapes 1 and 2 ‘Integrated’ with Chroma-Keying. The Landscapes Form a More Unified Scene

Figure 11 - Combining Images Using Transparency Adjustments and Chroma-Keying

Chroma-Keying

One solution to this was to extract individual objects from one film by eliminating the background and superimposing them onto the other footage. This is commonly used in film and television where single objects, such as people, are recorded against a key colour screen so they can be later composited using chroma-keying against a new background. Chroma-keying is:

'A function that will render a specific color in a layer transparent. For example if you shoot someone in front of an evenly lit blue screen, you can use a chroma key function to render the blue completely transparent, thus revealing underlying video layers' (Long & Schenk, 2011, p.448).

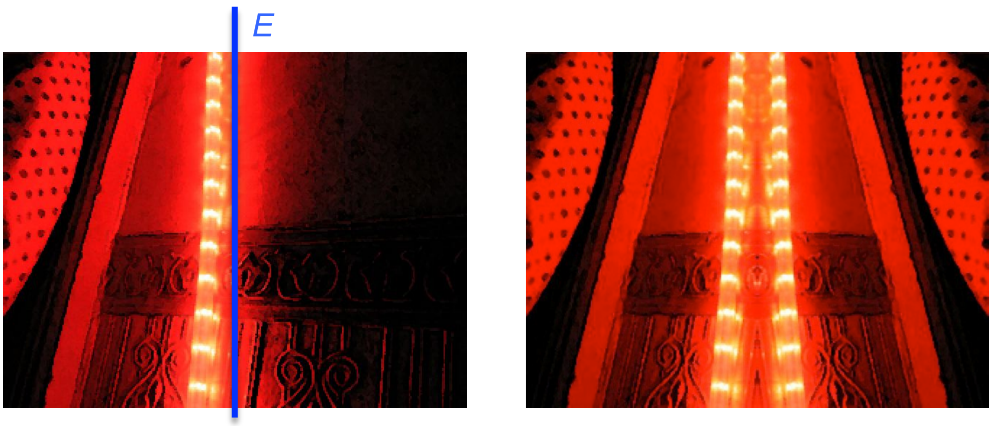
A classic example is the presentation of a weather forecaster in front of a green screen so a weather map can be superimposed into the background. Although it is common to use green or blue screens in film work, digital keying allows any colour to be chosen as the key. When this technique was used in a less conventional manner, an object or background colour from one video was chosen as the key colour. The non-keyed objects from that video were then overlaid on top of others. When applied to material that was not originally recorded with the intention of chroma-keying, for example in a complete moving scene which contained several objects, keying techniques created interesting cut out effects and sometimes the keyed image appeared to be part of the background image in the second video. This was a completely different end result than would have been achieved by blending the videos using transparency techniques, but it seemed more analogous to results obtained by mixing sounds by addition and gain adjustments. Even though the movement in one video did not necessarily match the movement of the other, the visual integration was much tighter. Although Figure 11 shows the results of keying two similar scenes together using this method, it was possible to juxtapose entirely unrelated visual material but still make them combine more convincingly. Chroma-keying therefore proved a very useful tool in creating the video compositions.

Symmetry in Video Production

Techniques involving symmetry were also used in several places in the video compositions. The principle reason for this was to create patterns and harmony where it was otherwise absent. As many of the videos were captured with a hand held camera, this resulted in some useable footage but also long sections that were somewhat mundane and visually uninteresting and incoherent. Imparting a symmetrical kaleidoscopic effect converted this into shifting abstract imagery, which was more suitable for the aims of audio-visual compositions at the core of this research. Images that contain symmetry can appear well balanced and proportioned and reflect the harmonious qualities found in music, as Weyl (1952) explained:

'the word symmetry is used in our everyday language in two meanings. In the one sense symmetric means something like well proportioned, well balanced, and symmetry denotes that sort of concordance of several parts by which they integrate into a whole. Beauty is bound up with symmetry. Thus Polykleitos, who wrote a book on proportion and whom the ancients praised for the harmonious perfection of his sculptures, uses the word, and Dürer follows him in setting down a canon of proportions for the human figure. In this sense the idea is by no means restricted to spatial objects; the synonym "harmony" points more toward its acoustical and musical than its geometric applications' (Weyl, 1952, p.3).

One form of symmetry used in the portfolio is bilateral symmetry. This is where, *'A body, a spatial configuration, is symmetric with respect to a given plane'* (Weyl, 1952, p.4). This type of symmetry can be seen in nature, the left and right wings of butterflies, although not exact replicas are largely symmetrical about the centre line of the butterfly's body. In images, bilateral symmetry can be created simply by reflecting one half of an image onto the other half as demonstrated in Figure 12. When applied to moving images this creates an evolving pattern of lines and colours that appear to move outwards or inwards relative to the plane of reflection. Examples of this can be seen in *Soni-Chrome* and *Colour Mirror*.



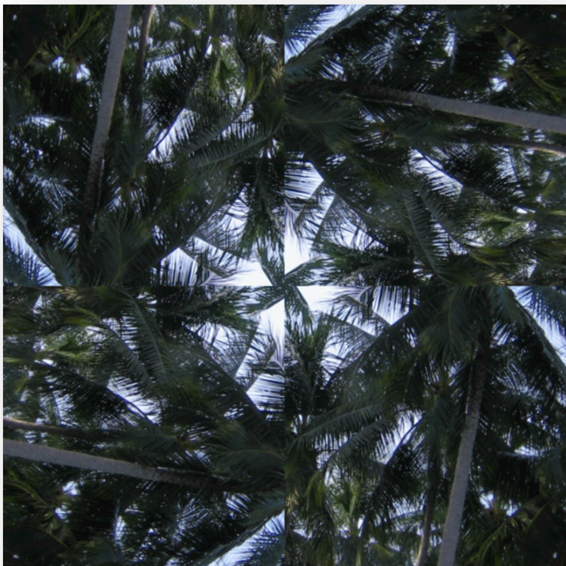
Original Image. Plane 'E' in Blue

Left Side of Original Image reflected in Plane

Figure 12 - Reflecting One Half of an Image in a Plane to Create Bilateral Symmetry

Another type of symmetry used in the portfolio is rotational symmetry. In this, a small portion of an image is selected and rotated several times around a point. In Figure 13, the bottom right quarter of the image is repeated 4 times by rotating it 90 degrees about the centre of the image. It is also possible to select a smaller portion of the image and rotate it a greater number of times for more complex symmetry. With additional mirroring this creates kaleidoscope type effects, several of which were used in *Soni-Chrome, Colour Mirror* and *Space Movement Sound.*

Original Image. Centre Labelled by 'O'



Highlighted Section of Original Image Rotated 90 Degrees Around 'O' to Produce Rotational Symmetry

Figure 13 - Creating Rotational Symmetry

4. Hue Music

This chapter details the Hue Music algorithmic program that creates timbral soundscapes from coloured pictures. It addresses the first aim of this investigation - to use material transference techniques for producing visual music. Specifically, the program converts from colours in the visual domain to timbres in the audio domains by analysing the colour content of a picture and mapping it to sound amplitudes to produce musical soundscapes.

See DVD 1. Hue Music, a Standalone application to run on Macintosh or PC Computers. The full MAX MSP Patch is also available. The standalone program will play sound and render video automatically when run. Instructions how to use the program further and load other images are available on the interface. The original sound files are available in the labelled folder on the DVD.

4. Hue Music

The motivation for making Hue Music was an idea that it might be possible to convert pictures automatically into music thus creating different compositions based on the content of the pictures. Some inspiration was taken from the sonification studies referred to in Chapter 2, but the intention was to place more emphasis on the aesthetic qualities of the music rather than there being a scientific basis as with sonification. There were two main processes involved in converting the images to music, analysis of the colours and mapping this information to sound. One method of analysing an image is to scan through its pixels row by row and generate a sound that responds to the brightness and position of each one. Several programs, such as Metasynth's Image Synth editor (Spiegel, 2006) and the vOICe (Meijer, 1992), use this technique. In both these, pixel lightness and vertical position information are used to determine amplitude and pitch values of sine wave oscillators. Alexander Zolotov's Virtual ANS (Zolotov, 2014) is a further enhancement of this technique allowing more advanced manipulation and editing functionality. The sonic results of this type of mapping ranges from randomly changing pitched sine tones to more fluid glissandi and drone like textures but all with a synthetic quality. By starting with a series of pre-recorded sound files possessing a diversity of sonic textures in Hue Music*,* it was envisaged that music with greater variety would be produced. Instead of using individual pixels, which creates rapidly changing pitches in vOICe, it was decided to use larger sections of the image by breaking it into a grid pattern. This would also potentially be less processor intensive and avoid the rapid granular changes in pitch.

Colour Analysis and Sound Mapping

At the heart of the image analysis part of the program for Hue Music is a routine that breaks the image into an 8x8 grid pattern, identifies the colour hue value of each part of the grid and quantises it to the closest colour in Table 2. Eight hues can be identified, and these are mapped to different timbres. Although this permits the mapping of eight colours to eight sounds, only seven are used. White is equated to silence. Using an artistic analogy, the white areas of an artist's canvas have not been coloured. Seven sounds would also provide enough opportunities for timbral layering and more sounds than this could be potentially confusing, as Landy stated, *'Those who choose layering as a tool of construction tend not to use too many sound types in a composition in order to avoid confusing the listener. The number of layers of sound does not normally exceed four at any given moment'* (Landy, 2007, p.69). Furthermore, analysis of more colours would diminish the elegance of the use of the two primary RGB and CMYK colour systems shown here in Table 2.

1	2	3	4	5	6	7	8
Black	Red	Yellow	Green	Cyan	Blue	Magenta	White

Table 2 - Hue Values Analysed for Timbral Association

As an example of how the analysis and mapping operates, consider the image in Figure 14, a simple half blue, half yellow image. This picture is loaded into Jitter and broken down into an 8 x 8 grid as shown in Figure 15. This produces 64 subsections.

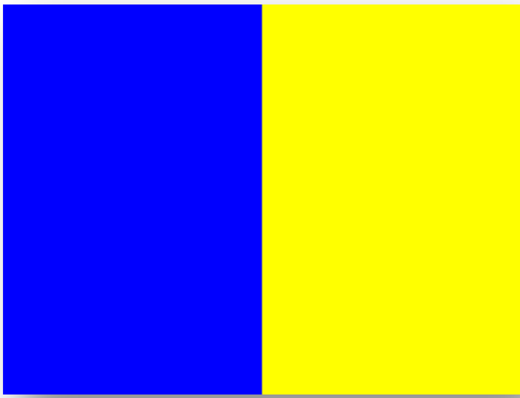


Figure 14 - Blue - Yellow Image

The colours in the subsections are counted and, in this case, produce values of 32 grids of blue colour and 32 of yellow. These numbers are then processed through the sound generation routine that produces a sound that is a combination of the blue and yellow timbres at equal amplitude.

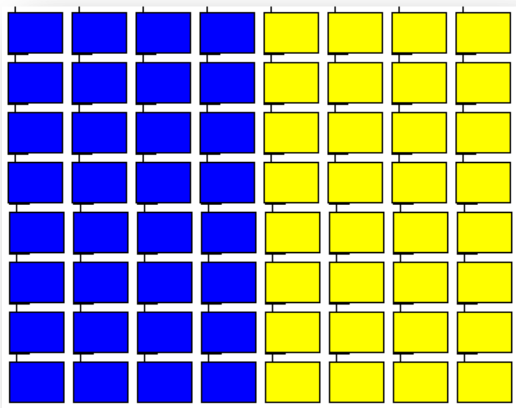


Figure 15 - Blue - Yellow Grid Pattern

Hue Quantisation

The preceding image contains only blue and yellow, which are among the hue values identified in Table 2. A more complicated problem is when the image contains other hue values not accounted for. This would be the case for many photographs of real scenes and when this occurs the colours are quantised to the nearest hue value based on their proximity to the primary colours. As an example of this process, the aquarium photograph in Figure 16 is used. The musical results from this image will be compared to others later in this chapter.

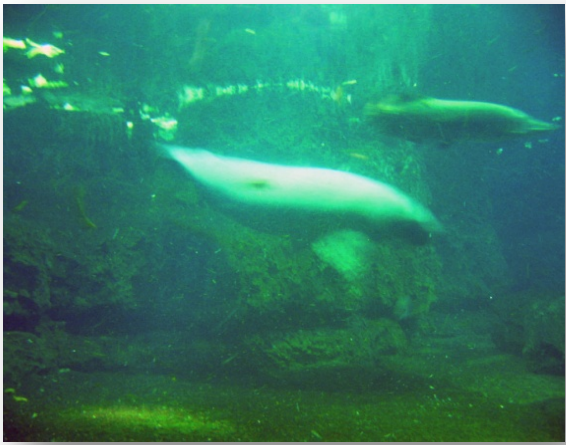


Figure 16 - Aquarium Photograph

First, the image is segmented into the 8x8 grid as shown in Figure 17. Each of the grid sections is then analysed for colour content and quantised. In Figure 17, the section containing the lightest shade of colour is in row 4 column 5; this section is used for demonstration purposes but the process is the same for all 64 sections. The statistical mean value of the RGB content was analysed producing the quantities of: Red = 125, Green = 217 and Blue = 182. The maximum possible value for each colour plane was 255, with 128 being the halfway point. Anything above 127 was rounded up to 255 and anything below 128 was rounded down to 0. Table 3 shows how the quantised values were then mapped to the colours in Table 2.

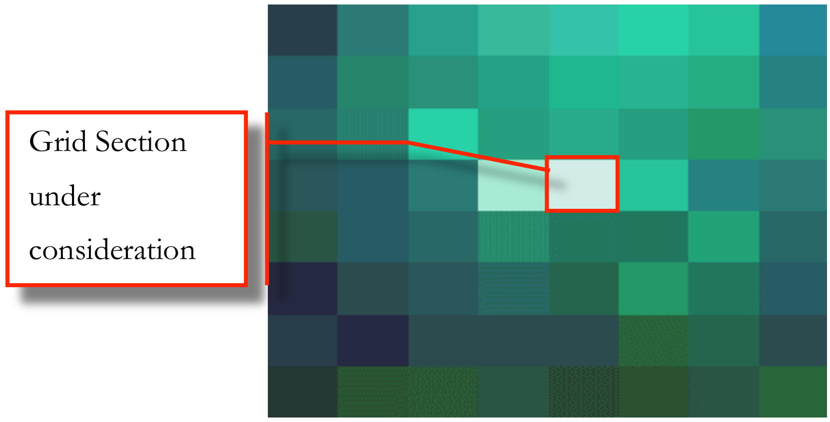


Figure 17 - Aquarium Down-Sampled into an 8x8 Grid Pattern

		Calculated Values		
		Red	Green	Blue
Quantised Colours	Black	0	0	0
	Red	255	0	0
	Yellow	255	255	0
	Green	0	255	0
	Cyan	0	255	255
	Blue	0	0	255
	Magenta	255	0	255
	White	255	255	255

Table 3 - Hue Values Quantised from RGB Values

The values from the section under consideration in Figure 17 would therefore be quantised to Red = 0 (actually 125 which is <128 $\therefore$ given a value of 0), Green = 255 (actually 217 which is >127 $\therefore$ given a value of 255), Blue = 255 (actually 182 which is >127 $\therefore$ given a value of 255). The combination of Red=0, Green=255 and Blue=255 gives a resultant hue of Cyan as shown in row 5 in Table 3. The entire completed quantised grid pattern is shown in Figure 18.

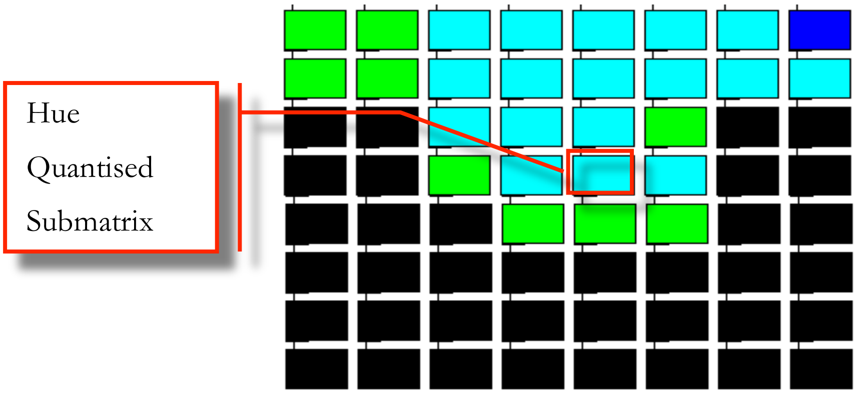


Figure 18 - 8x8 Grid of Quantised Hue Values

Matrix Histogram

The 64 quantised grids are then counted to determine the quantity containing the same hue values. This is tabulated in a histogram. In Figure 18 there are 36 black sections, 10 green sections, 1 blue section, 17 cyan sections and the remaining colours are not represented. These histogram values were then used to drive the timbral mixer described below, and in this case the black timbre is dominant.

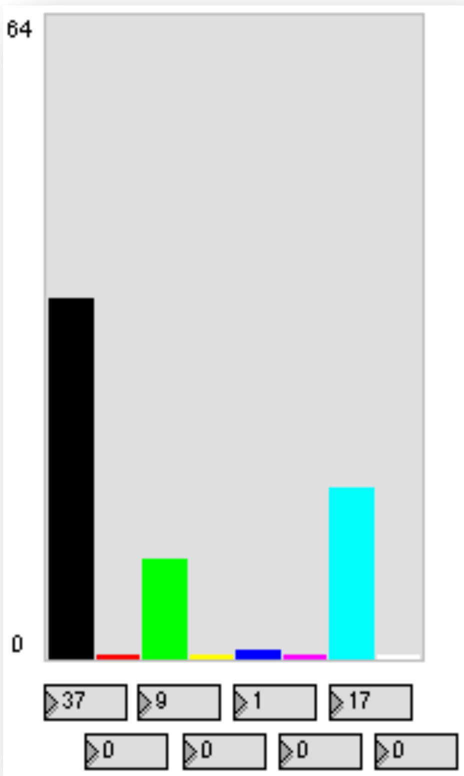


Figure 19 - Hue Histogram for the Figure 17. Colours Left to Right as in Table 2

Scanning and Focus

By converting only the colour quantities in the picture to timbres, no sense of the spatial composition of the picture is conveyed. This is resolved by the ability to zoom into a particular area in the image. By scanning across various parts of the picture, the timbre will change as different colours are emphasised and give auditory clues as to the compositional nature of the picture.

Without this zoom feature, the timbral soundscape would be quite static. Some variety would be produced because of the varying lengths of the looped sound files, the dynamic quality of the recordings and the way different timbres interact. There would, however, be little in the way of variation over longer periods.

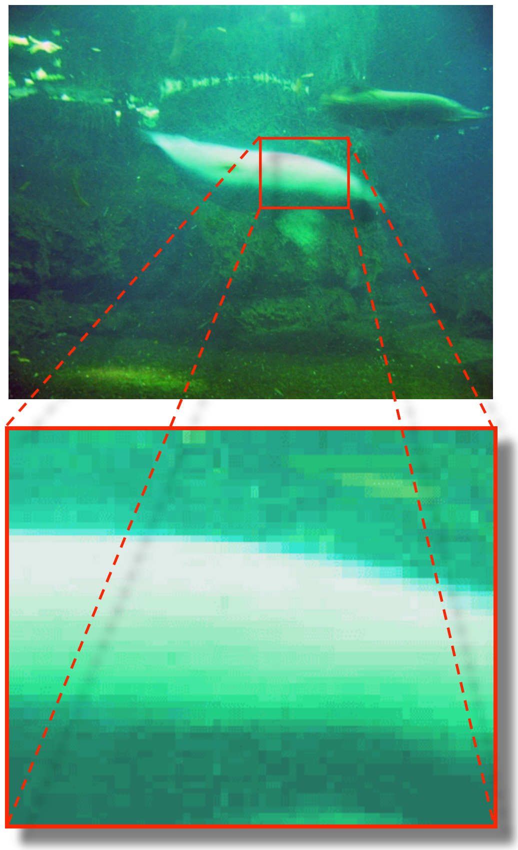


Figure 20 - Focussing on an Image Area

Yeo (2005) discussed several techniques that could be used for introducing a time base into a static image to allow movement and focus between different areas and pixels in the picture. These involved various scanning, probing and path definition methods. The technique used in *Hue Music* was to focus on a rectangular subset of the image, initiated by a probing mouse click. This emulated the process of an observer choosing a focal point in the picture and looking at this area in more detail. The focus then returned to an overview of the picture after which the observer again focused into the point of interest. This process of zooming into the focal point and then moving back to an overview continued unless a different focal point was chosen. Some high frequency jitter was also included in a similar way that the eye refreshes its visual receptors by small high frequency movements as described by Gregory (1997). This excited the audio mix a little, adding a form of amplitude modulation. The saccadic eye movement[4] was

[4] Saccadic eye movements are unconscious movements made by both eyes when scanning images or objects to give the observer information about their spatial composition.

emulated by the tracking from overview to zoomed localisation at a predetermined rate. This had a more gradual effect on how the sound evolved over time. The user initiated zooming by identifying a focal point in the image and clicking the mouse at that point. The program then gradually repositioned the display to the chosen co-ordinates and resized the display around the rectangular focus. For example, in Figure 20, the user had clicked into the light region on the back of the Manatee and the program enlarged this area with the clicked point being the centre of the rescaled image. This had the effect of making the black amplitude reduce and the lighter colours and their associated sounds increase.

Audio Timbre Mixer

Each of the timbres for the program were recorded with the composer attempting to create a sound that resembled the chosen colour. This was based partly on the literature of Kandinsky (1914), Gerstner (1981), Lavignac (Jones, 1973) as reviewed in Chapter 2, and partly on the composer's own intuitive interpretations. Black and blue were considered to align with deep, more bass like sounds. Yellow and green were brighter sharper sounds, for example. The synthesis programs were adjusted from starting sounds until the timbre matched the colour being associated[5]. All the sounds were recorded to last approximately thirty seconds with some variation in length between the audio files to ensure more variety when they were looped during playback. All the sound files were normalised in amplitude to ensure consistent sound levels.

[5] The original recordings can be found on DVD 1.

Timbre Amplitude Calculation

The values generated from the colour matrix and identified in the histogram, shown in Figure 19, were doubled to give values between 0 and 127[6]. A value of 0 for a hue would equate to an amplitude of zero for that sound, i.e. the sound is not heard. A value of 127 for any hue would mean that the associated timbre was played at maximum amplitude, in which case no other sound is heard, as the image would be monochromatic.

The process can be envisaged as a seven channel stereo audio mixer. Each of the stereo samples was continuously looped and their amplitudes adjusted by the colours calculated via the histogram. The mix levels would change dynamically as the image was scanned and zoomed. In Figure 21, the timbre associated with magenta would be the loudest one in the music. All the other timbres would be represented but at a reduced amplitude. The quantity of white in the image reduces the overall amplitude as white sections reduce the count available for other colours and it has no sound. This equates to a canvas with more white space and less coloured area.

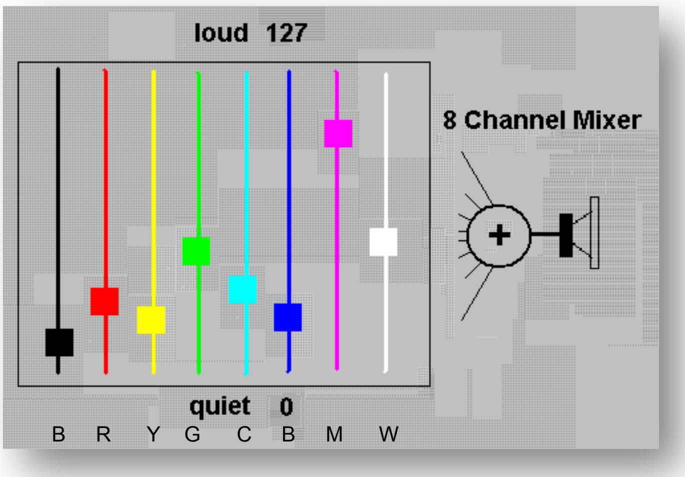


Figure 21 - Timbral 'Hue' Mixing. Colours Left to Right as in Table 2

[6] Initially values between 0 and 63 are generated because there are 64 blocks in the segmented image. The audio timbre mixer, however, has double this resolution at 128.

Compositions

To demonstrate the process further, three pictures were rendered through the software.

Figure 22 - Wedding Dance Photograph

The first picture, Figure 22, highlights a limitation of this algorithm. The wedding picture produces similar music to the aquarium photograph in Figure 16. The colour content of these pictures is similar but the context is very different. One would expect the music for each to be different. The reason for the similarity is that black and green dominate both images and the result was a gentle sweeping soundtrack similar to the one already produced for the aquarium.

Figure 23 - Tree Bark Photograph

To demonstrate the effect of a quantity of white in an image, Figure 23 is a close up of tree bark. Although the predominant colour appears to be a general shade of brown, when processed through the quantisation process many of the brown shades reduced to white because of low RGB values. The overall result of this was a reduced amplitude piece of music with some black, red and yellow timbres.

Figure 24 - Flowers Photograph

Finally the small group of flowers in Figure 24, contains mainly yellow and green hues. These were translated to the associated yellow and green timbres producing music comprised predominantly of these two sounds.

Improvements on the Algorithm

The current implementation has several limitations that could be resolved by further investigation and refinement of the program. First, and probably most importantly, is the fact that pictures with similar colour values produce similar music even though the pictures may contain very different content. This was partially resolved by the scanning and focus process, but it is envisaged that this could be further improved by subdividing the picture into a finer grid pattern. If the scanning process was also made more rigid, and based on a fixed path across the entire picture, more information regarding the visual composition would be conveyed. Other refinements could be made to the image analysis and sound generation routines. If important objects were identified in the picture they could be represented by a strong timbral focus or identifiable musical composition themselves. If this were the case, background colours could be assigned reduced amplitude in the mix. Additional manipulation of the pitch of the timbre files based on the colour saturation, as described by Giannakis (2001), could also potentially enhance the variety of the generated music. This would be possible in the current program by making the playback rate of the sound files proportional to colour saturation. Finally, the selection of a different bank of timbres for different images would produce different results and potentially allow for a greater match between sound and image.

Summary

The *Hue Music* algorithm is a means of using the hue content of an image to create music through automated timbral mixing. The software produced music that suitably complimented the aquarium picture with a slowly evolving soundscape mimicking the gradual motion of undulating water waves. It was less satisfactory at conveying the content of other images and differentiating between those containing similar colours. At the outset of the development of the software it was envisaged there might have been a universally acceptable way of mapping between colour and sound. Through this investigation, and verified by Motluk (1996), however, it was determined that there is no single approach that can be universally applied in all situations. It is the context of the colours in the picture and how they map to the sounds that determines whether the result is appropriate. In aesthetic terms, this gives the composer the freedom to choose his own preferred colour-timbre associations and mapping a single colour to a single timbre reduces the artistic flexibility.

This page included for formatting purposes

5. Colour Mirror and Soni-Chrome

This chapter discusses the production of these two pieces and describes the transition from algorithmic production techniques to the composer arranged work of later portfolio pieces. Both videos made use of compositional thinking in development of their compositional forms. This was a requirement for Aim 2. Objective 6 was also addressed, making use of visual symmetry to impart harmony in images that were originally photographs. Musically, *Colour Mirro*r addresses Aim 1 and Objective 4 of the investigation. It transfers content algorithmically between video and audio. Multiple sound types were used to address Objective 5 and enabled comparison of synthesised and found sound sources.

The compositions revealed how inter-media bonding is enabled when algorithmic methods were used, and how conventional compositional methods permitted a more intuitive approach to be used during the production process.

The compositions can be found on DVD 2

Textual Mnemonics

Colour Mirror

Soft degraded sound accompanies brightly coloured geometric patterns mirrored around the centre of the screen. The patterns are in a constant state of evolution and the kaleidoscope imagery rotates as strained synthetic string sounds gently drift in pitch, in harmony with the changing forms and hues. The colours eventually dissolve and the sound degrades even further during this period where image and music become pointillistic, broken into dots and short percussive melodies. After the colours reform, steady drones and pitched tones begin to dominate and flood the landscape with echoes and reverberant textures until the dotted grey images fade away and give the screen back to brightly coloured hues. Sweeping gestural movements of the geometric shapes are mirrored with string harmonies until the sound and forms eventually collapse.

Soni-Chrome

Abstract distorted shapes feed in and out of the screen in a kaleidoscope pattern. The shapes blur and become more vividly coloured. The sound is hidden in reverb and echoes which faintly mimic the movement of the patterns. The atmosphere is dark and mysterious, a feeling created by the music and the uncertainty as to the nature and intent of the patterns.

5. Colour Mirror and Soni-Chrome

Hue Music was an experiment in mapping colours to timbre and took an entirely algorithmic approach to audiovisual composition production. *Colour Mirror* and *Soni-Chrome* relied progressively less on algorithmic techniques and helped develop the technical and artistic skills required for a more conventional approach to working with sound and visual materials. *Colour Mirror* made a partial shift in this direction, using some algorithmic processing, but *Soni-Chrome* was created entirely by the composer editing and arranging the recorded materials. By reducing the algorithmic element, it was envisaged the compositional complexity and detail could be improved as it was somewhat lacking in Hue Music.

Colour Mirror acts as a complementary piece to *Soni-Chrome* and the name, *Colour Mirror,* alludes to the fact that it is a reflection on and development of the *Soni-Chrome* work. The name also refers to the kaleidoscopic mirroring production techniques used in creating the video, which creates a hypnotic effect. *Soni-Chrome* used some of the kaleidoscope video methods too, but had a different approach to sound design that made it darker in atmosphere. *Colour Mirror* and *Soni-Chrome* were both composed during the same eight week period, with attention switching between them as ideas developed. This shifting of focus allowed periods of reflection and gave a renewed objectivity when returning to work on the other piece.

Visual Development

There were several stages involved in creating suitable imagery for the videos described in this chapter. One technique was to import images into the Hue Music software and zoom and scan through them to produce moving images from still photographs. Zooming into digital photographs in this way created low-resolution pixelated results, as initially there was no smoothing carried out. This resulted in reduced video quality but the low-resolution artefacts added to the characteristic retro-like charm that was to be further enhanced through symmetry techniques. Another production technique was to edit and combine multiple images to create abstract forms with contrasting colours. Figure 25 demonstrates the results this created. These images were later down-sampled to enhance the colours as demonstrated in Figure 26.

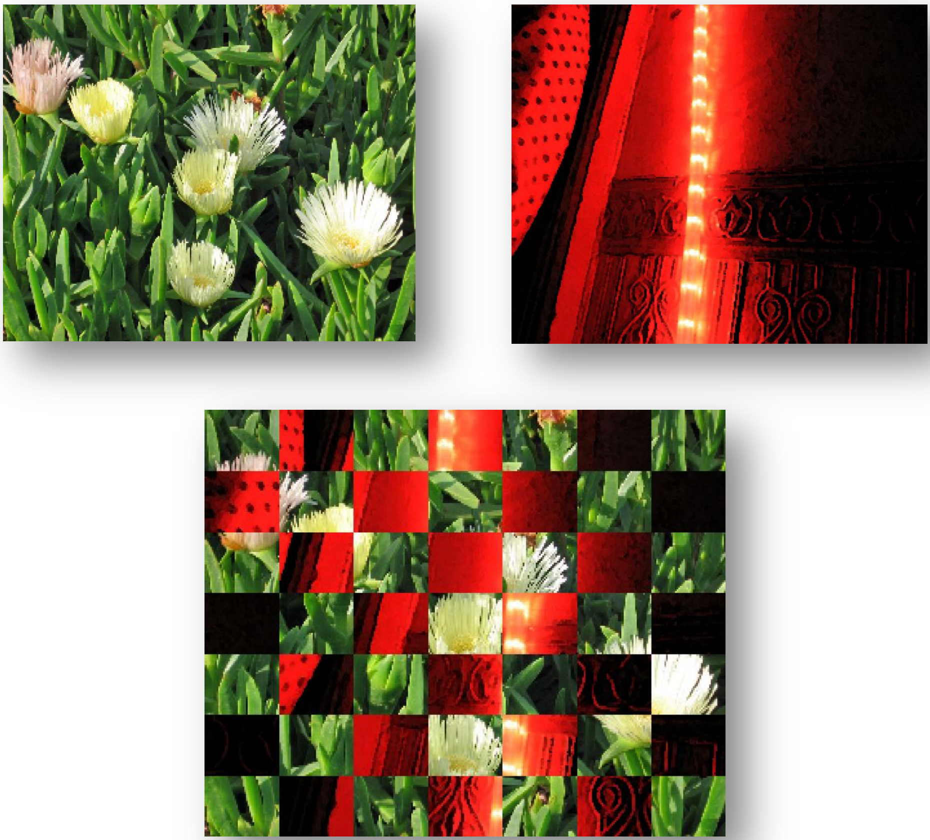


Figure 25 - Photographic Images Sliced and Recombined

Symmetry was also used but instead of only reflecting in the horizontal plane for bilateral symmetry, images were reflected again in the vertical plane. This resulted in one quarter of the video being repeated in the other quadrants as shown in Figure 26[7]. Treating the video in this way made the moving images behave as a constantly evolving series of coloured shapes anchored around the centre of the screen. It also distanced the imagery from its original content in a similar way that sound transformation can remove the sound from its original source cause. This was considered beneficial as the movements and transformations of the coloured shapes were to be the primary focus of the videos.

[7] Note how this differs from the result achieved by rotational symmetry as depicted in Figure 13 in Chapter 3. Here the image is symmetrical in the vertical and horizontal planes rather than rotating a section through a 90° angle.

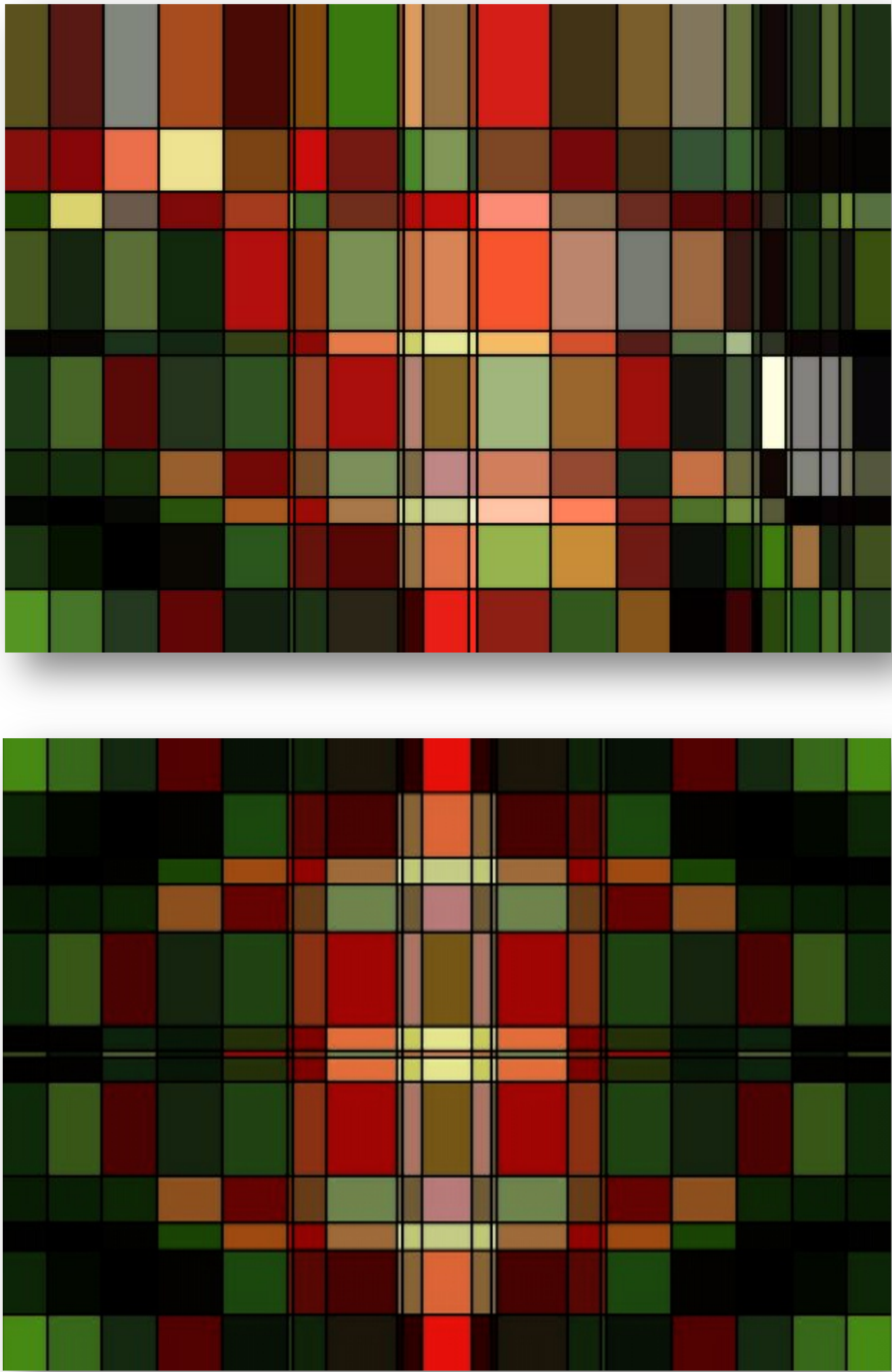


Figure 26 – Bottom Image of Figure 25 First Resampled to Emphasise the Colours, Then Reflected, through the Vertical and Horizontal Planes to Create Symmetry

Creating blended transitions between two photographs was another method of producing some of the video footage. The effects created by these transitions actually produced what were considered to be some of the more interesting results. The way the shapes and their colours interacted produced a wide variety of coloured hues. Figure 27 is one example of the colours and textural effects that were created from this technique.

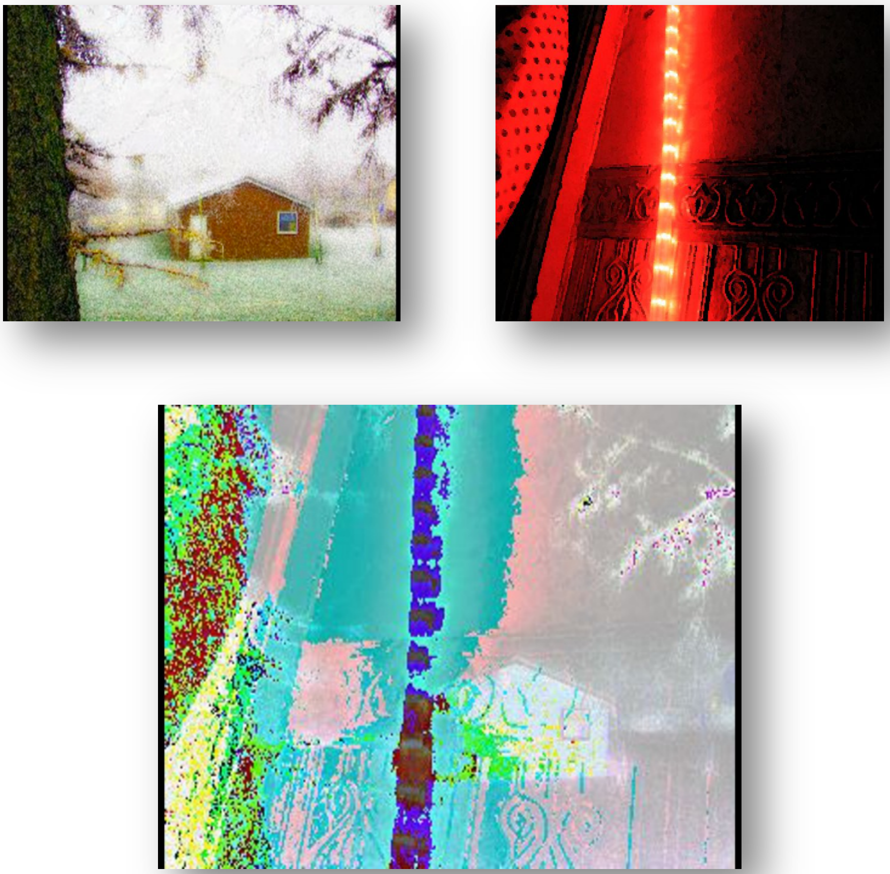


Figure 27 - Blended Pictures Creating Additional texture and Colour Effects

This figure also begins to highlight the pixilation effects created from the low-resolution images. Although this was acceptable, it did become repetitive when present throughout the entire video. To alleviate this, smoothing was carried out on some of the images by introducing blurring as shown in the bottom image of Figure 28. The results achieved through this method produced a contrast between the pixelated images and the smoother ones. Each were used at different places in the videos.

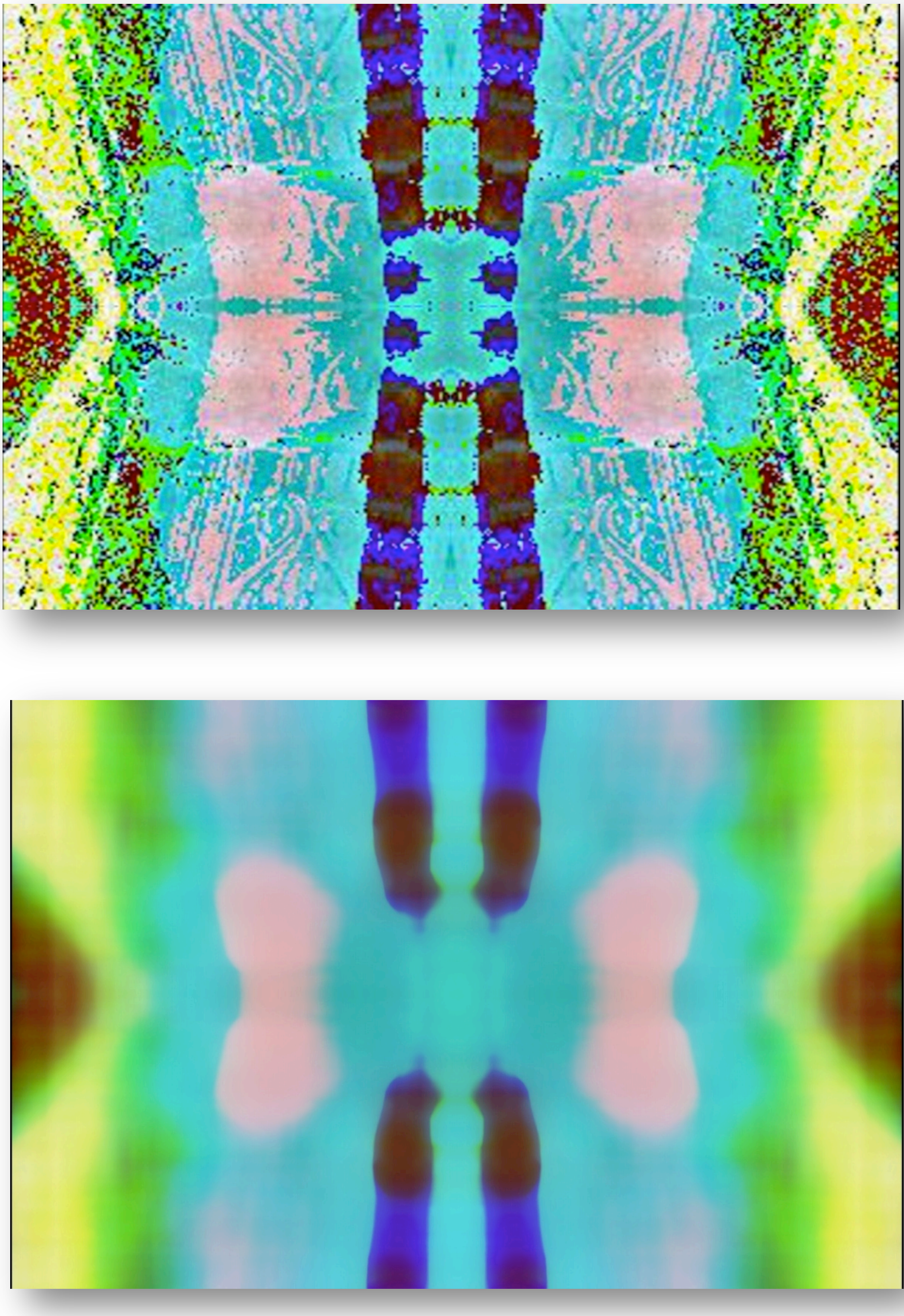


Figure 28 - Blurring the Image and Creating Symmetry from Figure 27

Visual Compositional Forms

The videos for both pieces were composed before the music and were partly influenced by the processes involved in musical composition thinking. Hyde (2012) described this visual composition technique as, '*the application of more abstract ideas and principles derived from music to ocular media'* (Hyde, 2012, p.171). Although not classical in style, there are elements of classical musical form that can be used to describe the visual compositions. *Soni-Chrome* is an étude comprised of a short exposition between 0' 30" and 1' 10", followed by development of related and transforming materials in the central section and closed with a brief coda at 3' 26". *Colour Mirror* has a three part ternary form, '*consisting of three parts or sections. It may be represented by the letter scheme ABA, the final section being a repeat of the first'* (Tucker & Cochrane, 2011). The exposition of the first part, A, continues from 0' 17" until 1' 50" and the contrasting middle, part B, is the video passage that becomes distorted and less saturated in colour between 1' 50" and 3' 45". The recapitulation of the themes from part A occurs in the final passage from 3' 45" until the piece's end. The videos were actually created by working with visual materials directly and gradually building the aforementioned forms from the bottom up. Once they had been rendered into the video, however, they imposed themselves, top down, onto the musical compositions. This reduced the potential to improvise with the structures during the musical composition phase but allowed more attention to be given to the sound design.

Algorithmic Sound Design for Colour Mirror

Additional manipulation and transformations carried out on the *Colour Mirror* imagery made it acquire a more synthetic quality. Angular forms were emphasised and the colours transformed into a series of more vibrant and saturated primary oriented hues. In order to portray these effects in music, the *Colour Mirror* soundtrack was created exclusively from synthesised sounds. Six audio files were synthesised, two different timbres for each of the RGB colours. The choice of sounds was influenced by the literature as described in the Hue Music chapter. Red was considered the brightest and most harmonically rich timbre, deeper bass frequencies were present in the blue timbre and green contained characteristics in between these two. A sufficient range of timbres was, therefore, available for layering during the later arrangement phase of the composition.

These recordings were then manipulated in two distinct ways by algorithmic means. First, their playback rate was varied according to the average intensity of the RGB colours in the images. The sounds could be replayed in a range between 0.5 and 1.5 times their original rate. The fastest rate occurred when there was the highest concentration of the associated colour present and the slowest rate when the colour was absent. Secondly, the average RGB colour content adjusted the centre frequency and resonance of a bandpass filter. High average colour content created a more resonant narrow band filter in the upper mid-range of the spectrum and a low average content a less resonant filter lower in the spectrum.

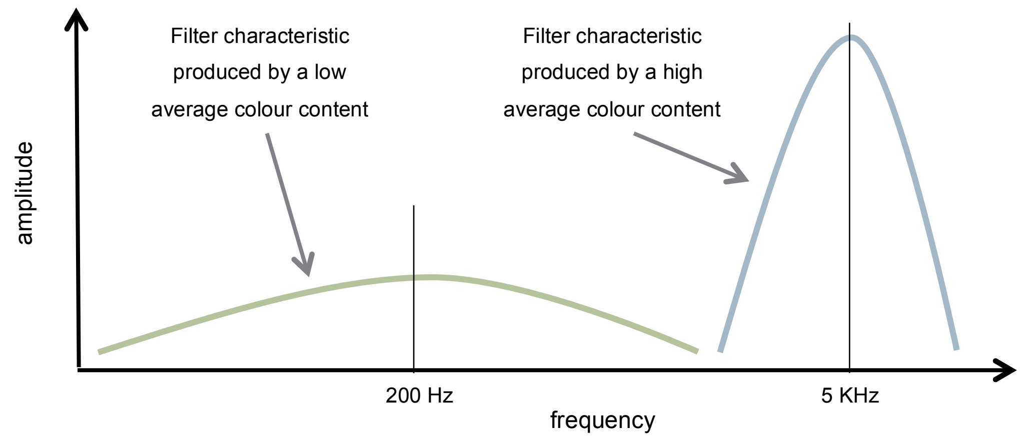


Figure 29 - Filter Characteristics Created by Different Average Colour Content

To illustrate these processes, consider Figure 31 below, in which the red content is high and green and blue low. At this point in the video, both red timbres were reproduced close to their original rates, and green and blue were played much slower. Audio files that are resampled to play back more slowly possess more low frequency content. At the same amplitude the ear is less sensitive to lower frequencies than ones in the mid-range, as demonstrated in the Fletcher-Munson curves in Figure 30. The frequency

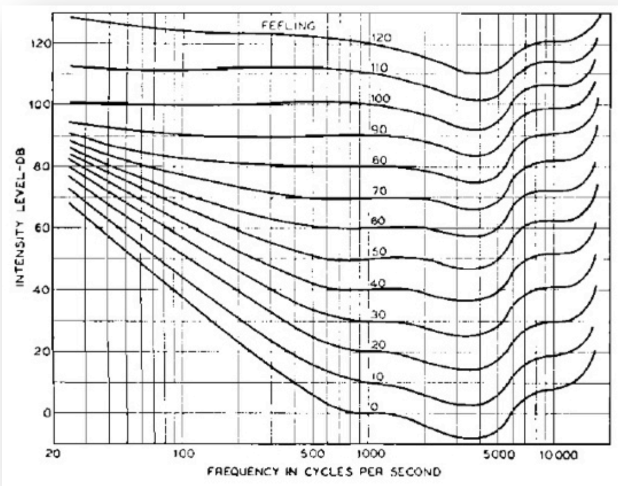


Figure 30 - The Equal Loudness Contour Curves Formulated by Fletcher and Munson (1933)

range between 4KHz and 6KHz is the region in which the ear is most sensitive, as highlighted by the contour lines, labelled 'FEELING', dipping in this region in Figure 30. The lines are higher in the lower frequencies indicating reduced sensitivity in this region. Green and blue sounds are therefore perceived as quieter in the mix and red as louder at this point.

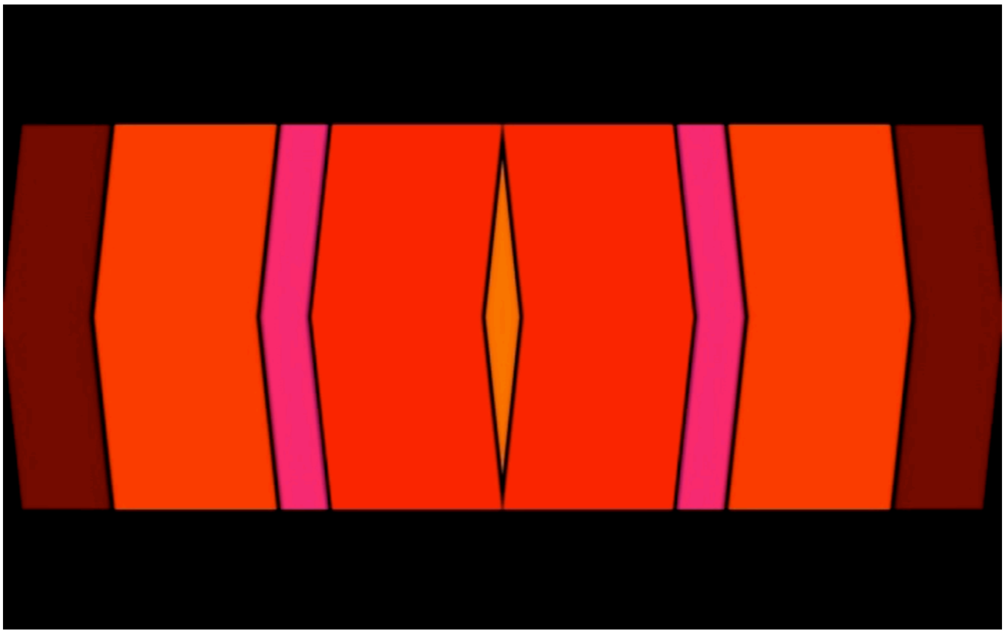


Figure 31 - Still from Colour Mirror with a High Red Content. The Red Timbre is Emphasised at this Point

The manipulation of the filter parameters was designed to reinforce this effect. With red dominating the frame, the two red timbres would be filtered around a narrow band of frequencies centred on 5 KHz as indicated by the filter characteristic in Figure 29.

As an alternative example consider Figure 32, which is predominantly black. Blue has some presence, but this is relatively small so all RGB channels have low values. Because of this, the filters for all sounds would be situated towards the low end of the spectrum. Accompanied with a reduction in playback rate deeper sounds are produced, creating a darker atmosphere in the music. Conversely, when the scene content is closer to white, all the timbres play back nearer to their original rate and with higher frequency content. In this case the resulting combined sound would be denser and brighter in quality.

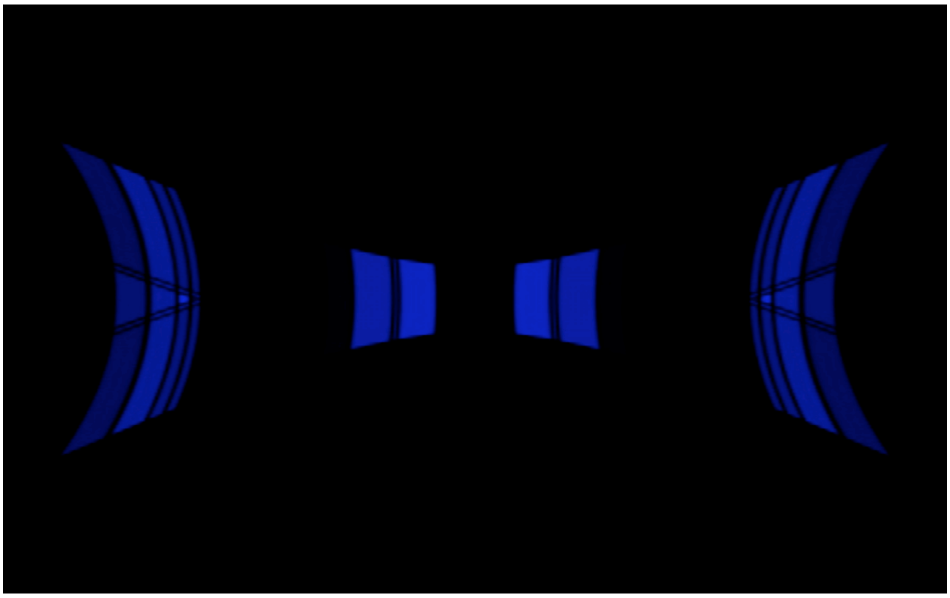


Figure 32 - Still from Colour Mirror with Low RGB Values. Results in Low Frequency Dominance in all Audio Channels.

Black and White Sound

Black and white colours were represented by sound differently in *Colour Mirror* and Hue Music. Black had its own individual timbre in Hue Music, and white had no sound. *Colour Mirror* was almost the reverse of this concept. White produced rich dominant timbres and black was perceptibly quieter. Each of these strategies can be equated to the colour mixing systems described in Chapter 2. Hue Music sound was comparable to subtractive CMYK colour mixing, in which black has its own ink and timbre and white was an absence of sound and colour. With *Colour Mirror* using additive RGB mixing, when the scene had high colour content in all channels, white is produced resulting in a richer sound. Black is an absence of colour, and silence in sound.

Additional Musical Arrangement in Colour Mirror

Since structural form was already present in the video and imparted algorithmically into the sound files, the original intention was to use the audio without any further editing and arrangement. As the work progressed, however, it became clear that more satisfactory results were achieved with increased composer input. The algorithmically processed sound files were compiled onto the DAW timeline, but the timbres did not always combine in a favourable way. At several points many sounds occupied the same frequency range creating a harsh amalgamation of timbres. In these cases edits were made to reduce the number of sounds playing simultaneously. Volume fades and amplitude adjustments were also made to ensure the spectrum remained uncluttered and the output undistorted. On other occasions the algorithm had produced more sonically interesting results on one sound file than the others. The tempo and dynamics reflected the content of the visuals more effectively for example. These sounds were soloed in the mix to benefit from these fortuitous effects. Coupled with this editing and compilation process, additional sounds were added for phrasing and punctuation. There were moments where the colours changed rapidly in the video but the sound algorithm did not respond quickly or satisfactorily enough to represent this. In these situations, momentary synthesised sound events were used and examples can be observed at 1' 18" and 3' 16". This also increased the sense of synchronisation between sound and image.

Soni-Chrome Musical Composition

At this stage in the portfolio, composer arrangement replaced algorithmic techniques as indicated in Figure 8 in Chapter 3. The *Soni-Chrome* soundtrack was the composer's first production using these techniques and it was also the first piece to use only found sound recordings. Apart from some programming of the synthesisers and minor adjustments to the arrangement, the music for Hue Music and *Colour Mirror* was produced by the algorithms. Beginning with the completed video and untreated sound recordings for *Soni-Chrome* required more effort to be applied to the sound design processes, experimentation with sound combinations and overall arrangement. The process was primarily the one described in the audiovisual production workflow section in Chapter 3, but the interpretative and compositional skills were at an early developmental level at this stage. Interpreting visual composition with music was also a new challenge, which up until this point had been enabled by the software mapping routines. It was tempting to add many sound layers to emphasise the density of the visual work, but saturating the soundtrack in this way produced a confusing assembly of different visual and auditory stimuli. It became apparent that reduced audio content was sufficient in most cases, as the video carried the momentum of the composition. This developmental and transitional period was also aided by the fact that the piece was only a short étude and the compositional form was already in place in the form of the completed video.

A Critique of Algorithmic versus Traditional Composition Techniques in these Pieces

In a continuum between purely algorithmic and entirely composer directed works, these first three parts of the investigation span across it. Hue Music was entirely algorithmic, *Colour Mirror* used a combined approach and *Soni-Chrome* was composer arranged. The bonding between video and music was realised in Hue Music and *Colour Mirror* by material transference between visual qualities and sonic ones. This was simple to achieve in that, once the algorithms were programmed, the transference was automatic. *Soni-Chrome* completely eliminated algorithmic methods and was created by the composer working directly with sound and visual materials in the DAW and video programs. Development of the sound and image relationships required interpretation and judgement rather than programming competence to ensure synergy. The DAWs aided this process by allowing video and audio materials to be combined readily and compositional changes to be made easily. New edits and musical arrangements could be evaluated rapidly allowing a degree of compositional improvisation once familiarity with the interface was gained. At the outset of the process however, there was a blank canvas upon which the library of sounds were to be arranged.

One piece that was created by purely algorithmic means is Bret Battey's *Autarkeia Aggregatum* (2005a). In this work both the visuals and music were created via programming methods. His programs visually generate, *a constantly transforming, massed animation of nearly 12,000 individual points in a high-definition (720p) visual field* (Battey, 2006, p.1) and musically create *naturalistic and expressive glissandi and continuous-pitch melodies* (Battey, 2005b). The level of detail embedded in the programs ensured the rendered piece was of a high quality in both technical and aesthetic terms. However, the programs will always produce works with a similar granular style. To maintain diversity and originality each new piece requires a new algorithm, or at least a modification of the original. This would also be the case for Hue Music and *Colour Mirror;* although they could both actually produce new music with a range of different starting timbres. This rule-based approach to composition is valid but, once put into practice, it became more a computer programming exercise than a musical composing one, limiting the intricacy of the compositions. The flexibility and speed of modern multimedia workstations allowed a very intuitive approach to music and video composition and ideas were developed quickly. This approach became a preferred way of working for the remainder of the portfolio, although some algorithmic elements were still used in the sound design for *Diffraction*.

6. Theravada Colour Morph and Sunset

This chapter examines issues related to combining acousmatic music with video. It discusses the differences between the audiovisual and audio only modes of experiencing media. It also examines different approaches to synchronisation, from very tight synchronisation between image and sound in *Theravada Colour Morph* to a more complimentary approach in *Sunset*. The compositions address Objectives 5 and 6 of the investigation by using found sounds and recorded video to create visual music.

The compositions can be found on DVD 2

Textual Mnemonics

Theravada Colour Morph

The video opens with a shaking grid mirrored by a grainy shaking sound texture. The observer is gradually introduced to the compositional themes as it settles into more subtle variations that transform over longer periods, transitioning from shaking grids to subtle cloud veils and on to interleaved animal scale like textures. These textures eventually break up into flashing staccato colours woven together over moving bars, which are emphasised with modulated pulsating sounds. This is a visually intense section of the work where video processing artefacts manifest themselves as vividly coloured flashing blobs of light and sound. The flashing gradually subsides and there is pause and reflection before the impending crescendo to the piece. The 'white out' section allows a brief respite. The high frequency tone and the white screen guide the listener into a period of suspended animation with only slight suggestions of movement. The music then begins to descend back into colour and tension is introduced through pitch manipulation of a single frequency tone. As the picture darkens, the musical pitch drops and the volume intensity increases. The pitch variations from high during the pause, to low as the screen becomes darker, and then back to high again, sonically guides the listener through the more static visual elements and begins to create anticipation of further movement. The stuttering sound gradually builds and the video accompanies this with chroma-keyed flashing colour shapes as the pitch climbs and intensifies to the climactic end.

Sunset

A stationary camera sits on the horizon recording the transition of a sunset from light to dark. The sunset gradually progresses with orange and yellow hues losing their saturation and intensity in the fading light. The whole scene is reflected and mirrored across the centre of the screen. This creates a gentle inward movement towards the centre as the darkness descends. The music reflects the sunset transition. Slowly evolving time stretched textures dominate, with flutters and subtle transitions creating a drifting atmosphere. The sound eventually decays to a few simple tones that continue to fade as the light dims.

6. Theravada Colour Morph and Sunset

These two pieces were produced with greater attention being applied to the musical compositions than had previously been the case. In the previous algorithmic productions, more time had been allocated to programming and video production, which led to the music becoming subservient to the visuals. This was partly addressed in *Soni-Chrome* but to further redress the imbalance the two musical compositions were, to a large degree, composed independently of the videos. For *Theravada Colour Morph* the video was produced after the music was complete. No attempt was made to modify the music in response to the added imagery, ensuring the form of the music composition remained intact. For *Sunset,* the video was completed first and the soundtrack added afterwards. The influence the video imparted was, however, very subtle and suggestive simply of a general theme for the music. The soundtrack mirrors the very slow movement of the colours and light but also has its own textural qualities and structure that would permit independent listening without the video.

Both these pieces were produced in the tradition of electroacoustic musical works that had first been investigated in *Soni-Chrome*. Although other genres have the potential to suggest visual imagery to the listener, electroacoustic music possesses qualities that potentially make this more probable. As Emmerson described,

'The acousmatic condition deliberately reduces information on source and cause which we (products of evolution) attempt to 'fill in'. For me – and I believe many others – that process has a visual component. The imagination constructs a quasi-visual mindscape with many of the characteristics of 'real' vision' (Emmerson, 2007, p.169).

This is due in part to the way the recordings are captured and processed and also to a composition's subsequent acousmatic reproduction. As electroacoustic music intrinsically possesses its own visual component, there could be a mismatch between the inherent imagery and that which is added in audiovisual composition. It was necessary to be sensitive to this to prevent possible confusion, but also to use it potentially as a compositional tool. As well as creating seemingly obvious visual-musical relationships, the audience can be challenged by meeting their expectations with surprising combinations.

Theravada Colour Morph

Theravada Colour Morph reflects the vibrancy of the culture and colours that can be witnessed in Thailand. It also provides a visual and sonic commentary on the indigenous sights and sounds that can be experienced in widely contrasting locations throughout the country. Audio and video footage captured exclusively from this single source was used in its composition. This imparts a characteristic quality on the composition that is inherited from the material's origin. The colour spectrum, for example, is determined by the enhanced and bold use of certain combinations that can be observed on signs, in temples and public places around the country. Greens, purples, yellows and reds are used liberally and dramatically in a culturally identifiable way. The original footage is treated in ways that often make it unrecognisable from the source but the end result still has elements of the Thai culture woven into its fabric. In response to this it was decided that the music should be richly coloured and varied. This was not going to be a study based on a minimal design concept centred on few techniques. It was to be a challenging, demanding and varied experience exploring all the dimensions of sound and sight together. The result is a dramatic soundtrack created by multiple sound layers coupled with several variations in dynamic intensity. There are moments for pause in the music but even they contain traces of sound.

The recordings themselves were made on a high definition hand held camera for the video and a portable field recorder for the audio. This allowed the devices to be carried into any location, meaning any environmental scene or sound could be captured very quickly. Also, as the audio recorder was two channel stereo, a certain amount of natural space and movement was captured in the audio recordings. Instead of artificially panning a sound, it was possible to walk past a source (or for something to move past a static recording location) and have it naturally move in space. The sound also acquired the natural filtering effects and spatialisation inherent in the recording environment. This imparted a natural quality to the sounds.

Making the music subservient to the visuals in previous work caused the compositional form of the videos to be transferred to the music. This created some problems, as when a sound was edited in response to a visual change, it was sometimes too abrupt and unnatural sounding. To give the music a more dominant role and natural compositional flow it was decided to compose it first, independently of the video. The musical compositional form therefore influences the visual structure, whereas in *Colour Mirror* and *Soni-Chrome* the reverse of this was true.

Synchronisation in Theravada Colour Morph

A component of *Theravada Colour Morph* and many other visual music pieces is the way the video and audio interact in a synchronous way. In audiovisual terms, one result of this synchronisation is 'synchresis', defined as:

'the spontaneous and irresistible weld produced between a particular auditory phenomenon and visual phenomenon when they occur at the same time. This join results independently of any rational logic.' (Chion, 1994, p.63).

Although these synchretic moments can be very short in duration, the effect they produce can persist throughout a piece, ensuring a continued multimedia bond between sound and video. Garro (2012, p.107) suggested, however, that synchresis is only one point on a continuum which extends on an axis from separation at one end, through intuitive complementarity and synchresis in the middle, and ends with parametric mapping at the other end. Separation is the loosest form of synchronisation on the left of the continuum and parametric mapping the tightest to the right, as shown in Figure 33.

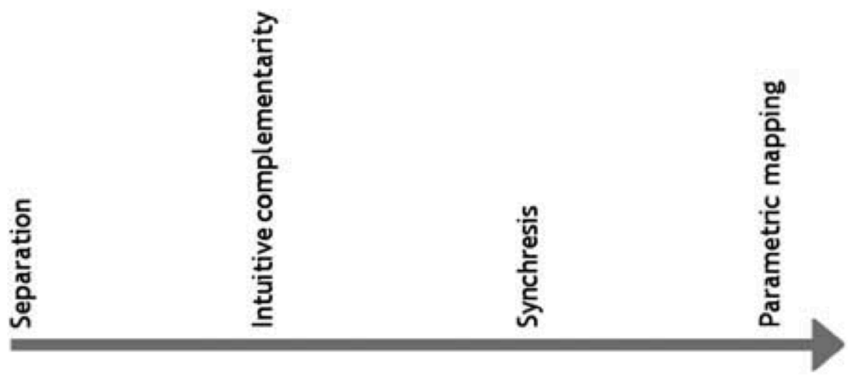


Figure 33 - Garro's Continuum of Gestural Audio vs. Visual Association Strategies (Garro, 2012, p. 107)

This means there are various ways in which sound can be synchronised with picture.

Synchronisation and synchresis can be a natural result of the production process. An example of this is *Open Circuits* (Cope & Howle, 2003). The video was produced from several silent video clips that were mixed together in real time. The video artist, Nick Cope, rapidly switched between the clips creating a disorientating effect. The resultant video was recorded and passed onto Tim Howle who composed the music in response to the imagery. In the initial sections of the piece, the music responds to the quickly changing video with rapid edits from one sound to another. This naturally creates a tight synchronisation producing several synchretic moments. In the latter parts of the piece, the synchronisation breaks down and the music and video separate, moving towards the left of Garro's continuum. Another example, *End Transmission* (Hyde, 2009), incorporates various levels of synchronisation which are focussed more to the right of the continuum. This is due in part to the nature of its hardware hacking production techniques. Analogue equipment was used to produce simultaneously both the sound and images and the results straddle the area between synchresis and parametric mapping.

Several examples of these various forms of synchronisation can also be observed in *Theravada Colour Morph.* At 1' 41" and 2' 07", for example, a brief flash of a second image is revealed underneath the more steadily evolving colour textures. Synchronised to these visual revelations is a short highly pitched sound event producing a synchretic effect. An example of where a more sustained synchronisation between sound and image occurs begins at 4'42". Here, the heavily modulated sound corresponds with the stroboscopic flashing coloured circles. A similar sustained example can be found beginning at 7'45" where the hard piercing timbres accompany shaking yellow squares. In these two examples, the sound and video are synchronised and coalesced, as Garro described:

"Coalescing' strategies are those which seek to establish audiovisual discourses principally through morphological convergence of the sonic and visual streams.' (Garro, 2012, p.108).

In each case, the coalescence is producing a synchretic effect. The video and audio weld together as in Chion's original description of synchresis. A less tight integration between sound and image also occurs in a few other places. From 1'30", after the introduction, the red sunset fades slowly alongside a sustained audio texture. Here sound and image move more loosely in a similar trajectory. Similarly, during the diminuendo from 6'00", the music subsides and the screen appears mainly white. The imagery actually presents little opportunity for synchronisation during these phases so the music tends to compliment the imagery without being able to synchronise to specific events. These phases produce more relaxed periods of the composition and permit a reflective form of observation, different from that required when presented with tightly bonded material. The use of multiple levels of synchronisation during the piece therefore presents the viewer with periods of tension and relaxation. There is an alternation between calm and intensity contributing to a changing narrative and dynamic variation within the piece.

Fusion of Sound

Although synchresis, as described by Chion, relates to the connection between sound and picture there can be considered a similar phenomenon occurring purely with sound. This is where two sounds occur at the same time and become unified as a single sound object. An example of this occurs alongside the multimedia bonding taking place from 4'42", with the flashing coloured circular artefacts described above. Two independent sounds have been treated with the same intense form of amplitude modulation. Regardless of the tonal quality of the original sounds, because of the processing undertaken on them they become audibly fused as a single sound source. Wishart (1996) described a similar phenomenon when processing three different audio recordings in similar ways until the resultant sounds were indistinguishable.

'... all three sounds now appear very closely related whereas the sounds from which they originated have no relationship whatsoever. At this distance of derivation it is the overall morphology of the sound structures which predominates' (Wishart, 1996, p.66).

In *Theravada Colour Morph,* this technique was used to create a very dense sound that could not have been created with a single source alone. It is a very different result to that which would be created by the simple mixing and editing of several sound sources to occupy the same point in time.

Sunset

Although used extensively in *Theravada Colour Morph*, techniques involving synchronisation were in many ways removed from *Sunset*. Referring back to Garro's continuum, *Sunset* lies in the area between separation and intuitive complementarity. The video is a slowly evolving recording of an actual sunset made by Heather Minchin. Part of Minchin's artistic drive is to capture visual recordings that can be used and appreciated by others. They allow the natural scenery to be experienced by many other people in settings beyond their original point of capture. They also have an emphasis on colours and light and the results they produce. *Sunset* is intended to be experienced in the correct setting, in a dimly lit or completely darkened room with the images projected onto a large screen. This allows the natural colours of the video to be the main, or only source of lighting and gives the observer time to experience the subtlety of the changes in light. The *Sunset* video also makes further use of symmetry, but the purpose of its inclusion here was not for enhancement purposes as in the previous portfolio pieces. Minchin described her use of mirroring as relating to the physical and philosophical concepts she was attempting to portray:

'As for my own films, I am always experimenting with different methods of filmmaking and observing image reflection, mirroring and the mediums that affect this (thickness of glass, lens and surface types etc.). Fortunately, the very way I consider the duration and creation of sound and image fit to the philosophical ideas of Bergson and my ideas on memory and perception. An important notion is that memory (of images\sounds\smells etc) is not just a reflection on our past but instead is part of our continuous process of new perceptions and memories becoming' (Minchin, 2013).

Emotionally, *Sunset* has a calming and peaceful effect as the light dims and eventually fades to darkness. There is also minimal distraction from the reduced listening mode, as dramatic changes in the video are few. In the absence of any visual imagery at all, when listening to music, the audience is able to be completely absorbed in the listening experience. When visual material and music are combined, Coulter suggested the audience are in the audiovisual mode where attention is on both media and in,

'the process of adding moving images to EAM (Electroacoustic Music) listeners are forced to change modes from audio-only to audiovisual irrespective of audiovisual style, and that the audiovisual mode changes the quality of sounds, and hides certain aspects of sounds irrespective of audio style' (Coulter, 2007, p.3).

This can be considered a negative influence, where visual imagery distracts the listener from experiencing the music to its fullest extent. Coulter did, however, show through experimentation that minimal visual stimuli, such as coloured lights, can still allow the listener to enter the audio-only mode. With the minimisation of movement and an emphasis on light and colour, *Sunset* presents the possibility for the audience to apply more attention to the listening experience. This does not mean the video is not important to the piece but that it is does not have a distracting effect on the perception of the music. For *Sunset*, therefore, it should be possible for an audience to appreciate both media streams to their fullest potential.

Sound Textures and Time Dilation

Being very subtle in visual style, *Sunset* required a soundtrack that was also gentle and changing only gradually over time and this removed the possibility of using synchronisation as a compositional tool. The music could actually be moved several seconds either side of the video as the overall progression of the piece tends towards darkened light and quietened sound and the synchronisation does not have to be precise. There are few pieces of visual music that completely remove the use of synchronisation, but some use an extended approach to creating associations between the video and audio. *Amorphisms* (Miller & Young Ha, 2008), for example, is a piece that uses a delicate, relatively dynamically consistent, soundtrack to accompany a visual animation constructed from large areas of interchanging colours. There is no deliberate attempt at synchronisation, as the flowing colour spaces allow little opportunity for this. There are occasional flourishes in both sound and video but the main theme is a sustained consistent atmosphere in music and colour.

Smalley's discussion of gesture and texture in electroacoustic music (Smalley, 1986, pp.80–84) is also useful in describing the musical and visual qualities of *Sunset*. He explained:

'Gesture is concerned with action directed away from a previous goal or towards a new goal; it is concerned with the application of energy and its consequences; it is synonymous with intervention, growth and progress, and is married to causality' (Smalley, 1986, p.82).

Gesture is a movement and development in the musical materials and would commonly be experienced over a relatively short duration.

'Texture, on the other hand, is concerned with internal behaviour patterning, energy directed inwards or reinjected, self-propagating; once instigated it is seemingly left to its own devices; instead of being provoked to act it merely continues behaving' (Smalley, 1986, p.82)

Textural sound is steadier and evolves gradually; obvious gestural movements are minimised. These ideas can also be applied to the visual medium. The *Sunset* video is a gradually evolving visual change from light to dark. There is no provocation of this; once it begins it continues to its conclusion. Although this could be described as a gesture, it is an extended one and this emphasises the textural qualities of the video. Textural sounds would therefore be suitable compliments to the visual experience and can be produced by time stretching audio materials.

'The more gesture is stretched in time the more the ear is drawn to expect textural focus. The balance tips in texture's favour as the ear is distanced from memories of causality, and protected from desires of resolution as it turns inwards to contemplate textural criteria.' (Smalley, 1986, p.84).

There are several ways of doing this, such as granular synthesis techniques, but the chosen method was Fast Fourier Transform (FFT) spectral freezing. By passing the sound through an FFT filter, a single frame of spectral data can be held and continuously looped. It would have been possible to extend a single frame over the entire duration of the video, but that would not have represented the subtle changes in light as the sunset progressed. Several frozen moments were therefore chosen and recorded, placed appropriately through the film and filtered to produce a gentle movement in the soundtrack. Alongside these time-stretched timbres there are occasional flurries of sound, which add a little punctuation and variety to prevent the soundtrack becoming too static. The music also gradually reduces in intensity as the piece progresses to mimic the fading light.

After completing Sunset it became evident that this piece would work as an installation. In a suitable setting, the audience should experience the natural light of a real sunset but with a virtual sonic landscape. It would also be possible for people to watch the sunset from any point in time without restricting it to a fixed media concert presentation. The intention is, therefore, to use this piece as an installation to supplement the main programme of concerts at an event.

7. Space Movement Sound

This chapter examines the creation of visual music using the lumia factors of form, colour and motion. The three factors are examined in different combinations and implemented creatively in the études, *Colour Blends* and *Motion Shifts*. Lumia's equivalent factors in sound are also considered. It addresses Aims 1 and 3 and Objectives 2 and 3 of the investigation.

The compositions can be found on DVD 2

Textual Mnemonics

Colour Blends

Starting as completely black, a coloured dot soon appears in the centre of the screen. It expands and slowly engulfs the space. Now the colour has poured into every pixel, areas of colour textures shift and command the visual space. The colours continue to rotate and blend between states creating a constantly evolving textural colour space. Eventually, the homogenous textures break into a series of segmented lines of complimentary colours, which interleave and slowly separate before being attracted back together. The lines finally collapse into a single colour area before cutting back to black and visual silence.

Motion Shifts

A series of lines and patterns move across the screen gradually fading into footage of running water. This begins to break and degrade until it rapidly switches into a split screen with more water and linear patterns. The water shot cuts to further patterns before the light begins to strobe and alternates between geometric kaleidoscopic shapes. Slowly the tension builds towards an intermediate visual crescendo and then swiftly cuts to another rotating split screen. After a brief pause, the shifting patterns return and alternate with geometric line patterns. The piece climaxes with a strobing kaleidoscope, before cutting to black.

7. Space Movement Sound

Space Movement Sound was influenced by Wilfred's lumia art form and is a study in form, colour and motion. The intention was to investigate how lumia, which were a performance based art, could influence and be implemented in fixed media productions. To achieve this, contemporary visual music compositions were analysed to isolate the roles lumia played. This information was then interpreted in two new complimentary études that contrasted lumia's different aspects. Colour was the principle factor implemented in the first étude, *Colour Blends*. Form and motion were employed to create *Motion Shifts*. These two études were later combined to create the completed piece, *Space Movement Sound.*

Colour had been the primary lumia factor used to create Hue Music and *Colour Mirror*. It became apparent, through their production, that it was difficult to isolate it completely without also considering form and motion. Colour on its own can be used to create a light show, in more complex animations it will begin to take on a form that could also move. Equally, form and motion are unable to exist without basic colour qualities, even when in monochrome. It is generally the case, therefore, that one or more of the lumia factors will dominate parts of an animation and dictate the visual aesthetic. To examine this further, the roles of form, colour and motion in fixed media visual music and their correlates in sound will be analysed.

Form in Visual Music

In many artistic disciplines the subjects and forms of the artwork are an important focus, rather than the colours from which they are created. In classical sculpture, a bust may be carved, or otherwise formed, from a single material of uniform or near-uniform colour. The sketching artist may use a graphite pencil to draw quickly the shapes of people and other objects. In photography, black and white images are still used and occasionally films, either completely or in part, are made without colour. The subjects or objects in films are often the important focus, possibly because they are something with which the audience can relate or identify. Colour can often be omitted without modifying the visual narrative. Visual music compositions also frequently contain objects or forms, however abstract, whose behaviour is central to the composition. Such objects are rarely static, and their movement is often used to inform the modulation and tempo of the music. Moritz (2004) quoted Fischinger's work plan for constructing *R-1 Formspiel* (Form Play) and some notes for *R-2* which he believed were related, which highlights this point.

'Points of Staffs start to dance slowly, rhythmically, and arise gradually up to the middle of the picture. The tempo at first is practically non-existent, and then begins only slowly to become perceptible. Now single pieces grow out above the general line and take the lead in a particular way. Then they destroy the uniform line and attempt to lead an individual, independent life' (Fischinger, 2004, p.176).

These notes describe an abstract piece that concentrates on the evolution and movement of variously formed objects. Although very descriptive in terms of movement and pace, the abstract forms, which the objects possess, appear to play an important role in the design of this piece. The more recent work *Aerial* (Hegarty & Hegarty, 2004) takes a more minimalist approach to form, using a rendered silk cloth that continuously moves and reshapes. Accompanied by a treated vocal harmony, the changing form of the square silk cloth becomes the focus of the audiovisual experience. It is difficult to separate the form from the movement to which the cloth is being subjected but, as the cloth shifts and reforms, it is reflected by changes in the vocal soundtrack.

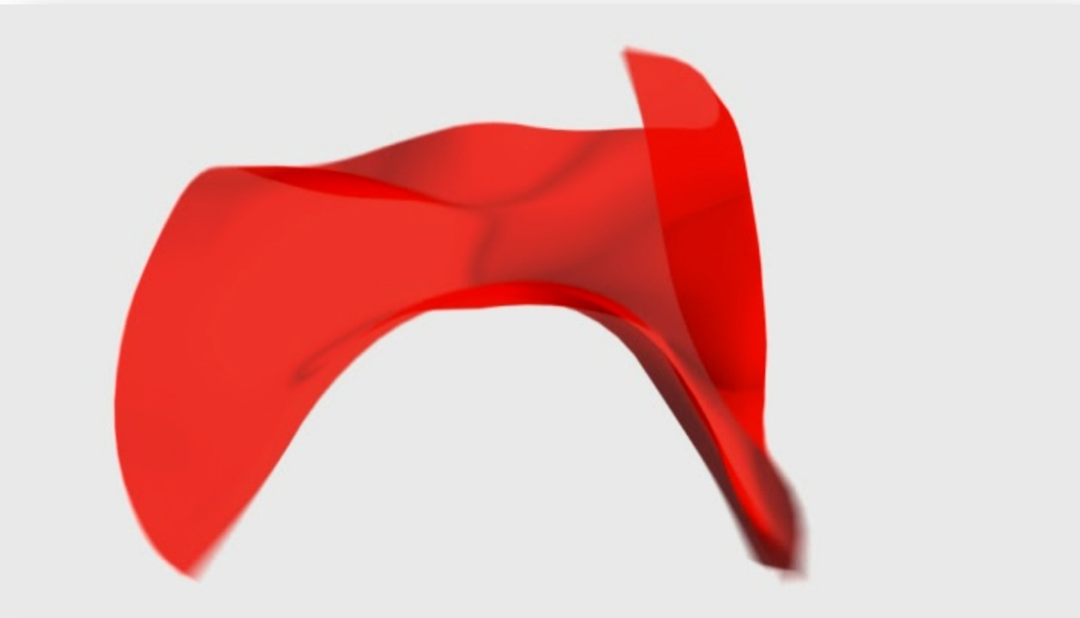


Figure 34 - Still from Aerial by Hegarty and Hegarty (2004)

Colour in Visual Music

Can colour exist without form and motion? Possibly the closest we can get to this state visually is a colour field. A colour field is an area of colour that completely engulfs the visual domain, and was described:

'The color field is an area of any single homogeneous color extending as far as the observing eye can see at that moment. This translates, in experiential terms, to the experience of seeing nothing but, say, light green' (Sloane, 1989, p.168).

In practical terms, this visual sensation could be achieved by holding a smooth surfaced piece of monochromatic coloured card in close proximity to the eyes. With uniform lighting a constant colour would be perceived. If the card were to be moved away from the eyes, the colour would eventually take on the rectangular form of the card and the pure experience of colour would be lost. This is similarly the case for colours that are rendered onto a computer or other screen. Although the screen may be filled with a single colour, it is constrained by the physical shape of the display. In art a canvas filled with a single hue would be very minimal, but some artists have created works that approach this. One example is *Vir Heroicus Sublimis* (Man, Heroic and Sublime) by Barnett Newman (1950):

'Newman was one of the several Abstract Expressionists who eliminated signs of the action of the painter's hand, preferring to work with broad, even expanses of deep color. Vir Heroicus Sublimis is large enough so that when the viewer stands close to it, as Newman intended, it creates an engulfing environment—a vast red field, broken by five thin vertical stripes' (Museum of Modern Art, New York, 2004, p.195).

The painting is two metres high and five metres wide. It is filled primarily with a vast expanse of red colour with five narrow vertical differently coloured 'zips'. As suggested by the Museum of Modern Art in their catalogue notes (Anon, 2013), this painting is to be experienced closely; the shape and texture of the canvas are not as important as the colour and its depth and the observer's interaction with it.

In contemporary visual music there are examples where colour has been used in relatively pure ways with abstract forms, the piece, *Phase,* by Andrew Hill (2011) being one of these. Although described as a study exploring the transformation between states, *Phase* uses slowly evolving colours and abstract cloud like formations to convey this transformation. The result is an organic evolving colour space.

A similar use of abstract colour spaces can be found in *Colour Blends* between 1' 10" and 2' 00".

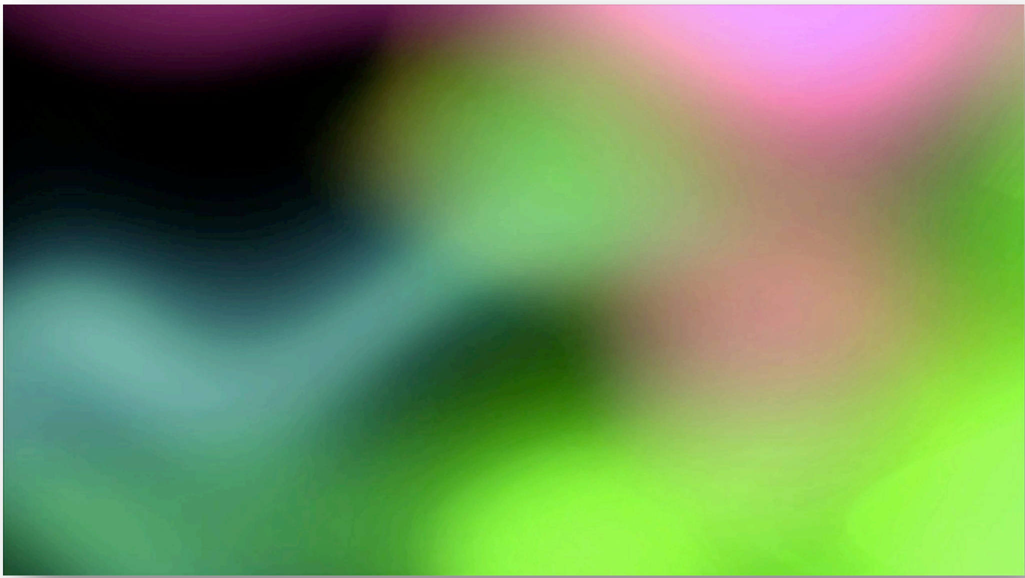


Figure 35 - Still from Phase by Andrew Hill

Motion in Visual Music

Filmed recordings implicitly contain motion. Even if the camera recording a scene was in a fixed position, as in *Sunset*, there will be some movement of light and shadow over time. If a series of still images were presented as a film or slideshow there would be movement or light changes as the images were transitioned. These are quite minimal examples of motion; it is more common for objects to move in an obvious, and often gestural, manner in visual music. An early animated film exploring temporal design and motion is *Symphonie Diagonale* (Diagonal Symphony) by Viking Eggeling (1924). This piece could also be interpreted as a study in geometric form, but the diagonal movement of abstract objects dictates the pace of the animation. A less overt approach, but nonetheless effective use of motion, is in the film *Heliocentric* by Semiconductor (Jarman & Gerhardt, 2010). This piece used time-lapse recordings of the sun passing across various landscapes. The motion of the sun is tracked and accentuated by the music, which is predominantly constructed from a high pitch ringing tone. As the name *Heliocentric* suggests, the Sun is always at the centre of the screen. The ringing tone, which depicts it, is therefore always centrally panned in the stereo image. As objects in the landscape obscure the sun, the ringing tone becomes quieter. When the screen is brightened, as clouds diffuse the sunlight, the sound becomes louder. Although seemingly simple in concept, the quality of the video recordings and the attention to detail in the soundtrack combine to make the motion of the sun very apparent, although in reality it is the earth and landscape which is moving.

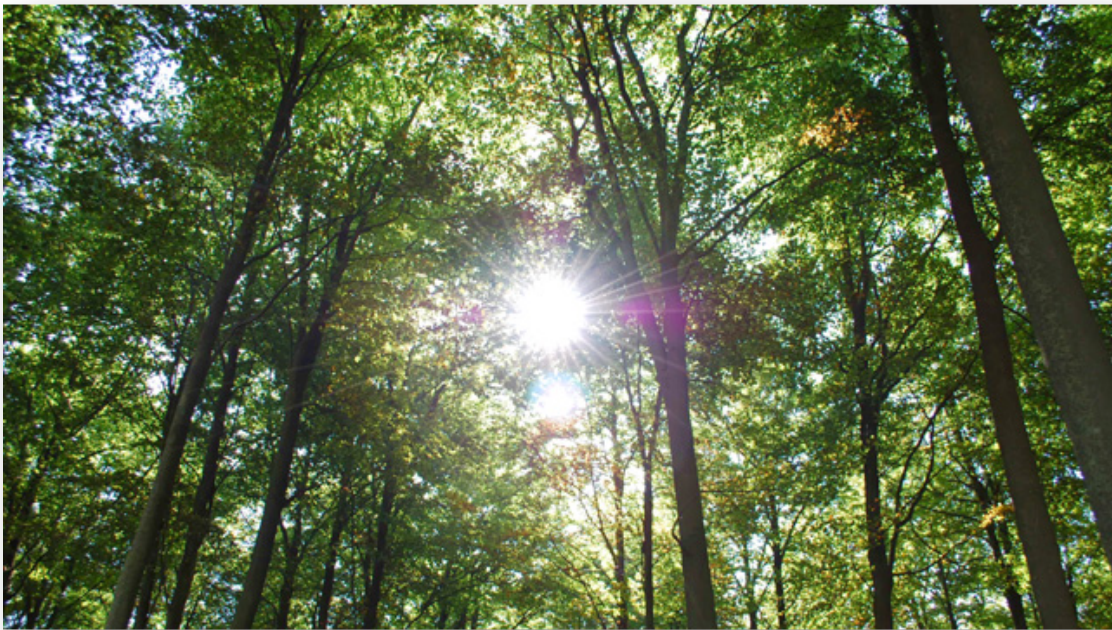


Figure 36 - Still from Heliocentric by Semiconductor (2010)

The entire *Motion Shifts* section of *Space Movement Sound* is designed to suggest movement in a more exaggerated way. The captured footage already contains movement but the way it is treated and edits between shots were designed to enhance this. Changes in lighting also give the suggestion of motion even when the objects are relatively static.

Combinations of Form, Colour and Motion

Another way of considering the lumia factors is how they pair with each other. The possible combinations are illustrated in Figure 37 overleaf, and Wilfred summarised:

Form, color and motion are the three basic factors in lumia—as in all visual experience—and form and motion are the two most important. A lumia artist may compose and perform in black and white only, never using color. The use of form and color alone—static composition with projected light—constitutes a less important, but still practical field in lumia. The only two-factor combination that cannot meet the requirements is motion and color, without form. This is because it violates a basic principle in vision. The human eye must have an anchorage, a point to focus on. If a spectator is facing an absolutely formless and unbroken area of color, his two eyes are unable to perform an orientational triangulation and he will quickly seek a visual anchorage elsewhere, an apex for the distance-measuring triangle that has its base between the pupils of his eyes. (Wilfred, 1947, pp.252–253)

Although Wilfred suggested motion and form cannot be paired naturally, McClaren (1978) later demonstrated that in animation motion can relate to change. Changes in the lighting, texture and colour of static objects are movements between states and are therefore a subtle type of motion.

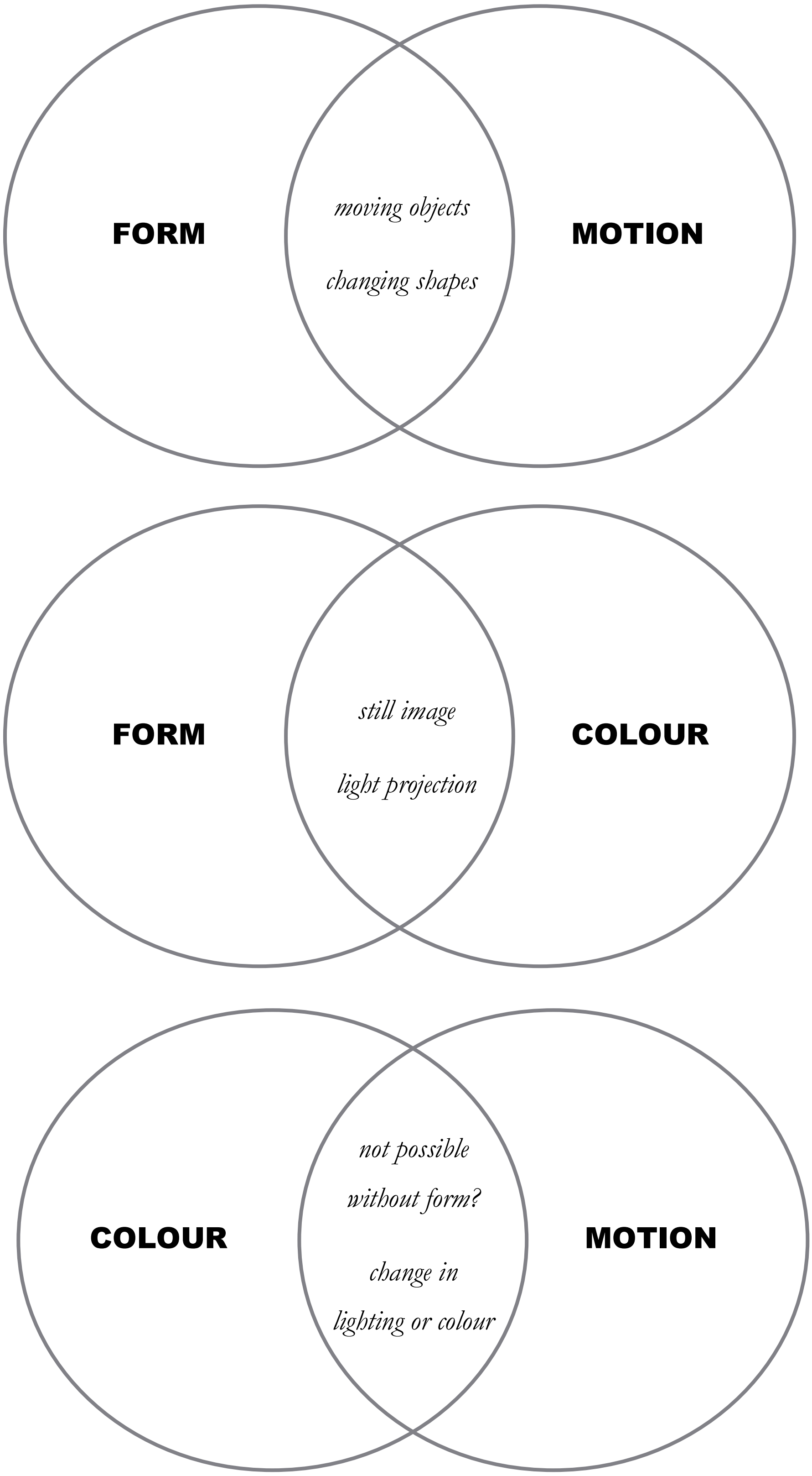


Figure 37 – Diagrammatic Representations of the Combinations of Lumia Factors. Based on Wilfred (1947)

Sonic Equivalents of Lumia

After lumia's relationships to fixed media were determined as above, sonic equivalents were considered and used to influence some of the musical composition decisions. Wilfred's further subdivision of form, colour and motion into their sub-factors were used in this process and are described below.

Sound Form

'Form has four sub-factors: LOCATION—Where is it? VOLUME—How big? SHAPE—What is it? CHARACTER—What is there about it?' (Wilfred, 1947, p.253).

The word form is commonly used to describe the compositional structure of music. Wilfred's definitions of its sub factors refer, however, to individual lumia, so the aim was to determine qualities of individual sounds relating to these. The first of his four sub-factors is location. In audio terms this can be related to the spatial positioning of a sound. Across two speakers, a sound can be panned somewhere between the left and right extremities of the sound field[8]. Between 4' 13" and 4' 25" in *Motion Shifts* video footage of flowing water appears first to the left and then to the right of a split screen. The audio recording of water naturally pans left and then right to match its visual position. Distance and the proximity of a sound can also be captured by various microphone techniques and simulated by adjusting the levels of dry and reverberated sound.

Another possible relationship between location and sound is the one between physical height and pitch. This concept was addressed by Roger Shepard (2001) when examining methods of representing pitch, height and something he labels chroma[9]. Chroma is the pitch of a note, independent of its octave. So the note 'C' is a chromatic value, but there is a middle C, C an octave above this and so on. Shepard went on to say,

'in the world, height and pitch are almost always linked, and things that ascend in height usually ascend in pitch' (Shepard, 2001, p.160).

Although a commonly used concept, objects that move in the vertical plane are not necessarily represented by a changing pitch value. It could be a consideration when creating visual music but is not used in this portfolio.

---

[8] This pan position could also be changed dynamically and will be dealt with in the description of motion and its sub-factors.

[9] Note that Shepard is using chroma here to refer to musical pitch. It is not the same as Wilfred's chroma, which is a sub-factor of colour as described below.

Volume, form's second sub-factor, can be associated with a sound's amplitude. This has a basis in physical phenomena as summarised by Smalley (1986):

'In the environment, when a sound approaches the listener its spectral and dynamic intensity increase at a rate proportional to perceived velocity. Moreover, the increase in spectral intensity permits the revelation of internal spectral detail as a function of spatial proximity' (Smalley, 1986, p.68).

An approaching sound could be one created by a car, for example. As it approaches it is perceived visually as becoming physically larger. The sound of the engine becomes louder to accompany this. An example of physical size influencing sound amplitude can be found in *Colour Blends*. During the expansion of the circle, that takes place between 46" and 1'10", the accompanying sound increases in intensity. The two remaining sub-factors, shape and character, are suggestive of timbral qualities. Timbre, applies more naturally to colour rather than form as described in Chapter 2 and will be examined below. One other relationship that could apply, however, is to the sound's envelope. Percussive and gentler sounds, for example, have very different characters and envelope shapes. Many of the directly drawn sound experiments described in Chapter 2 appear to confirm this analogy.

Sound Colour

'HUE—What color is it—red, green, blue? CHROMA—How much gray has been mixed with the pure hue? VALUE—How much white in that gray? INTENSITY—How strong is the light it sheds?' (Wilfred, 1947, p.253).

Colour has several relationships to sound. The ones between hue, pitch and timbre have been described in Chapter 2. Wilfred's sub-factors of hue, chroma and value can be equated to the hue, saturation and lightness (HSV) colour system also described in Chapter 2. This system was used to develop a sound selection system by Stephen Barrass (1997, pp.127–137) and is one possible method of mapping between colour and sound in a more precise way. In his experiment, hues were mapped to different timbres, saturation to their pitch and value (lightness) to how much high frequency content they contained.

The final sub-factor, intensity, could once again refer to the sound's amplitude. This appears to be a duplication of the volume sub-factor of form, but does not confuse the issue as a large intensely coloured object could also be represented with a loud sound. This relationship is demonstrated in *Motion Shifts* between 4' 32" and 4' 50", with flashing lights matched in intensity with amplitude modulated audio textures.

Aside from Wilfred's definition, colours can be described as possessing spatial qualities. They fill the space between painted lines and object forms and could therefore be portrayed in music with sounds that naturally fill the aural space. This can be accomplished with sounds of longer duration; these would fill the temporal space. Extended sounds of this nature would frequently be more textural, with gradual envelope characteristics and a focus on timbral transformation as described in Chapter 6.

Sound Motion

ORBIT—Where is it going? TEMPO—How fast? Speeding up? Slowing down? RHYTHM—Does it repeat anything? FIELD—Is it constantly visible, or does any part of its orbit carry it beyond the range of vision? (Wilfred, 1947, p.253).

The third lumia component, motion, also has four sub-factors. Orbit and tempo can be associated with the spatial positioning of sounds in a similar way to the location sub-factor of form but in this case motion is applied. If an object moved across the screen from left to right this could be accompanied by a sound that also panned left to right. The quicker the object moves the more rapid this audio pan would be. Composers often use this effect and several examples can be found in *End Transmission* (Hyde, 2009). Rhythmic movement of on screen objects could also be represented by regular panning of the sound, or a percussive or melodic musical rhythm. The 'field' sub-factor is less intuitively linked to sounds but could be said to apply to one that becomes silent. An object 'beyond the range of hearing', in this case, would not be heard. Alternatively, if a sound was tracking an object that moved off-screen it could actually appear to also move off screen. This is a phenomenon Chion (2009) calls 'spatial magnetization' and is perceived even if there is only a single speaker producing all the sound.

'If the sound that comes from the fixed speaker is attributed to an onscreen character, and if we see him or her move to the right, we are going to hear the sound move to the right; if the character exists offscreen, we hear the sound as outside the screen too. The phenomenon of spatial magnetization, whereby our attribution of a sound's location depends on what we see of the real or supposed source, can be observed on countless occasions every day' (Chion, 2009, p.248).

Even though the object cannot be seen it could still be heard. This idea was used later in *Diffraction*. During the middle section, from 3' 42" to 4' 53", there are times when the screen is blank but sounds can be heard either to the left or right of the sound field. Coloured forms then appear with louder sounds giving the impression that the colours were initially being heard off screen.

Space Movement Sound

This analysis of visual music in relation to lumia factors and their sonic equivalents led to the development of *Space Movement Sound*. Not all the findings were implemented in a literal sense, but informed some of the compositional details and concept for each étude. Since form and motion grouped together most naturally, they were the main compositional tools use to create *Motion Shifts*. Colour therefore remained to be explored in *Colour Blends*.

Motion Shifts

Form and motion combined naturally in *Motion Shifts*. Motion is evident throughout the piece and various forms are transformed to produce a constantly changing visual experience. Changes in light intensity, often in a strobing manner, also suggested movement. Although colour was not compositionally important, there are subtle colour effects evident on closer inspection. Primarily, however, low colour saturation video footage was used, and in several instances the images are simply grey scale. This created a contrast between the more deliberate uses of colour exhibited in *Colour Blends*. The dynamic movement and transitions in the video footage encouraged tight synchronisation between sound and image. This was not without certain problems, as it was difficult for the sound to follow a straight video cut from one scene to another. Translating this directly would have meant an abrupt switch between two different recordings. Some of the transitions were therefore softened by use of volume and cross fades, or through the addition of reverb and delay effects that extended them for a short time. Although the audio did not change as immediately as the image, the illusion of a rapid audiovisual switch was maintained. The reverb technique can be observed at 4’00” and an extended volume fade from high to low intensity at 5’04” in *Motion Shifts*.

Colour Blends

Colour was the remaining lumia component to be investigated in *Colour Blends*. Isolating colour in this way is difficult since, following Wilfred's discussion colour cannot exist completely without a form. To alleviate this, some compromise was made. Subtle suggestions of form and motion were added to create abstract colour textures in a slowly evolving organic animation. As in *Sunset* the focus was shifted towards the textural qualities and away from gesture. Many different textures were produced with different colour gradients and blending operations carried out between them. This created many different colour shades throughout the étude.

A consequence of minimising form and motion in this way was that the visual composition has limited punctuation and transients, which translated to reduced dramatic musical gestures when compared to *Motion Shifts*. Instead, the spatial nature of the colours was emphasised and the soundtrack composed with sounds that filled the aural space. Expansive musical ambiances were often created using washes of sound, sonic airbrushes, or what in digital synthesiser's parlance are commonly referred to as pad sounds.

'Pads are smooth, string-like sounds that can fill out the harmony of a song. They work especially well in slower tempos or in sections where other instruments are more percussive; they can smooth out the sound of the song as a whole. Some pads have a "violin-ish" sound to them, while others sound more electronic or synthesized. Other pad sounds can vary widely in sound and timbre. Some will have a slow attack, meaning that the sound is not heard immediately after striking a key. These slower-moving sounds work best in songs or sections with slower tempos or those that don't require sharp attacks. Other sounds will have a long decay or release, meaning that the notes will linger after you let go of them' (Dryden, 2001, p.15).

Using this type of sound, its timbre, pervasiveness and gradual transformation were more important than its pitch articulation and phrasing. Apart from synthesiser pads, transformation and time stretching of found sound recordings resulted in timbres having a definite textural quality, as described in Chapter 6. Outdoor field recordings also inherently contained their own spatial qualities acquired from the environment in which they were recorded.

Notes on Colour Blends Video Production

The colours used in *Colour Blends* were all extracted from photographs of physical objects, or scenes, in natural light. Figure 38 shows some of the images used in this process. Three shades of each colour from lightest to darkest were chosen to produce a number of different colour gradients. Any colour could have been synthesised in software but it was believed the result could have looked somewhat artificial. The organic textured backgrounds were therefore rendered initially in black and white, and the colour gradients overlaid. The visual result was that the colours remained true to ones that could have been created through natural lighting conditions.

Figure 38 - Some of the Images used to Extract the Colour Palette for Colour Blends

Space Movement Sound Summary

This composition demonstrated how lumia factors could influence the production of audiovisual fixed media. Slowly changing colours were combined with evenly paced textural sound, and form and motion used to create a more dynamic and synchronous audiovisual experience. Lumia's form and motion factors applied most naturally to fixed media composition. The sub-factors relating to position, movement, shape and volume could be portrayed easily in both sound and image. The gestural behaviours of moving objects and edits in video also suggested similar qualities in music. Composing to the dynamically changing video was therefore a relatively simple task. Conversely, composing music to the textured colour animations in *Colour Blends* proved more of a challenge. With limited visual change and movement the sounds were sustained for longer periods. This resulted in little visual or auditory punctuation creating stasis and repetition in the audiovisual experience. The nature of this étude, however, further highlighted the relationships between reduced visual gesture and textural sound previously discussed in Chapter 6. Even though gesture was minimised it presented opportunities to work more intently on gradual sound transformations.

This page included for formatting purposes

8. Diffraction

***Diffraction* examines the results produced when an iterative approach is taken to audiovisual composition. Allowing the influence to flow between media in a fluid way created interconnectedness and coherence between image and sound. This piece was created by adhering closely to a central design theme and represents the culmination of previous techniques and ideas presented in this thesis and the portfolio.**

The composition can be found on DVD 2

Textual Mnemonics

Diffraction

Gently falling rain sends ripples across a concrete patio. The downpour quickens and the sound of falling water is accompanied with drifting harmonic tones. Sunlight appears brightly, cuts through the shower and splits the light into fragmented refracted coloured rays. The scene fades to darkness before lights enter from corners of the screen and are joined by textured chords that sweep with the flowing colours. Movement pauses before a light flashes and intense thunderbolts of sound and light alternate between rain and bright colours. This subsides and yields to an abstract space through which colours transform, refract and diffract and long textural drones fill the auditory space. Noise gives way to colours and the colours bend like liquid overlaid on fragmented grey particles. Multi-coloured rain now returns with bright harmonic textures until the colour subsides, the rain absorbs the light and the transformations are complete.

8. Diffraction

Diffraction was the final piece created for the composition portfolio and it made use of many of the preceding ideas. It followed on naturally from the concepts formulated in *Space Movement Sound. Colour Blends,* in particular, was a strong influence on the direction of this composition, especially the way abstract colour animations drove the momentum of the piece in a more evolutionary and textural manner. There was also more experimentation with form and motion. The animations contained coloured forms that adopted motion, changed shapes and evolved in abstract ways, departing from the relatively static textures present in *Colour Blends*. The electroacoustic musical composition techniques that had been developed during the production of *Soni-Chrome*, *Theravada Colour Morph* and *Sunset* were employed in the creation of the soundtrack. The ensuing range of sounds, textures and transformations reflected the abstract qualities of the video.

In general terms, the piece began with a simple programmatic concept, one that would use refraction and diffraction as themes around which all the sounds and images would be formulated. A creative interpretation of these effects would allow a further exploration of the use of colour, and its sound relationships, when applied to visual music composition. Although a relatively simple idea in itself, it expanded into several methods and techniques during the production of the composition.

Refraction, Diffraction and Rainbows

The piece is entitled *Diffraction* but is an artistic interpretation of the effects produced both by diffraction and refraction. *Diffraction* was preferred as a title as it is a more diverse process when compared to refraction, which is commonly associated with the production of rainbows. Diffraction causes light to change its path in a number of ways depending on the obstacle it meets. Even so, the production of rainbows from white light was a core influence on the composition. An interest in rainbows has been documented over a long period, as attested to by Koyre: *'The production of spectral colors by crystals and drops of water, and the concomitant theory of the rainbow, has a long history and even prehistory behind it extending through the Middle Ages to antiquity'* (Koyre, 1968, p.3). A pioneer in the study of refraction, Isaac Newton, carried out a scientific investigation and experimentation of creating rainbow spectra with prisms. His treatise of the reflections, refractions, inflections, and colours of light, documented in Opticks (1704), details his experiments. Refraction is the bending of light when it passes from one medium to another. The amount by which it bends is, in part, determined by its colour. As Newton stated, '*Lights which differ in Colour, differ also in Degrees of Refrangibility*' (1704, p.21). A colour with a larger degree of refrangibility will bend more than a colour with a lower one. If white light is passed through a prism, its individual coloured components will bend by differing amounts and exit at different angles. This causes the white light to be separated into the rainbow spectrum, coloured from red to violet. A similar result is achieved when sunlight passes through raindrops to create rainbows.

The effect of diffraction is somewhat different, and is that which occurs when light or other waveforms encounter an obstacle. It was first documented by Francesco Grimaldi (1665).

'Propositio I. Lumen propagatur seu diffunditur non solum directe, refracte, ac reflexe, sed etiam alio quodam quarto modo, diffracte' (Grimaldi, 1665, p.1).

Proposition I. Light is transmitted or diffused not only in straight lines, by refraction and reflection, but also in some other fourth way, diffraction.

Grimaldi therefore suggested that diffraction was a phenomenon that differed from the existing knowledge on the behaviour of light and it should be given its own classification. When light encounters an obstacle it will bend and when it passes through a small opening it will spread out and diffuse. If light passes through more than one opening, patterns of multiple light points can be created dependent on the way diffuses and recombines. These are all types of diffraction and although commonly associated with light, sound pressure waves can also be diffracted.

Many of these effects were used as creative influences on the composition. Animations and sound treatments based around these themes were created to produce a range of visual music materials. Many of the physical contributors to the processes, such as sunlight and rain, were also recorded and used directly in the video and audio compositions.

The Composition Process

In structural terms, the composition comprised three different sections, an introduction and two following stages that were interrelated. The first section was an initial exposition that introduced the physical components of rain and sunlight. In the following two sections colour is investigated in a more abstract way, as if it had escaped from the pure white light, post refraction, and was undergoing further transformation through diffraction.

The first section was composed video first and the music created afterwards. Since the visual elements of refraction were being introduced, it was appropriate to let them dominate and dictate the nature of this passage. Sound would assume more importance as the piece progressed, creating bi-directional sonic and visual relationships. Composing to imagery of rain and sunlight during this phase resulted in evenly paced textured sound materials with little variation in intensity. A change in dynamics was therefore necessary, during the middle section, to interrupt the flow of the piece and maintain interest. A consistent pace and atmosphere can be used in composition, as demonstrated in *Océanes* by Jean Piché (2011). Throughout its 9' 15" duration, rendered particle animations are accompanied by vocal like synthesised harmonies resulting in an absorbing multimedia work. Although presentable in a concert situation, this piece is also designed for use as an installation. An audience could experience it in shorter sections and observe similar material regardless of the point they enter into the installation space. The extended nature of the themes is therefore not an issue. Being a fixed media piece for presentation exclusively at a concert, more variation was desired in *Diffraction*. Taking this into consideration the music for the middle sections of *Diffraction* was created before the video so the desired qualities were inherent and not dictated by the form of the video. To achieve a change in dynamics, sounds were designed that had a percussive attack and extended release phases. Between these percussive elements there were pauses with fewer quieter sounds. Although the tempo is similar to the introduction, the soundtrack and visual elements create anticipation by delivering sequences of dramatic sounds and colours separated by darker softer passages.

The final section of video was actually the first piece of visual media to be created. The programme themes, of refraction and diffraction, were held in mind and abstract colour transformations animated to represent them. This resulted in bright colours and shapes that were suggestive of the behaviour of colours after they had been separated by refraction and further modified by diffraction. This animation was therefore suitable to represent light after it had undergone several transformations and could be used as the final section of the piece.

Each of these three sections were composed independently and later combined to create the completed piece. There was a distinct style within each section of the composition, and a consequence of this was that there was no inherent transition between the stages. This made compiling the sections together as a coherent whole difficult, and creating continuity in the piece proved to be one of the greatest challenges. Having a programme theme helped to alleviate this problem, as did the use of similar production technologies.

Creating Refraction in Sound

Another challenging aspect of the composition was to create a soundtrack that had traits that were analogous to the visual themes. This could have been approached in many different ways, but it was decided to attempt to recreate the refraction process in sound. To achieve this, sound had to be split into its component parts as light is split into component colours. The reverse procedure of this, the recombination of separated sound materials into a more holistic one, was also investigated.

As white light is a starting point from which refraction in light can take place, an equivalent starting sound had to be found. Noise was chosen for this purpose as it contains many frequencies in a similar way that Newton proved white light contains many colours. To refract noise, it had to somehow be broken apart. This could have been achieved by granulation and this would split the sound over time. Alternatively, by treating the noise so that specific frequency components were enhanced and isolated, the sound could be refracted, in the sense that its spectrum is broken into several component frequencies. This would therefore be a spectral refraction rather than a time based one. This was the chosen method and it also proved useful for the reverse refraction process whereby coloured lights are recombined back into blended shades and white. This is an original aspect of this work; a similar approach has not been observed in other compositions.

A Refraction Program

The spectral refraction effect was created primarily by passing the white noise source through Michael Norris' Spectral Dronemaker plugin. This plugin is part of his

SoundMagic Spectral Shapers, which *'is a FREEWARE suite of 24 Audio Unit plug-ins that implement real-time spectral processing of sound'* (Norris, 2014). To make the use of Spectral Dronemaker more interactive, MAX/MSP was used to host the plugin and a gestural interface designed that allowed the user to react to changes in the visual imagery and create sounds in response to these. The gestural interface received data from hand movements on the laptop trackpad so as fingers were swept across it, more noise was fed into the signal processing chain. Additionally, the SoundMagic SpectralStretch plugin was included in the signal processing chain. Its 'beta stretch' component was manipulated to pitch shift all the frequency components of the noise up or down the spectrum. The result was a program that could be performed while watching the video and had flexibility for creating a wide range of sonic textures.

Details of the Audio Refraction Process

Initially white noise was passed through Spectral DroneMaker with its filter level and resonance set to zero, interpolation length increased to between 5 and 10 and the remaining parameters at their default values. With this configuration the plugin extended the duration of the sound and imparted a somewhat processed characteristic to it. These processing artefacts were more noticeable with a low FFT size. When the FFT size was increased to 16384 points and above, the noise remained relatively unchanged. To allow the characteristic filter sound to be imparted by the plugin, its filter level and resonance were increased to very high values, typically 99 out of a maximum of 100 for each parameter. This caused the noise to be filtered into a series of resonant peaks positioned across the audio spectrum, as illustrated in Figure 39. The plugin allows these peaks be placed at harmonic intervals across the audio spectrum to create chord structures and several types were used to match the nature of the visuals.

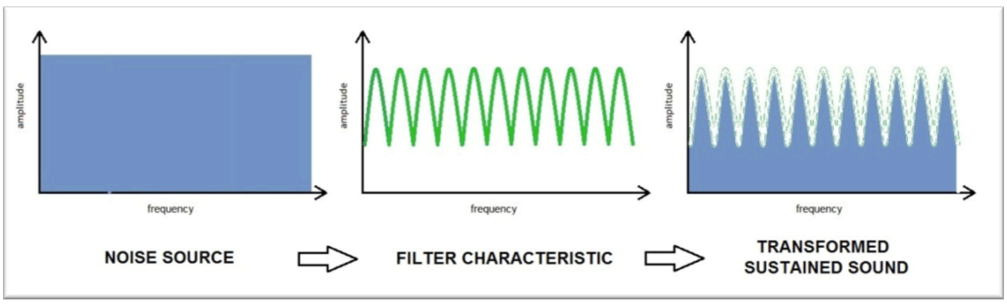


Figure 39 - Creating Tones by Filtering Noise

The blue rectangular area on the left of Figure 39 represents the white noise input, containing all frequencies at the same amplitude. The green line, with a series of peaks in the centre of the image, represents the filter characteristic created by the plugin. When noise is passed through this filter, the result is a sound made up from the frequency spectrum, displayed to the right of the diagram. Much of the spectral content has been removed from the noise, leaving a more clearly defined harmonic structure.

This process is further illustrated with the spectrograms in Figure 40. The x-axis denotes time and the y-axis frequency content. The upper part of the figure shows the input noise source filling the entire frequency spectrum indicated by the saturated orange colour extending left to right over time and bottom to top in frequency content. The colour intensity reduces to the left and right of the spectrogram indicating a gradual amplitude fade in and out. The lower part of the figure shows the noise filtered into a series of resonant peaks after being passed through the software. The horizontal orange lines indicate these.

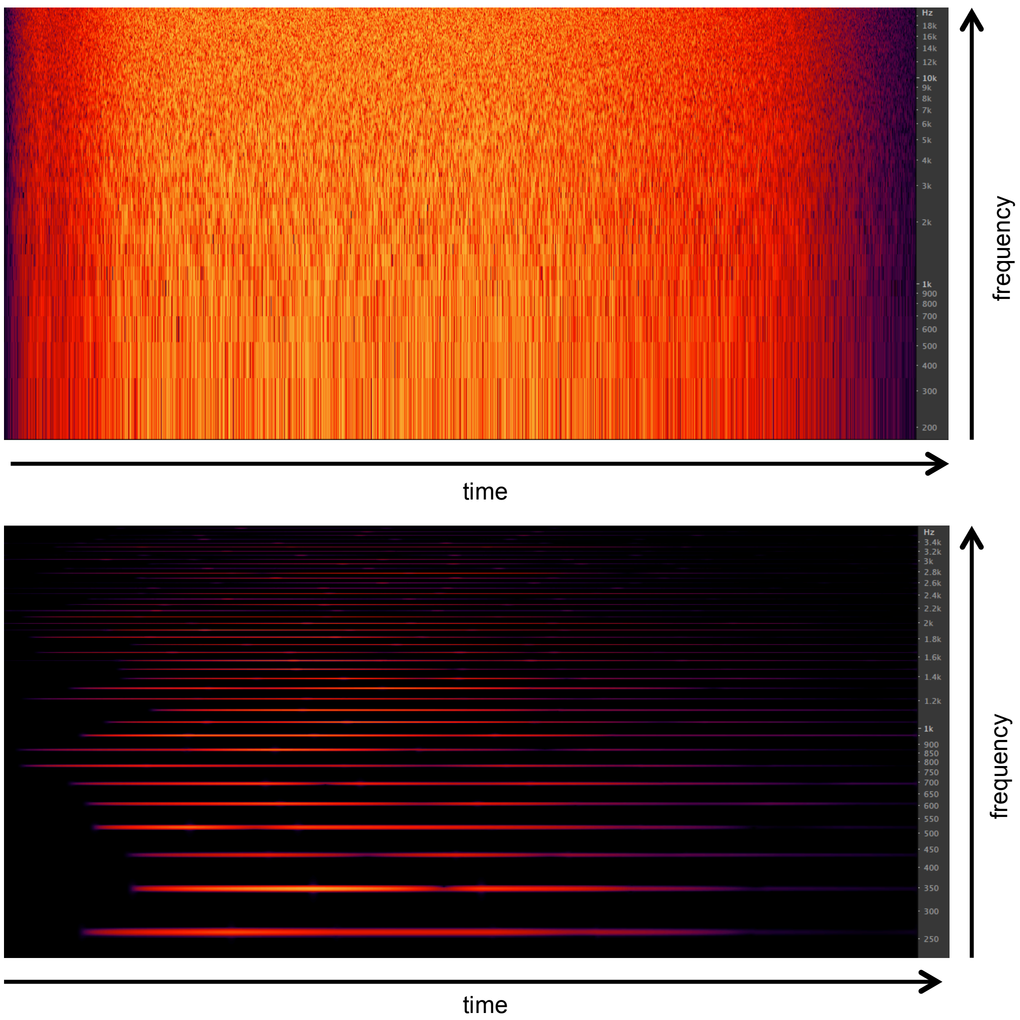


Figure 40 - Spectrograms of the Input Noise Source and Filtered Sine Tones Created by the Filtering Process

Many recordings were taken from repeated use of this program, each with minor changes, selection of different chord structures and with different gestural input while watching the videos. The result was a large quantity of so-called refracted sounds that were added to the sound library and called upon at a later stage. Examples can be found in the composition between 2'25" and 2'45" and 8'00" and 8'25".

Recombining Tones into Noisy Textures

If the end result of noise refraction produced a series of tones structured into a chord, the reverse process would be to use tones as the starting point from which noise like sounds could be recreated. This can be considered as a Fourier type synthesis, where a series of independent single frequencies are combined to create a complex tone. *'Fourier synthesis allows us to create a waveform from a specification of the strengths of its various harmonics. That is, in fact, all a spectrum really is: a specification (in the form of a function or a list) of the strengths of the harmonics of a waveform'* (Loy & Chowning, 2011, p.103). If the specified sound is noise, using Fourier synthesis it would be necessary to use an infinite number of tones to recreate it, as white noise contains every single frequency at equal amplitude. In practice, it proved unnecessary to create pure white noise. It was sufficient to create a very dense sound that approached the qualities of a noisy drone, and was suitable for use in the composition. This idea was carried out in practical terms by modifying the previous Max patch. The input source was changed from noise to a sine wave. The gestural interface was maintained, but in this version of the program it was used to sweep a sine wave across a range of frequencies. The amplitude of the swept sine wave was sustained so the spectrum was gradually filled to become denser. As an illustrative example, the input sine wave could be swept from 100 Hz to 1 KHz by moving fingers across the computer trackpad. As this occurs, the intermediate frequencies are sustained and the spectrum temporarily contains all partials between 100 Hz and 1 KHz. With reference to Figure 41, the blue line in the leftmost part of the diagram represents the starting point of a pure sine tone. The initial frequency of the tone is actually arbitrary and can be chosen through the gestural interface. As the interface is excited further, more frequency partials are produced, as indicated by the larger blue coloured area leading up to the sustain phase shown on the right of the diagram.

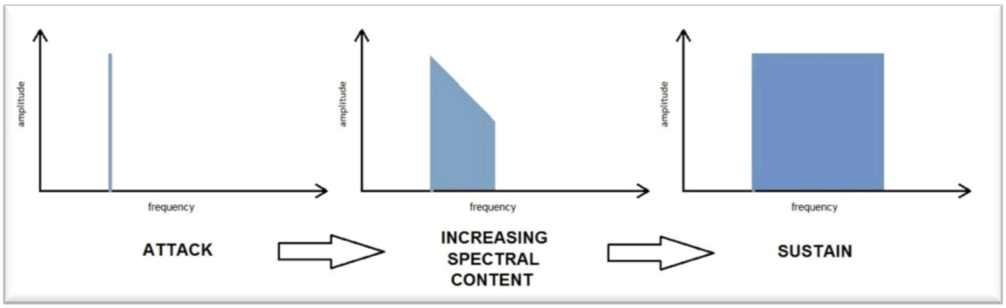


Figure 41 - The Attack and Sustain Phase and Increasing Spectral Content

When the gestural input is removed, the sound enters the decay and release phases as shown in the left and central sections of Figure 42 below. The blue area of the spectrum continues to be sustained for a short while after the input is removed. After this period, the energy in the lower part of the spectrum begins to decay and to reduce in amplitude. This continues during the release phase until the entire spectrum has decayed to silence. The high frequencies are the last to be removed in this example, but reversing the gestural input will cause the lower ones to be sustained the longest. The SoundMagic SpectralStretch and Spectral Dronemaker plugins were kept in the signal processing chain but were used minimally for added sustain and harmonics. The filter parameters in Spectral Dronemaker were set to very low values so as not to eliminate any frequency components.

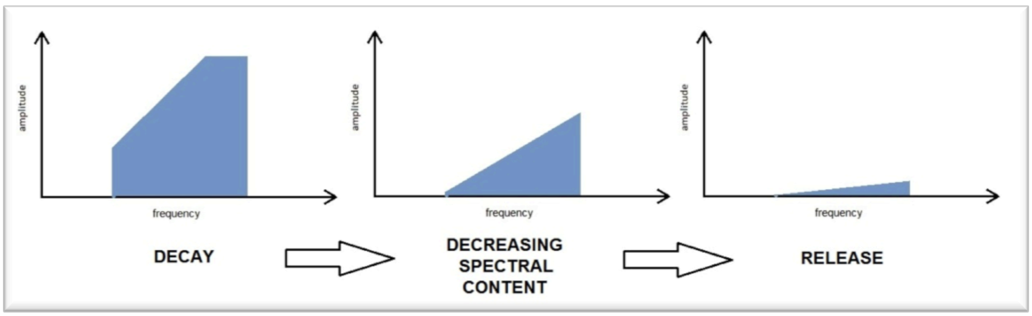


Figure 42 - The Release Phase and Decreasing Spectral Content

Figure 43 is a spectrogram of the resultant sound, which illustrates the spectral behaviour of the tones over time. Not all the intermediate frequencies are present; there is a noticeable quantity of individual harmonics across the spectrum. This is partly due to the FFT processing in the SoundMagic plugins and the resolution of the sweeping action not being sufficiently fine enough to produce a perfect continuous sweep. As the frequency partials are large in number, however, they are not noticeable as individual tones and the resultant sound is a dense drone like texture.

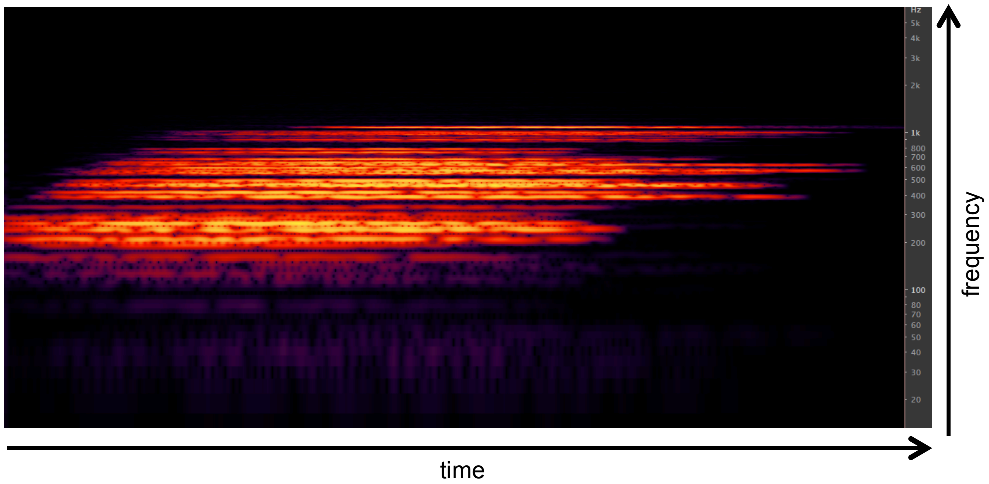


Figure 43 - Spectrogram of a Noisy Drone Produced for Diffraction

Again, this program was used repeatedly to add many sounds to the library for later use in the composition and examples can be found between 2'22" and 3'00" and 4'01" and 4'11".

Other Uses of Noise in the Composition

These programs produced the vast majority of sounds used in the composition. There was still a need, however, for other materials to aid structuring and to accompany scenes that contained rain and other noisy visual textures. Audio noise sources were one component useful in this respect. Noise can be synthesised quite easily, but is static both in terms of dynamic behaviour and spectral content unless manipulated in some way. Working with more uncertain and varied materials in previous compositions had aided the creative process so alternative noise sources were sought. One consideration was the use of natural noise sources. These already contain variation, which is acquired through natural filtering processes and the way they interact with objects in the environment. An example of this is the sound created by waves as they crash against rocks on the seashore. Another natural noise sound is created by falling rain. This produces a more consistent type of noise but also contains natural variations in quality as the wind and rain intensity changes. Rain was therefore chosen as another sound source and formed a natural accompaniment to the rain scenes in the video. Synthesised noise was still used but combined with actual audio recordings of rain. This afforded greater flexibility in the sound design process. A few seconds of synthesised pink noise was cross-faded with a real recording of rain, for example. This caused the continuous synthesised noise to become grainier in quality as the fade progressed. This fragmentation of a continuous noise source into smaller particles was used to accompany sections of the video where similar events were taking place. Where dense grey scale noisy images gave way to broken colourful scenes or disintegrated into smaller particles between 6' 50" and 7' 10", for example. Another sound design technique produced the reverse of this effect. Small grains of sound were used as a starting point and their density gradually increased towards a continuous noise texture. This effect can be heard at the start of the composition between 0' 10" and 1' 00".

Conclusion

Diffraction consolidated many previous techniques and compositional processes and proved to be very challenging. A resolution had been made to explore the chosen programme themes in great depth. There was also a desire to produce a final composition that would demonstrate a high level of technical and aesthetic competency. Although the compositional skills had been practised in earlier work, this previous experience set a self-imposed requirement to work at an even higher standard. In order to explore the themes from several different perspectives, alternative compositional strategies were employed in each section. This resulted in contrasting audiovisual synergies as the piece progressed. An alternative approach could have been to use a single consistent method around which the creativity revolved. Good results can be achieved by limiting oneself in this way, as demonstrated in *Colour Mirror* and *20Hz* (Jarman & Gerhardt, 2011) by Semiconductor, for example. *20Hz* has a consistent aesthetic and relationship between its aural and ocular components. This is imbued partly by the grey scale imagery from which it is constructed, but also from the primary compositional method, which involved the visualisation of atmospheric data. Since this singular-process type approach had been utilised in previous pieces such as *Colour Mirror*, it seemed more appropriate to use a variety of techniques that would demonstrate a range of production skills and create a composition with greater variety.

This page included for formatting purposes

9. Evaluation, Conclusions and Future Work

9. Evaluation, Conclusions and Future Work

The practical outcomes of this investigation are an algorithmic computer program and six audiovisual fixed media compositions. This thesis documents the creative processes, describes several novel approaches to creating visual music and how relationships can be developed between media. Before discussing important factors related to this exploration, the original aims and objectives are re-stated with explanations as to how they were addressed.

Meeting the Aims and Objectives

Aim 1. To explore the use of material transference to interpret between audio and visual domains and create visual music

Material transference was one of two specific techniques employed during composition, and it assisted in creating relationships between sound and image. Hue Music achieved material transference via algorithmic means. It creates a sonic rendering of an image by transferring hue quantity to timbre amplitude and provides an impression of its visual composition by scanning and focus. *Colour Mirror* used a refined version of this technique by manipulating the pitch and frequency content of sounds based on the quantity of colours present in the video. By increasing the complexity of the mapping and influence of the colours over the sounds, there was a greater degree of visual transference into sound.

In *Space Movement Sound,* the nature of the transference was based on concepts related to the visual performance art of lumia. Instead of algorithmic mapping, lumia influenced the musical compositional decisions as detailed in Chapter 7. In this case the composer enabled the transference by working directly with the audiovisual materials and deciding on the most appropriate way to represent lumia in video and sound. A similar approach was taken in *Diffraction* but this piece was composed in a more iterative manner. The transference occurred bi-directionally, as qualities of the completed media fragments were interpreted back and forth between domains.

Material transference proved to be a very productive technique in producing the bulk of audiovisual material for the portfolio and creating a bond between sound and picture.

Aim 2. To explore the use of compositional thinking techniques to create visual music

This was another technique used in composition, the results of which are present in *Colour Mirror, Soni-Chrome, Space Movement Sound*, *Theravada Colour Morph*, *Sunset* and *Diffraction*. Although *Theravada Colour Morph* and *Sunset* are discussed in terms of synchronisation and textural musical qualities, in Chapter 6, they can also be considered in relation to compositional thinking. *Theravada Colour Morph* was composed music first and its structural form translated into the visual domain. Since the music was completed prior to the visual composition, the video clips had to be arranged to the existing phases of the soundtrack. This imparted a musical form into the video. Conversely, the musical form of *Sunset* was dictated by the visual medium. The sunset was not filmed with the intention to capture a musical form, but the result possessed a subtle atmospheric quality that could be interpreted in a similar styled musical composition. The extended visual transition from light to dark imparted itself in sound as a gradual quietening and darkening of aural atmosphere.

The final section of *Diffraction* from 5' 50" onwards is another place where Hyde's original definition of compositional thinking as *'the application of more abstract ideas and principles derived from music to ocular media'* (Hyde, 2012, p.171), can be observed. It was animated with the deliberate attempt to make the colours behave with musical gestures and timing and these qualities were reflected in the resultant soundtrack.

Although compositional thinking had the effect of transferring qualities between media in a similar way to material transference, it occurred at the broader structural level rather than between the individual components of sound and video. Compositional thinking therefore dictated the macro structural form of a piece and material transference modified the small micro building blocks of sound and image.

Aim 3. To create visual music compositions influenced by historical developments in musical and visual composition

The portfolio works were created by, and possess, elements of audiovisual practice undertaken by other artists and composers. This process is most readily observed in *Space Movement Sound* and *Diffraction*. They both employed concepts relating to Thomas Wilfred's lumia as described in Chapter 7. Colour and timbral relationships, as described in Chapter 2, also played their part in the Hue Music program, and became a consideration during construction of the subsequent compositions.

From a musical perspective, sound based musical composition and spectromorphology, as described in Chapters 2 and 3, were considered to form natural accompaniments to the transforming video and coloured animations in *Soni-Chrome*, *Theravada Colour Morph, Space Movement Sound* and *Diffraction*. The flexibility of the sound design techniques and range of timbres produced reflected the dynamic visual morphology of the manipulated video footage and animations. Further inspiration was also taken from the composers listed in Chapter 1. The sound design and visual style contained in their works influenced aesthetic decisions during composition.

Objective 1. To explore the aesthetic links that exist between visual and musical arts

This objective is examined in Chapter 2, 'Historical Background'. In this chapter, influential composers are discussed and inventions and aesthetic concepts related to visual music composition described. This objective is also addressed in practical terms in the composition portfolio.

Objective 2. To investigate methods for recreating Thomas Wilfred's Lumia in fixed media video

It was discovered that the three lumia factors of form, colour and motion can be used as a means of analysing and influencing visual music compositions. Chapter 7 detailed the lumia factors and their equivalent sound properties and informed the production of *Space Movement Sound*. This piece sought to disassemble the factors, examine them each in turn and resynthesize them into a new composition. *Diffraction* took a less analytical approach to lumia, but still attempted to convey some of their aesthetic qualities. The visual style, particularly in the more abstract sections of *Diffraction,* resembles the lumia performance of Wilfred's *Opus 147 "Multidimensional"* (Wilfred, 1957), for example. To appreciate fully the transforming and illuminating qualities of the colours, *Diffraction* should be projected onto a large screen with a powerful projector in a darkened room.

Objective 3. To investigate algorithmic techniques to translate from visual to audio domains

This was a method of material transference used in the early pieces. Chapter 4, Hue Music and the accompanying program demonstrate a deliberate algorithmic mapping between coloured hues and musical timbres. There is further evidence of algorithmic mapping between colour content and musical pitch and timbre in Chapter 2, *Colour Mirror* and *Soni-Chrome*. The use of algorithms enabled the music to be programmed as a series of rules rather than by working directly with audiovisual materials. This approach was useful for sound design, rather than aiding in creating compositional form and detail. It created coherence and bonding between sounds and images. Once an algorithm was programmed, a large amount of material could be produced from the same process by using different source materials. This made algorithmic techniques a very efficient way of producing media content, although more focus was required in programming rather than composition.

Objective 4. To explore the use of synthesised and concrete found sounds or a combination of both to compose music for abstract video

This objective is addressed throughout the portfolio. The compositions deliberately used a wide variety of source sounds, which led to a diverse range of music. Contemporary approaches to electroacoustic music composition were also employed. Sound materials were transformed and arranged and compositional forms gradually developed, mirroring the approach taken to create the visual compositions.

Objective 5. To explore the use of animated visuals and real footage or a combination of both to create abstract video with musical qualities

This objective is addressed by the employment of material transference and compositional thinking in video composition. The visual compositions possess musical qualities by virtue of these techniques. As the music was composed from a diverse palette of source materials, the use of multiple visual source materials complemented this approach. Video synthesis and manipulation of recorded footage required different skillsets that were refined throughout the portfolio construction.

Discussion

Although a number of approaches were taken to create the compositions, a similar aesthetic style permeates the portfolio. This reflects a consistent approach of using abstract colour animations coupled with multiple layers of sound. These aesthetic preferences had been acquired through previous experience in musical composition, where utilising many sound layers had produced desirable results. By having more sounds available, intricacy could be developed by layering them in the frequency domain and editing and arranging them in the time domain. These techniques carried over into the video composition process by adding materials to the timeline before blending and editing to create rich visual montages.

Abstract animations were favoured over real imagery and concrete forms. When beginning work during the early stages of the portfolio, the use of symmetry created harmonious results and suggested musical movement and structures. The original forms contained in the videos were rendered less recognisable, but this was not considered a problem. They were considered to be visual equivalents to Field's (2000) virtual and non-real sonic landscapes that were present in the music. This preference for abstract imagery later influenced the results created through animation. Rather than attempting to create lifelike imagery, abstract forms were produced. These had the additional benefit of reflecting the behaviour of lumia and similar abstract visual animation techniques. Another consideration was that by adding recognisable elements into the video, such as people, they could have become the focus of the audiences attention. This could have distracted from the relationships being developed between music and picture. The use of these types of images could, however, be a consideration in future works as described below.

Colour and Monochrome

The deliberate attempt to develop colour and sound relationships, eventually led to slowly evolving expansive sonic and visual compositions. This is somewhat contradictory to current compositions of other academic and practitioners. A visual style found in many contemporary visual music compositions, such as *End Transmission* (Hyde, 2009), *Bric-a-Brac* (Dolphin & Ramsay, 2011) and *Océanes* (Piché, 2011), is a minimal use of colour and tendency towards the use of grey scale visuals. This could be due to an unconscious or deliberate recognition of Hyde's suggestion that black screens, minimal imagery, and visual noise or video snow, are useful equivalents in visual terms to silence and noise in electroacoustic compositions. He stated: *'I believe that silence and noise, or tending-towards silence and tending-towards noise, represent particularly fertile creative ground across visual and sonic media within visual music practice … [they] have demonstrable physical and phenomenological qualities in common – of particular interest to the visual music artist, I believe, is their propensity to enable a state close to reduced listening and the ocular equivalent I propose here, visual suspension'* (Hyde, 2012, p.177). These visual components are, therefore, particularly suited to reduced listening as preferred for the appreciation of electroacoustic music. The works presented here, however, have demonstrated that colour can be used expressively and accompanied with electroacoustic music without compromising the reduced listening experience. As discussed by Coulter (2007), this approach is most successful when the coloured imagery is quite minimal in nature and is one reason the later pieces, *Colour Blends* in *Space Movement Sound* and the middle section of *Diffraction,* developed this type of visual style. Colours are used sparingly as lighting effects, and motion and form are minimised, allowing the audience to enter more deeply into the listening experience. Using colours in abstract animations is not unique, other pieces such as *Phase* (Hill, 2011) and *Amorphisms* (Miller & Young Ha, 2008) demonstrate this, but parts of *Diffraction* use a more minimalist approach.

Future Work

Although the portfolio is self-contained and satisfies the aims and objectives for this research project, there is potential to create further fixed media works using alternative approaches. Following an approach based on lumia concepts resulted in works with enhanced colour and spatial qualities, textural emphasis and steady pacing. Although this was desirable in conveying steadily evolving colour transformations, it tended to reduce the variations in tempo in the accompanying soundtracks. Form and motion could be further investigated to see how it combines with colour in a more dynamic way to create the variation in pacing to be found in *Theravada Colour Morph*.

Counterpoint

Another approach to audiovisual composition could be one that explored counterpoint between sound and image. The current portfolio could be analysed in terms of counterpoint but it was not a consideration during the composition process. In audiovisual media, counterpoint can relate to the relative motion between sound and image, as Kapucinsky explained:

'The expression of motion of an aural or visual object depends on the motion of other objects in the field of perception. Counterpoint can be defined as the relationship of independent motion of a minimum of two objects. If the rules of linking are observed and sounds and images are referring to each other, because they belong to different modalities they can always be perceived independently, therefore they naturally create counterpoint' (Kapuscinski, 1998, p.46).

Counterpoint could be created between an object moving on screen and a melody performed on musical instrument, for example. Physical movements of visual objects could be countered with changes in musical pitch. This could be translated into the electroacoustic domain by pairing sound transformations with visual ones. This would potentially be a more complex technique, due to the variety of transformations possible, but it would permit deeper analysis and contribute to a greater understanding of the relationships that were developed between sound and picture in contemporary visual music.

Colour and Lights

One finding in relation to the nature of colours, was that they are constrained within artificial boundaries when rendered for video projection. *Colour Blends* illustrates this, as the expanding coloured circle cannot continually expand; it has to adopt a rectangular form as it meets the edges of the screen. Although projections can illuminate a darkened room, it is the screen itself that is observed and the visuals are restricted to its rectangular form. It is possible to eliminate the screen entirely and shine and adjust coloured lights alongside a musical performance inside a concert venue. This parallels the original design of some colour organs, where the coloured lights were projected freely rather than being rendered onto a screen. Subtle changes in lighting could be used to enhance and reflect the musical qualities during a performance.

Conclusion

Visual symmetry imparts a consistent style in many of the videos. When reflecting on its usage, it can be found primarily in the compositions that were considered to be more formative and developmental. *Colour Mirror* and *Soni-Chrome* used symmetry extensively and both these were created at a formative period in the portfolio. A comparison between algorithmic and composer led musical composition was being made. The piece immediately following this, *Theravada Colour Morph,* did not use symmetry. This composition can be considered to be a resynthesis of the earlier exploration and evaluation that was taking place during the preceding two pieces. *Space Movement Sound* was another experimental piece that used symmetry; in this case methods of using lumia were being explored. The work carried out here influenced the production of *Diffraction*, which was free from symmetrical imagery. Symmetry was therefore a useful developmental tool, during periods where more attention was being given to music composition and comparison between sound and image and also for the patterns and harmony it imparted in the imagery. *Sunset* was the exception to this general observation. Its video was created by Heather Minchin, who coincidentally made use of symmetry without her having any knowledge as to the nature of my existing works.

The portfolio demonstrates a continuum of progression between the early experimental pieces and the later works. This was due to a number of reasons. First, the development coincided with a gradual replacement of automated material transference techniques, with ones that were determined by the composer. Working first hand with multimedia materials gave greater creative control over the aesthetic outcomes without having to organise them indirectly through a layer of coding. Programming tools were still used in the later pieces, but this was for specific sound design purposes within a greater compositional process.

The use of clearly defined themes was the second major factor that influenced the results. The chosen themes had the effect of focussing the composition towards a more thorough exploration within a predefined, finite set of constraints. This meant the virtually endless array of possibilities for sound design and video manipulation were framed within a limited context. *Theravada Colour Morph* is framed in this way by virtue of its use of sonic and visual materials being from a single source. *Diffraction* has a coherence that was imbued by its themes of refraction and diffraction, around which all the animations and sound design were based. Future works would, therefore, be composed to a theme to take advantage of the sharper focus they provide.

Finally, there was a technological change that impacted on the results. This is evident from *Theravada Colour Morph* onwards. In these later works, all the video recordings and animations were recorded and processed in high definition. The Jitter component in Max, which was used to generate most of the earlier visuals, could not process the data throughput of HD video on the computers available. This forced a compromise, with the lower quality images being acceptable for exploring early algorithmic and electroacoustic soundtrack composition, but not being capable of producing the desired quality of images that can be seen in in later works. High definition will therefore be used wherever possible unless there are specific reasons for using a lower resolution, such as creating a more retro style of digital imagery.

Selected Performances and Presentations

Selected Performances and Presentations

Listen – Awakening. A Composition with Auditory Display (Multichannel Music Performance)

- 8th July 2004. International Conference on Auditory Display (ICAD). Sydney Opera House Studio, Sydney Australia

Hue Music – Creating Timbral Soundscapes from Coloured Pictures (Poster Presentation)

- 26th – 29th, 2007. International Conference on Auditory Display (ICAD). McGill University, Montreal Quebec Candada

Colour Mirror

- 5th May, 2013. NoiseFloor Festival. Staffordshire University. Stafford. UK

Theravada Colour Morph

- 16th January, 2010. NoiseFloor Festival. Staffordshire University. Stafford. UK
- 20-21st February, 2010. MANTIS FESTIVAL. Martin Harris Centre, University of Manchester, UK
- 6th November, 2010. Soundings - International Festival of Sonic Art. Reid Concert Hall, Bristol Square, Edinburgh
- 30th October, 2011. Seeing Sound Visual Music Symposium. Bath Spa University. UK.

Space Movement Sound

- 16th November, 2011. XVIII International Festival of Electroacoustic Music - Meeting Point. Electroacoustic Music Association of Spain. Valencia, Spain
- 3rd May 2012. NoiseFloor Festival, Staffordshire University. Stafford. UK (Paper Presentation)

Diffraction

- 3rd May, 2012. NoiseFloor Festival. Staffordshire University. Stafford, UK
- 20-22nd September, 2013. flEXiff, First and Last Experimental Film Festival. Sydney, Australia

References

References

Adobe (2012). *Visual effects, motion graphics software | Adobe After Effects CS6*. [Online]. 2012. Adobe United Kingdom. Available from: http://www.adobe.com/uk/products/aftereffects.html. [Accessed: 29 August 2012].

Anon (2013). *MoMA | The Collection | Barnett Newman. Vir Heroicus Sublimis. 1950-51*. [Online]. 2013. MoMA | The Museum of Modern Art. Available from: http://www.moma.org/collection/object.php?object_id=79250. [Accessed: 15 November 2013].

Apple (2012). *Graphics and Animation - Mac OS X Technology Overview - Apple Developer*. [Online]. 2012. Apple Developer. Available from: https://developer.apple.com/technologies/mac/graphics-and-animation.html. [Accessed: 29 August 2012].

Aristotle, A. (350AD). *On Sense and the Sensible*. [Online]. Available from: http://classics.mit.edu/Aristotle/sense.html. [Accessed: 27 June 2012].

Barrass, S. (1997). *Auditory Information Design*. Australia: The Australian National University.

Barrass, S. (2004). *Listening to the Mind Listening. Concert of Sonifications at the Sydney Opera House*. [Online]. Available from: http://www.icad.org/websiteV2.0/Conferences/ICAD2004/concert.htm. [Accessed: 27 June 2012].

Battey, B. (2005a). *Autarkeia Aggregatum*. 2005.

Battey, B. (2006). Autarkeia Aggregatum: autonomous points, emergent textures. In: *ACM SIGGRAPH 2006 Sketches*. 2006, p. 92.

Battey, B. (2005b). *Bret Battey - Gallery*. [Online]. 2005. Available from: http://www.mti.dmu.ac.uk/~bbattey/Gallery/autark.html. [Accessed: 14 August 2013].

Bishop, B. (1893). *The Harmony Of Light*. New Russia, Essex County, N. Y.: The De Vinne Press.

Bonebright, T., Cook, P., Flowers, J., Miner, N., Neuhoff, J., Bargar, R., Barrass, S., Berger, J., Evreinov, G. & Fitch, W.T. (1999). *Sonification Report: Status of the Field and Research Agenda*.

Bute, M.E. (1938). *Synchromy No. 4: Escape*. 1938.

Candy, L. (2006). *Practice Based Research: A guide*. Sydney: Creativity and Cognition Studios.

Castel, L.-B. (1740). *L'optique Des Couleurs, Fondée Sur Les Simples Observations, & Tournée Surtout À La Pratique De La Peinture, De La Teinture & Des Autres Arts Coloristes...* Paris: Chez Briasson.

Chion, M. (1994). *Audio-Vision : Sound on Screen*. Columbia University Press.

Chion, M. (2009). *Film: a Sound Art*. Columbia University Press.

Chion, M. (1983). *Guide Des Objets Sonores. Pierre Schaeffer et la Recherche Musicale.* Translated from French. Paris: Institut National de l'Audiovisuel & Éditions Buchet/Chastel.

Collopy, F. (2000). Color, form, and motion: Dimensions of a musical art of light. *Leonardo*. 33 (5). p.pp. 355–360.

Cope, N. & Howle, T. (2003). *Open Circuits*. 2003.

Coulter, J. (2007). The Language of Electroacoustic Music with Moving Images. In: *EMS : Electroacoustic Music Studies Network*. 2007, De Montfort/Leicester.

cycling '74 (2012). *Max « Cycling 74*. [Online]. 2012. Cycling 74. Available from: http://cycling74.com/products/max/. [Accessed: 29 August 2012].

Dolphin, A. & Ramsay, B. (2011). *Bric-a-Brac*. 2011.

Dryden, J. (2001). *The Pro Keyboardist's Handbook*. Alfred Publishing Company.

Eggeling, V. (1924). *Symphonie Diagonale*. 1924.

Emmerson, S. (2007). *Living Electronic Music*. New Ed. Ashgate.

Evans, B. (2005). Foundations of a Visual Music. *Computer Music Journal*. 29 (4). pp. 11–24.

Field, A. (2000). Simulation and Reality: The New Sonic Objects. In: S. Emmerson (ed.). *Music, Electronic Media, and Culture*. Ashgate Pub Limited.

Fischinger, O. (2004). A Document Related to R-2. In: W. Moritz (ed.). *Optical Poetry: The Life and Work of Oskar Fischinger*. Indiana University Press, pp. 176–178.

Fischinger, O. (1937). *An Optical Poem*. 1937.

Fischinger, O. (1947). *Fischinger - My Statements*. [Online]. 1947. oskarfischinger.org. Available from: http://www.oskarfischinger.org/MyStatements.htm. [Accessed: 31 July 2013].

Fischinger, O. (1932). Sounding Ornaments. *Deutsche Allgemeine Zeitung*. [Online]. Available from: http://www.oskarfischinger.org/Sounding.htm. [Accessed: 25 July 2013].

Frankel, J. (2012). *REAPER | Audio Production Without Limits*. [Online]. 2012. REAPER | Audio Production Without Limits. Available from: http://www.reaper.fm/. [Accessed: 29 August 2012].

Franssen, M. (1991). The Ocular Harpsichord of Louis-Bertrand Castel. *Tractrix*. 3. p.pp. 15–77.

Frayling, C. (1997). *Practice based Doctorates in the Creative and Performing Arts and Design*. Lichfield, Staffordshire: UK Council for Graduate Education.

Garro, D. (2012). From Sonic Art to Visual Music: Divergences, convergences, intersections. *Organised Sound*. 17 (02). p.pp. 103–113.

Gerstner, K. (1981). *Spirit of Colour: Art of Karl Gerstner*. MIT Press.

Giannakis, K. (2001). *Sound Mosaics A Graphical User Interface For Sound Synthesis Based On Auditory-Visual Associations*. School of Computing Science: Middlesex University.

Gregory, R.L. (1997). *Eye and Brain: The Psychology of Seeing*. 5th Ed. OUP Oxford.

Grimaldi, F.M. (1665). *Physico-mathesis de lumine, coloribus, et iride, aliisque adnexis...* Bologna, Italy: Vittorio Bonati.

Harrison, J.E. & Baron-Cohen, S. (1996). Synaesthesia: an Introduction. In: *Synaesthesia: Classic and Contemporary Readings*. Wiley-Blackwell, pp. 269–277.

Hegarty, J.H. & Hegarty, J.S. (2004). *Aerial*. 2004.

Hermann, T., Nehls, A.V., Eitel, F., Barri, T. & Gammel, M. (2012). Tweetscapes-Real-time Sonification of Twitter Data Streams for Radio Broadcasting. In: *Proceedings of the 18th International Conference on Auditory Display*. 2012, Atlanta, Georgia, USA.

Hill, A. (2011). *Phase*. 2 March 2011.

Humberstone, L. (1991). Timbre Noun - Definition in the Collins English Dictionary. *Collins English Dicitonary - Third Edition*. p.p. 1613.

Hutton, J. (2003). Daphne Oram: innovator, writer and composer. *Organised Sound*. 8 (1). p.pp. 49–56.

Hyde, J. (2009). *End Transmission*. 2009.

Hyde, J. (2012). Musique Concrète Thinking in Visual Music Practice: Audiovisual silence and noise, reduced listening and visual suspension. *Organised Sound*. 17 (02). p.pp. 170–178.

Instruments, N. (2012). *REAKTOR 5.7 | NATIVE INSTRUMENTS : PRODUCER*. [Online]. 2012. Native Instruments. Available from: http://www.native-instruments.com/#/en/products/producer/reaktor-55/. [Accessed: 29 August 2012].

Jarman, R. & Gerhardt, J. (2011). *20Hz*. 2011.

Jarman, R. & Gerhardt, J. (2009). *Black Rain*. 2009.

Jarman, R. & Gerhardt, J. (2010). *Heliocentric*. 2010.

Jarman, R. & Gerhardt, J. (2012). *Semiconductor*. [Online]. 2012. Semiconductor. Available from: http://www.semiconductorfilms.com/index.html. [Accessed: 28 August 2012].

Jones, T.D. (1973). *Art of Light and Colour*. Van Nost. Reinhold.

Kandinsky, W. (1914). *Concerning the Spiritual in Art*. Dover Publications Inc. 1997. George Wittenborn Inc.

Kapuscinski, J. (1998). Basic Theory of Intermedia. Composing with Sounds and Images. *Monochord. De musica acta, studia et commentarii*. 19. p.pp. 43–50.

Katz, R. (2007). *Mastering Audio: The Art and the Science*. 2nd Ed. Canada: Focal Press.

Koyre, A. (1968). *Newtonian Studies*. Chicago: University of Chicago Press.

Landy, L. (2007). *Understanding the Art of Sound Organization*. Cambridge, Massachusetts.: MIT Press.

Lavignac, A. (1899). *Music and Musicians*. New York: Henry Holt and Company.

Levin, T.Y. (2003). 'Tones from out of Nowhere': Rudolph Pfenninger and the Archaeology of Synthetic Sound. *Grey Room*. p.pp. 32–79.

Long, B. & Schenk, S. (2011). *The Digital Filmmaking Handbook*. 4th Revised edition. Delmar Cengage Learning.

Loy, G. & Chowning, J. (2011). *Musimathics: The Mathematical Foundations of Music: 2*. MIT Press.

Lye, L. (1935). *A Colour Box*. 1935.

Margounakis, D. & Politis, D. (2006). Converting Images To Music Using Their Colour Properties. *Proceedings of the 12th International Conference on Auditory Display*.

McLaren, N. (1978). *Animated Motion: Part 5 by Norman McLaren, Grant Munro - NFB*. [Online]. 1978. Watch Documentaries and Animated Films Online - NFB.ca. Available from: http://www.nfb.ca/film/animated_motion_part_5. [Accessed: 20 January 2014].

McLaren, N. (1971). *Synchromy*. 1971.

Meijer, P.B.. (1992). An Experimental System for Auditory Image Representations. *IEEE Transactions on Biomedical Engineering*. 39 (2). p.pp. 112–121.

Miller, D. (2009). *Echoing Spaces*. 2009.

Miller, D. & Young Ha, M. (2008). *Amorphisms*. 26 October 2008.

Minchin, H. (2013). *Sunset Video and Influences*.

Mooney, J.R. (2006). *Sound Diffusion Systems for the Live Performance of Electroacoustic Music*. Sheffield: University of Sheffield, Department of Music.

Moritz, W. (2004). *Optical Poetry: The Life and Work of Oskar Fischinger*. Indiana University Press.

Motluk, A. (1996). Two Synaesthetes Talking Colour. In: J. E. Harrison & S. Baron-Cohen (eds.). *Synaesthesia: Classic and Contemporary Readings*. Wiley-Blackwell, pp. 269–277.

Museum of Modern Art (New York, N.Y. (2004). *MoMA highlights: 325 works from the Museum of Modern Art*. New York: Museum of Modern Art.

Newman, B. (1950). *Vir Heroicus Sublimis*.

Newton, S.I. (1704). *Opticks: Or a Treatise of the Reflections, Inflections, and Colours of Light*. London: The Prince's Arms in St Paul Church Yard.

Norris, M. (2014). *SOUNDMAGIC SPECTRAL*. [Online]. 2014. Michael Norris: Composer, Software Developer, Music Theorist. Available from: http://www.michaelnorris.info/software/soundmagic-spectral.html. [Accessed: 6 June 2014].

O'Donoghue, P. (2010). *A Diamond Forms Under Pressure*. 2010.

O'Donoghue, P. (2011). *Chasing Waves*.

O'Donoghue, P. (2012). *Ocusonic*. [Online]. 2012. Ocusonic. Available from: http://www.ocusonic.com/home.html. [Accessed: 19 November 2012].

Paterson, I. (2004). *A Dictionary of Colour: A Lexicon of the Language of Colour*. Thorogood.

Payling, D. (2004). Listen (Awakening): A Composition with Auditory Display. *ICAD 2004: The 10th Meeting of the International Conference on Auditory Display, Sydney, Australia, July 6-9 2004, Proceedings*.

Pengilly, S. (2004). *Patterns of Organic Energy*. 2004.

Piché, J. (1996). *Munjikal (paNi intiyA)*. 1996.

Piché, J. (2011). *Océanes*. 2011.

Piché, J. (2004). *www.JEANPICHE.com*. [Online]. 2004. Available from: http://www.jeanpiche.com/. [Accessed: 19 November 2012].

Rimington, A.W. (1895). *Method and Means or Apparatus for Producing Colour Effects*. p.p. 20.

Roads, C. (1996). *The Computer Music Tutorial*. Cambridge, Massachusetts.: MIT Press.

Scholes, P.A. (1950). *The Oxford Companion to Music*. 8th Ed. London: Oxford University Press.

Scrivener, S. (2002). *The art object does not embody a form of knowledge*. [Online]. 2002. Working Papers in Art and Design 2. Available from: http://sitem.herts.ac.uk/artdes_research/papers/wpades/vol2/scrivenerfull.html. [Accessed: 16 November 2012].

Shepard, R. (2001). Pitch Perception and Measurement. In: *Music, Cognition and Computerized Sound*. Cambridge, Massachusetts.: MIT Press, pp. 149–166.

Sloane, P. (1989). *The Visual Nature of Color*. New York: Design Press.

Smalley, D. (1986). Spectro-Morphology and Structuring Processes. In: S. Emmerson (ed.). *The Language of Electroacoustic Music*. Palgrave Macmillan, pp. 61–93.

Smirnov, A. (2005). *Sound out of Paper*. [Online]. 2005. Andrey Smirnov. Available from: http://asmir.info/gsound1.htm. [Accessed: 7 November 2012].

Smirnov, A. & Liubov, P. (2011). *Russian Pioneers of Sound Art in the 1920s*. [Online]. Available from: http://asmir.info/articles/Article_Madrid_2011.pdf. [Accessed: 7 November 2012].

Sony (2012). *Vegas Product Family Overview*. [Online]. 2012. Sony Creative Software - Vegas video - ACID & Sound Forge audio editing. Available from: http://www.sonycreativesoftware.com/vegassoftware. [Accessed: 29 August 2012].

Spiegel, E. (2006). *Metasynth 4.0. User Guide and Reference*. [Online]. Available from: http://www.uisoftware.com/DOCS_PUBLIC/MS4_Reference.pdf. [Accessed: 27 June 2012].

Stein, D., M. (1971). Thomas Wilfred: Lumia. *Press Preview*. 9 August.

Steinberg (2012). *Start : | http://www.steinberg.net/*. [Online]. 2012. Home : Welcome to Steinberg | http://www.steinberg.net/. Available from: http://www.steinberg.net/en/products/nuendo.html. [Accessed: 29 August 2012].

Tucker, G.M. & Cochrane, L. (2011). Ternary Form : The Oxford Companion to Music Oxford Reference. *The Oxford Companion to Music*. p.pp. 1266–1267.

Weyl, H. (1952). *Symmetry*. Princeton, New Jersey: Princeton University Press.

Whitney, J. (1966). *Lapis*. 1966.

Wilfred, T. (1947). Light and the Artist. *The Journal of Aesthetics and Art Criticism*. 5 (4). p.pp. 247–255.

Wilfred, T. (1957). *Thomas Wilfred's Opus 147 'Multidimensional'*. [Online]. 1957. Available from: http://vimeo.com/71871932. [Accessed: 1 November 2013].

Wishart, T. (1996). *On Sonic Art*. 2nd Revised edition. S. Emmerson (ed.). Amsterdam: Routledge.

Yeo, W.S. & Berger, J. (2005). A Framework For Designing Image Sonification Methods. *Proceedings of ICAD 05-Eleventh Meeting of the International Conference on Auditory Display*.

Zolotov, A. (2014). *WarmPlace.Ru. Virtual ANS Spectral Synthesizer*. [Online]. 2014. WarmPlace.Ru. Available from: http://www.warmplace.ru/soft/ans/. [Accessed: 5 June 2014].