Exploring a Visual/Sonic Representational Continuum

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ABSTRACT

This paper explores the relationships between sound and its visualisation, focussing upon the issues surrounding representation and interpretation of music through both performative and machine processes. The discussion proceeds in the context of five recent works by the author exploring the representation of sound and musical notation and their relationship to and with performance: *unhörbares wird hörbar* (the inaudible becomes audible) [2013], *EVP* [2012], *Lyrebird: environment player* [2014], *Nature Forms I* [2014] and *sacrificial zones* [2014]. Issues examined include: re-sonification of spectrograms, visualisation of spectral analysis data, control of spatialisation and audio processing using spectral analysis data, and reading issues related to scrolling screen score notation.

1. INTRODUCTION

This paper discusses a number of works exploring the interchange between visual and sonic data. An initial impetus for this work was the so-called "Phonorealism" of Peter Ablinger's *Quadraten* series, in which spectral analysis data from recordings is "reconstituted in various media: instrumental ensembles, white noise, or computer-controlled player piano" [1]. A key issue at the heart of *Quadraten* is representation or analogy made between "real" sounds and their reconstituted counterparts.

> *The reproduction of "phonographs" by instruments can be compared to photo-realist painting, or - what describes the technical aspect of the "Quadraturen" more precisely -with techniques in the graphic arts that use grids to transform photos into prints Using a smaller grain, e.g. 16 units per second, the original source approaches the border of recognition within the reproduction.* [2]

In 1993 Wileman proposed that a "realism continuum" [3] exists in forms of visual representation, spanning colour and then black and white photographs, silhouettes, line drawings, pictographs and text. Ablinger's comment presupposes a continuum of sonic representational forms, encompassing high fidelity recordings, analysis/resynthesis, techniques of Spectral composers (such as the orchestration of spectral data in Grisey's *Partiels* (1975) and "sound painting" in which natural sounds are evoked in a more figurative manner (such as the river Moldau in Smetana's tone poem of the same name (1874)). O'Callaghan has proposed a similar continuum, although from the standpoint of Emmerson's concept of musical mimesis as "the imitation not only of nature but also aspects of human culture not usually associated with musical material"[4]. O'Callaghan categorises three kinds of sonic representation:

- Category 1 transcriptions recognisable as representational of the source sound, and achieving a high level of verisimilitude;
- Category 2 some acoustic similarity to the source sound, but distant enough that it requires other extra-musical contexts to identify;
- Category 3 relies upon additional outside information, to be interpreted as mimetic. [5]

Visual forms of musical representation may also be considered to occupy a continuum, in this case between the spectrogram (a precise frequency/time/amplitude representation of sound), proportional notation, traditional notation, semantic graphical notation, non-semantic graphical notation and text scores that verbally describe the required sound.

Five recent works by the author exploring the representation of sound and musical notation and their relationship to and with performance and sonification are examined as part of this discussion: *unhörbares wird hörbar* (the inaudible becomes audible) [2013] that utilizes a spectrogram as both a score and a sonification source; *EVP* [2012] and *Lyrebird: environment player* [2014] that investigate the near realtime representation of indeterminate sounds as a score; *Nature Forms I* [2014] that explores the sonification and three modes of performer interpretation of visual images based on forms from nature; and *sacrificial zones* [2014] that presents a performer with five varied representations of the same sonic information.

The explorations of the interplay between these sonic and visual representation of sound described here are made in the context of the *Decibel Scoreplayer* [6] an App for the iPad that allows for the networked synchronization of multiple performers and audio processing.

2. THE SPECTROGRAM AS A SCORE

Using a spectrogram as the basis for a score poses a number of challenges, as Grill and Flexer have indicated, spectrogram "visualizations are highly abstract, lacking a direct relationship to perceptual attributes of sound"[7].

In particular the "spatial" representation of the sonogram lack the relational quantifiers of a traditional score that presents the representation of sonic events in the context of a tempo and frequency grid. This raised issues concerning the identification of parameters such as pitch, timbre, dynamics and orchestration, the issue of synchronization of multiple performers and importantly the resolution of the spectrogram itself.

The resolution available when creating a spectrogram is generally variable. Ideally a score generated from a spectrogram would provide the maximal degree of information to the performer about the characteristics of the sound. The spectrogram for this work was generated by Chris Cannam's *Sonic Visualiser* software [8] which allows for the magnification of the sonogram resolution to about 190ms x 5hz, represented by a rectangle of roughly 6.46 x 0.25 cm. Such a high resolution might be desirable to represent complex sonic phenomena, but this degree of temporal density poses problems as a score for musicians to read: it would need to be over 19 metres long and would need to be read at a rate of over 37 cm/s.

What then is a "normal" reading rate for a score and how does the rate impact upon the amount of sonic detail that is capable of being represented? Table one compares the notional average rate at which the score progresses as the performer reads the work: its "scroll-rate". The scroll-rate is calculated by dividing the length of the score by its average duration.

	work duration (s)	score length (cm)	scroll-rate (cm/s)
Beethoven: The Tempest (1802)	510	1171	2.41/ 0.48
Chopin: Minute Waltz (1847)	120	467	3.89
Ravel: *Pavane* (1899)	360	487	1.35
Debussy: *Voiles* (1909)	240	386	1.61
Hope: *In the Cut* (2009)	431	197	0.46
Hope: *Longing* (2011)	405	109	0.59
Hope: *Kuklinski's Dream* (2010)	490	249	0.51
Vickery: *Agilus, Mimoid Symmetriad* (2012)	574	875	1.52
Vickery: *Silent Revolution* (2013)	560	857	1.53

Table 1. A comparison of the notional "scroll-rates" of works with traditional scores by Beethoven, Chopin, Ravel, Debussy, and native "scrolling scores" by Hope and Vickery.

The works are varied: Beethoven *Piano Sonata No. 17 in D minor Op. 31 No. 2* (1802) (The Tempest) first movement includes significant changes of tempo in which the performer would be reading at different rates; the Chopin *Waltz in D-flat major Op. 64 No. 1* (1847) (Minute Waltz), Ravel *Pavane pour une infante défunte* (1899), Debussy *Voiles* (1909) might be considered examples at the high, low and centre of the scroll-rate speeds.

These rates give an indication of what is an acceptable and perhaps even conventional speed to read musical notation.

The final five works on the table are "scrolling scores" by Cat Hope and Lindsay Vickery, in which the score moves past the performer at a constant rate on an iPad screen. There is, at the least, a psychological distinction between this paradigm, where the performer is forced to view only a portion of the score at any time, and the fixed score where the performer directs their own gaze.

In 1997 Picking claimed that "a stave related to anything but slow music moved faster than the fixation threshold of the human eye" and that "a semi-quaver at 120 beats per minute would remain still for 125 milliseconds ± approximately half the duration of a typical eye fixation"[9] implying a maximum scroll rate approximately 2cm/s. Later sightreading studies by Gilman and Underwood [10] imply a maximal threshold rate for scrolling of about 3cm/s[1]. The comparatively slow scroll rates of the final five works appear to support the view that the maximal bound for reading of scrolling notation may be between 2 and 3cm/s.

It is worth noting that Picking's claim is based on the notion that it an eye fixation is only capable of capturing a single semi-quaver at a time: many studies indicate that experienced music readers fixate less frequently than less proficient readers, due to their ability to gather and group notational signifiers in a single fixation [11, 12, 13, 14]. This points to a second issue: the complexity and density of the notation itself. Gilman and Underwood have noted "eye-hand span" (the time that elapses between the eye's fixation on notation and its execution by the hand) is decreased by greater musical complexity [15]. Lochner and Nodine propose this is because "more complex patterns will take longer to recognize than simpler patterns, since more features must be examined"[16]. These findings indicate that maximal scroll rate might be impacted by the increase in eye fixations necessary for scores with greater information density and/or complexity.

The time critical issues of presenting notation on the screen considered above, point to the necessity for developing notation that is as efficient as possible and the works discussed here exemplify some of the solutions to these issues. This points to an inevitable need for and assessment of how to manage the necessary trade-off between the spatial size of the representation and the degree of detail it encompasses.

2.1 UNHÖRBARES WIRD HÖRBAR

The work *Unhörbares Wird Hörbar* [2013] (the inaudible becomes audible) uses a spectrogram as the basis for the score for flute, clarinet, viola, cello, percussion and elec-

[1] Reading from scrolling notation differs from traditional reading however, in that rather than the eye tracking from left to right along a static page, the eye is forced to fixate in approximately the same position as the score itself moves. Gilman and Underwood's study recorded saccade lengths of just more than 1.5 cm (57-62 pixels on a 72 dpi screen) and an eye-hand span (the distance between the point of fixation and the point of performance) between 1.5 and 1.9 cm.

tronics. The spectrogram upon which this work is based was taken from the second part of a recording of an improvisation by the author, *Study No. 3 for No-input Bass Clarinet* (2013). In this section feedback "shaped" by altering fingerings, percussive key clicks and microsounds from within the bass clarinet are combined with sine tones that glide between subsequent frequencies sampled from the performance.

Consideration of the scroll-rate versus sonic detail discussed above led to a decision for the resolution of the spectrogram-score of *unhörbares wird hörbar* of 0.425 seconds of the soundfile per centimeter (roughly 60ms/px) of the image. This resolution allows the performer to view elements of the sonogram that represent what Curtis Roads refers to as "basic units of music structure… complex and mutating sound events on a time scale ranging from a fraction of a second to several seconds"[17] while at the same time reading at an acceptable scroll rate of 2.35 cm/s. As this rate was in toward the maximal limit for reading scrolling information it was necessary to develop a method of defining the "perceptual attributes" of the sonogram that was maximally efficient and semantically sound, that is, inherently sensible to the reader, rather than necessitating learning and memorisation of new symbols that might impede the reading rate of the score.

One approach might have been to place the entire spectrogram beneath a grid – allowing the performer to more easily calculate pitch and temporal relationships. Percy Grainger had employed this technique in his *Free Music* works as far back as the 1930s (See Figure 1). However in the networked scrolling score medium, the temporal (and synchronization) issues were already resolved and therefore a minimalist approach was taken of indicating the pitch of material only where necessary and relying on the musicians to calculate glissandi and minor fluctuations in pitch themselves.

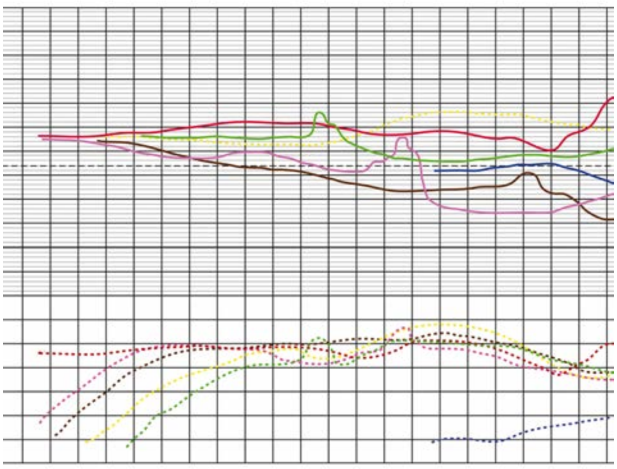

Figure 1. Excerpt from Percy Grainger's *Free Music 2* (1937).

One important factor contributing to the efficacy of notation is semantic soundness – the degree to which the graphical representation makes inherent sense to the reader, rather than necessitates learning and memorisation of new symbols. Prominent features of the spectrogram are indicated using: "floating" traditional staff/clef/pitch symbols to specify pitch, dynamics are indicated by the thickness of each player's line and transparency of the line (along with textual indication) is used to denote specific forms of timbral variation, from regular instrumental sound to diffused tones, "coloured noise" in Stockhausen's terminology[18]. The orchestration of individual instrument parts are colour coded: flute - green, clarinet - red, viola - orange, cello - blue and percussion – purple.

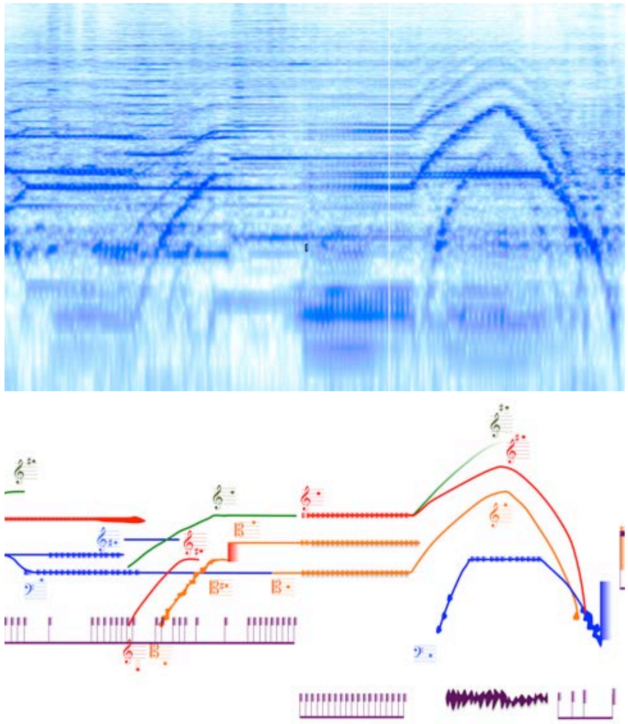

Figure 2. Excerpt from the spectrogram of *Study for No-Input Bass Clarinet* [2013] (above) and the corresponding section from the score of *unhörbares wird hörbar* [2013] (below).

The issue of synchronization is crucial in order to coordinate multiple live performers, but also because the live instruments perform in conjunction with a re-sonified version of the spectrogram.

3. RE-SONIFYING THE SPECTROGRAM

A patch in MaxMSP was developed to map each vertical pixel of a grayscale version of the spectrogram to 613 independent sinewaves at a horizontal rate of 25 pixels per second (See Figure 3). In the patch a .png file of the sonogram is loaded into a `jit.qt.movie`, it is then played through `jit.matrix` and `jit.submatrix` that send an image of one pixel width to the `jit.pwindow`. Data from the submatrix is split into a list of 613 values in `jit.spill` and these values are represented in a mutlislider. The vertical pixels are scaled logarithmically between 8 and 6645hz (the highest represented frequency in the sonogram and just beyond the highest pitch attainable by the ensemble) and mapped to an individual `cycle~` object. The grayscale value of each pixel is scales and mapped to the amplitude of each `cycle~` object. A comparison between sonograms of the soundfile of the original source recording and the re-sonified version indicate (See Figures 8 and 9 detail, which show a similar process in *Nature Forms I*) this simple process was quite effective.

The recording of the resonified spectrogram was diffused spatially in the performance, effectively "doubling" the instrumental lines. Spatial diffusion was controlled by mapping a realtime analysis of the frequency and amplitude of the third and seventh partial of the recording (using Miller Puckett's `sigmund~` object) to the azimuth and distance parameters of an eight speaker array in Dave Malham/Matthew Paradis' `ambipan~` object.

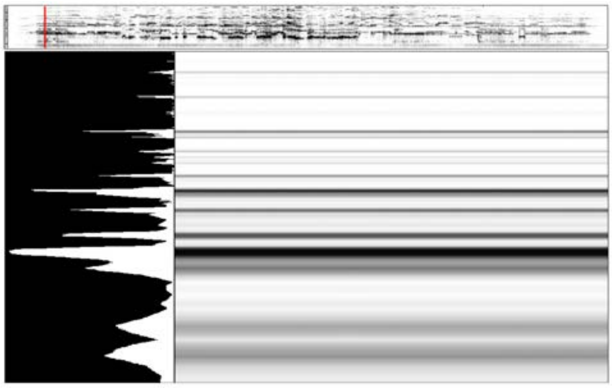

Figure 3. Sinereader patch developed in MaxMSP to re-sonify the spectrogram in *unhörbares wird hörbar*. The complete spectrogram with a "scrollbar" indicating progress through the image is displayed at the top of the image, the grayscale value of each vertical pixel in a one pixel segment is displayed on the bottom left and the resulting amplitude is displayed on the bottom right.

The recording was divided into a high-pass and a low-pass channel and the spatialition of the two resulting channels inverted and diffused on opposite sides of an eight-speaker array in a form of enhanced stereo (see Figure 4).

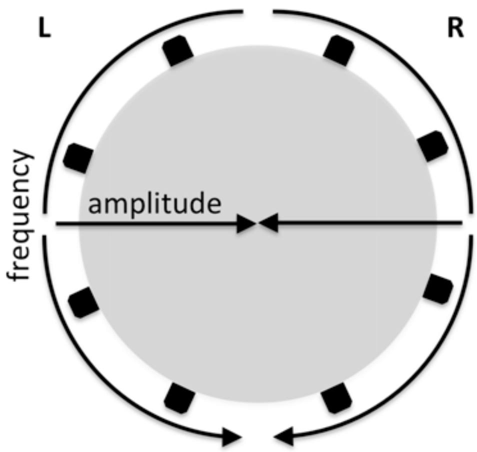

Figure 4. Schematic of the spatialisation layout for the work *unhörbares wird hörbar*.

4. REALTIME GENERATION OF A SONOGRAM-SCORE

Emulation of the sounds of the natural environment may be one of the earliest manifestations of musical improvisation. Alvin Lucier's *(Hartford) Memory Space* (1970) and *Carbon Copies* (1989) both explore this impulse, instructing performers to imitate the sounds of any indoor or outdoor environment (albeit pre-recorded), "as exactly as possible, without embellishment" [19].

4.1 EVP (2012)

The work *EVP* (Electronic Voice Phenomenon)[2] is in a similar format. A spatialised indeterminate collage was generated from a number of EVP recordings. The five performers were instructed to emulate the sounds in one of five channels of audio, with extended techniques on their instruments with the aid of a scrolling score that shows relative pitch, duration and dynamics of the EVP samples in real-time (See Figure 5).

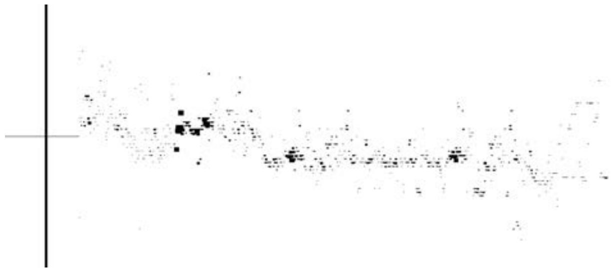

Figure 5. The scrolling scoreplayer for *EVP* [2012] showing visualized pitch and amplitude data.

The sounds in each channel were analysed using the MaxMSP object `sigmund~` to detect the single strongest sinusoidal peak, and the frequency and amplitude data was then scaled to determine the vertical orientation and thickness (pen-size) of line segments that were drawn onto a scrolling LCD object. The visualized sonic data was displayed for the performer on the right of the screen and scrolled to the left over a period of 11.2 seconds. The source recording from which the analysis was made is delayed so that it sounds as the visual representation arrives at the "playhead" (a black line of the left of the screen indicating the moment at which the performer should emulate the sound). This configuration allows the performer to preview the visualization of visualized sonic data, and therefore the basic units of music structure in the recording in advance of it actually sounding. The score scrolls at a rate of approximately 1.3cm/s.

[2] The term Electronic Voice Phenomenon describes the deliberate or inadvertent capturing of the voices of "ghosts" on electronic media such as tape recorders, video or radio. Around the world many thousands of people participate in projects to investigate spectral presences in haunted spaces by recording and then painstakingly analysing recordings. Whether this is a real phenomenon or an example of mental pattern recognition—finding structures in random data, like an aural Rorschach Test—is a matter of opinion.

4.2 LYREBIRD ENVIRONMENT PLAYER (2014)

The *Lyrebird: Environment Player* draws on the concept and techniques of *EVP*, but is intended to visualise sonic features of a "field recording". The work was commissioned by percussionist Vanessa Tomlinson for her Australian solo percussion program *Eight Hits*. The performance practice for the work was developed by the author and Tomlinson during her residency at the *Orpheus Instituut for Advanced Studies & Research In Music* in December 2013. It requires that Tomlinson make a field recording and collect objects to play in the vicinity of each new performance venue and that, in performance, she "play or improvise around" the environmental sounds. Familiarity with the recording and strategies for improvising are developed prior to its performance.

Again, the amplitude of the frequency of the single strongest detected sinusoidal peak is represented by the size of the rectangles drawn on a scrolling LCD obect (in this case *jit.lcd*). However in addition, brightness, noisiness and bark scale[3] data derived using Tristan Jehan's `analyzer~` object are used to determine the luminance, hue and saturation of each rectangle. This allows for the scoreplayer to visualise timbral features of the recorded sound. As with *EVP,* the visualised score depicting the principal features of a source recording is scrolled from right to left across the computer screen and playback of the source recording is delayed (12 seconds in this work) to allow the performer to see a visualization of the sounds before they appear. The score for Lyrebird also scrolls at a rate of approximately 1.3cm/s (See Figure 6).

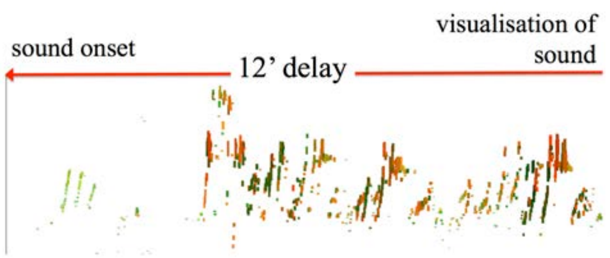

Figure 6. The scrolling scoreplayer for *Lyrebird: environment player* [2014] showing visualized pitch, amplitude and timbral data.

4.3 Figures, Tables, and Captions

All artwork must be centered, neat, clean, and legible. All lines should be very dark for purposes of reproduction and artwork should not be hand-drawn. The proceedings will be distributed in electronic form only, therefore color figures are allowed. However, you may want to check that your figures are understandable even if they are printed in black-and-white.

Lyrebird incorporates an analysis panel (See Figure 7) that provides controls for the performer to view and scale data from the field recording. This allows for the performer to "zoom" the visualization in or out on a particular range of frequency, amplitude, brightness, noisiness or bark scale data. To facilitate these decisions the data is represented both as a raw value and on a scrolling multislider displaying the its final scaled value so that the performer may confirm that the scaling is capturing the full data range. In the analysis panel, the performer may store the scaling values of up to 20 recordings.

The work creates an alternate form of spectrogram in which the strongest sinusoidal peak is represented vertically and horizontally and coloured according to brightness, noisiness and bark scale analysis. As such it goes someway toward alleviating the problem of "demonstrating coindexation and segmentation due to the difficulty in illustrating differences in timbre"[20] in a spectrogram and provides an (almost) realtime feature analysis of the recording in which contours and timbral shifts are readily recognizable.

Multiple scoreplayers may also be networked together, allowing multiple performers to interact with visualisations that focus of varied frequency, amplitude and timbral parameters of the same recording.

The desire for "semantic soundness" in the representation of sounds and in particular the ability to rescale the luminance, hue and saturation of the represented colours implies a need to determine if a certain palette of colours is more appropriate for particular timbres.

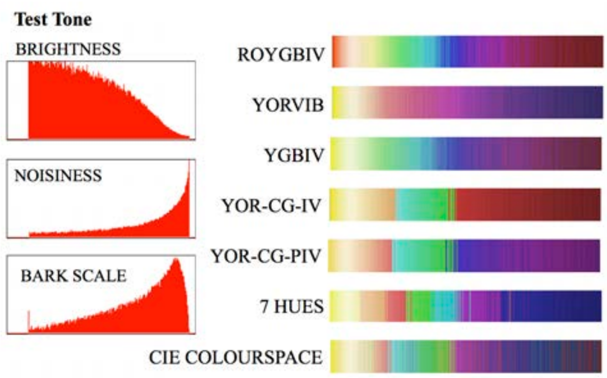

Figure 7. The Lyrebird: environment player currently implemented colour schema allowing for the following mappings of timbre to hue. The spectra on the right depict a test tone of increasing brightness, noisiness and bark scale depicted by a variety of mappings.

Research at The Visual Perception and Aesthetics Lab at the University of California Berkeley, suggests that there is a high degree of correlation between mappings of colour-to-sound in the population at large. Ramachandran and Hubbard have proposed that "there may be natural constraints on the ways in which sounds are mapped on to objects"[21]. Evidence of such constraints emerged through the study of synaesthesia, a rare condition causing individuals to experience sensory input cross-modally, the most common form being the simultaneous activation of the senses colour and sound. Their starting

[3] In the current version of this work, the median of 16 bark scale values (representing the deviations from expected critical bands) is used. This presupposes that the median value refers to the same critical band as the strongest sinusoidal component. In future it may be possible to model this parameter more accurately.

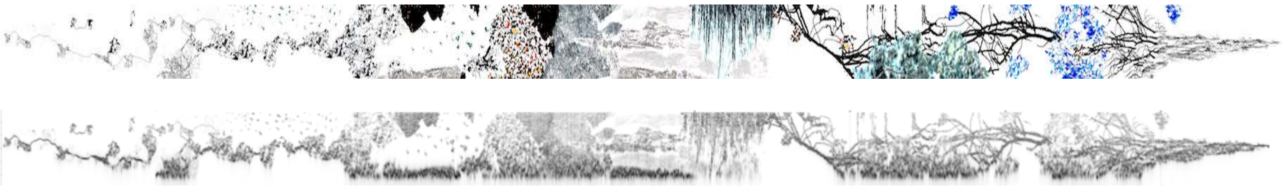

Figure 8. The score of *Nature Forms I* [2014] (above) and a sonogram of its sonification (below).

point was the bouba/kiki experiment[4] conducted by Wolfgang Köhler [22].

This correlation, and other similar associations, for example between shapes and sounds, and facial expressions and colours [23], led Barbiere et al. to propose the existence of a form of “weak synesthesia” exists in the general population [24]. Griscom and Palmer have proposed that there are systematic relationships between colour and a range of musical phenomena including timbre, pitch, tempo, intervals, triads and musical genres in non-synaesthetes[25, 26].

Grisolm and Palmer have observed, for example, that yellow-blue value is correlated with timbre attack time, whereas average red-green value is correlated with spectral brightness [25]. Such observations may provide indications of how best to represent timbral information in these works in future versions.

5. INTERACTION BETWEEN MODES OF VISUAL AND SONIC REPRESENTATION

The final two works *Nature Forms I* [2014] and *Sacrificial Zones* [2014] explore the interaction between modes of visual and sonic representation more explicitly.

5.1 NATURE FORMS I

In *Nature Forms I*, a score comprising manipulated images of organic shapes derived from photographs of trees, plants and rocks (See Figure 8 and 9 (detail)), is simultaneously sonified by performers and software. Three performers and software “read” from the same scrolling score on networked laptops with differing goals: Player 1 reads the score as non-semantic graphical notation, realising it primarily as an aesthetic representation of the character of the sound to be created. Player 2 reads the score semantically, with the notation indicating pitch vertically, duration horizontally and shade/hue timbrally. Player 3 reads the notation as tablature, spatially indicating which region of their instrument to be struck with shade indicating the manner in which it is to be struck.

In this way, four contrasting forms of reading/sonifcation are presented for the audience: machine sonification in which spatial position and colour are more or less precisely rendered; tablature in which spatial position and colour are recast against the geography of a specific instrument; semantic reading in which the performer’s understanding of notational conventions informs the outcome; and aesthetic reading in which the performer’s understanding of the conventions of sonic representation of broader conceptual issues are drawn upon.

Software written in MaxMSP sonifies the score in the manner employed in *unhörebares wird hörbare* (See Figure 8 and 9 (detail)). Frequency, amplitude, brightness, noisiness and bark scale data derived from the resulting soundfile is then used to control the spatialisation and processing of the soundfile.

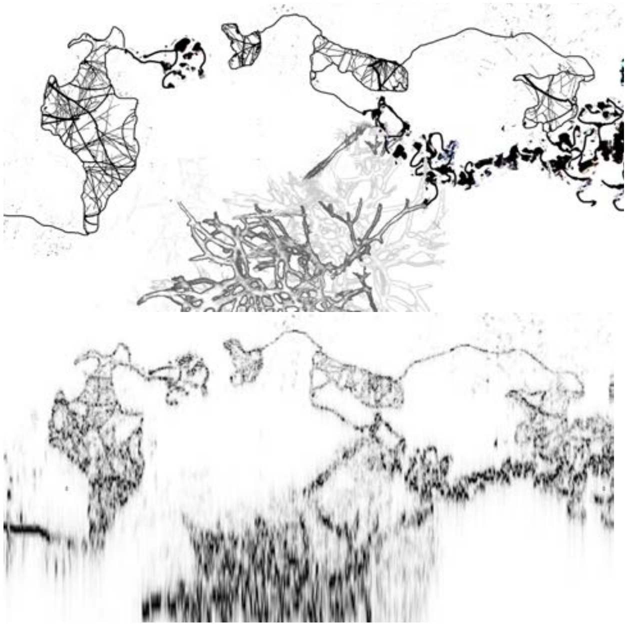

Figure 9. Comparison between an excerpt from the score of *Nature Forms I* [2014] (above) and a sonogram of its sonification (below).

The scores of each of the three players fade to black indeterminately for short periods throughout the performance creating changing combinations of 1, 2 and 3 players. The electronic component is divied into three channels independently spatialised over eight speakers. Rather than simply doubling the live performers, the live signal from the three performers attenuates the amplitude of the three channels of machine-sonified audio.

A control panel shows progress through the score (red line), the points at which there will be a change of instrumental combination (black lines): the changes are generated indeterminately but may be regenerated using the reset button. The spatial position of each part and the degree of attenuation of the computer signal is also shown (See Figure 10).

[4] The kiki/bouba effect: “because of the sharp inflection of the visual shape, subjects tend to map the name kiki onto the (pointed, star-like) figure (…), while the rounded contours of the (other) figure make it more like the rounded auditory inflection of bouba”[19][18].

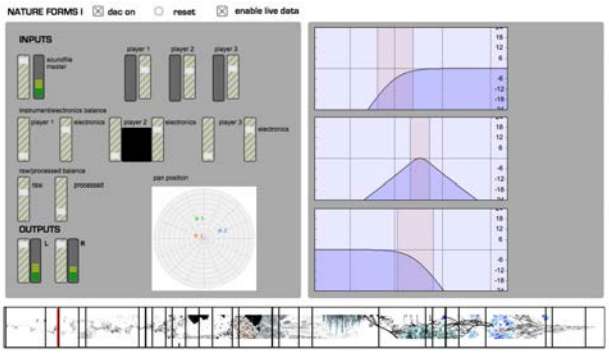

Figure 10. The sound processing and spatialisation control panel for *Nature Forms I* [2014].

5.2 SACRIFICIAL ZONES

Sacrificial Zones is a rhizomatic score - the notation moves along interconnected vertical and horizontal pathways (See Figure 11). A planchet (a circular outline) moves inderterminately along the interconnected rhizomatic pathways and the visual representation of sound to be realized by the performer. In addition, the score comprises five layered images, each notated in a manner corresponding to a different form of visual representation of sound: non-semantic graphical notation, semantic graphical notation, traditional notation, proportional notation and a spectrogram. The score cross-fades between the layers indeterminately.

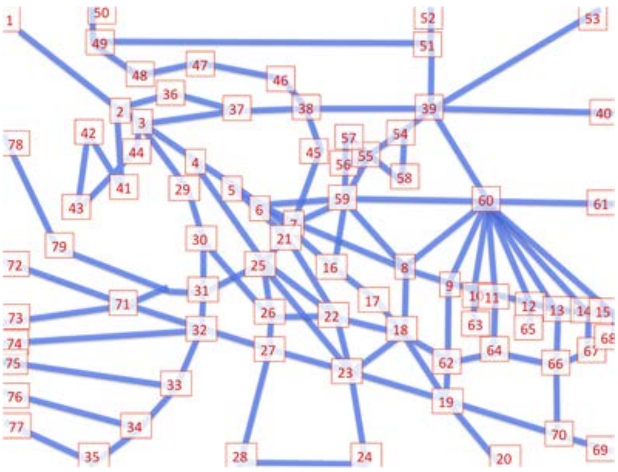

Figure 11. Rhizomatic pathways in *Sacrificial Zones* [2014].

The underlying "non-semantic" layer is a collage created from images of Camden, New Jersey one of the places Chris Hedges refers to as a sacrificial zone, where "where those discarded as human refuse are dumped, along with the physical refuse of postindustrial America"[27].

The notated score evolved from a performance of the non-semantic notation that followed the work's rhizomatic pathways. The spectrogram of the readings was then positioned along the same pathways and semantic graphical notation, traditional notation and proportional notation scores were "transcribed" on layers between them.

The spectrogram of the reading of the non-semantic notation was re-sonified in segments corresponding to the rhizomatic pathways. The computer audio in the work is cross-faded between the resonified spectrogram and audio processing of the live performance in correspondence to the score's proximity to non-semantic or the spectrogram versions of the notation. The audio processing of the live performer is mapped onto the rhizomatic pathways using a range and combination of strategies, including: pitch-shift/delay, spectral manipulation of the amplitude and frequency of individual sinusoidal components, reverberation, distortion and ring modulation. The sound is diffused across four speakers with spatialisation of the sound determined by the position of the performers' planchet on the score.

The score confronts the performer (and vicariously the audience) with the variation in freedom and constraint presented by a range of forms of notational representation. The rhizomatic and layered procedure for rendering the score allows for multiple versions of this work emphasising different aspects of the relationship between varied notations of the same musical object.

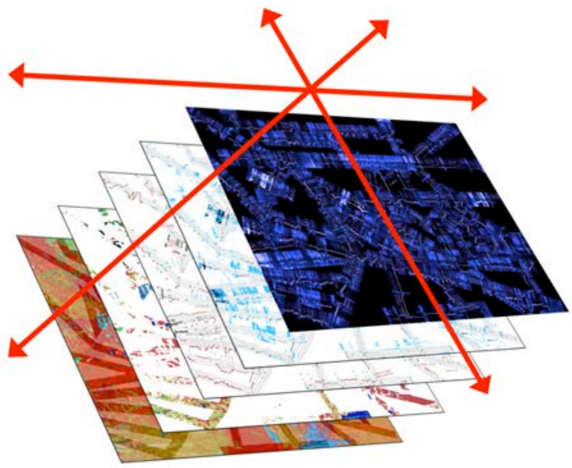

Figure 12. Layers of different visual representation of sound in *Sacrificial Zones*.

6. CONCLUSION

The works discussed here demonstrate a range of approaches to the representation of sound and musical notation and their relationship to and with performance and sonification. The author is currently investigating the consequences of various forms of screen notation reading using eye-tracking analysis. It is hoped that this work will add weight to the hypotheses regarding maximum readable scroll rate, the role played by information density in the score and perhaps even identify differing reading strategies employed in aesthetic, semantic and tablature score reading.

A forthcoming *Complete Cage Variations App* [28, 29] currently allows for generative versions of *Variation I* and *II*. Work is underway to allow generative notational data to be transmitted via network to the Decibel Scoreplayer in realtime.

The implications of growing research into "weak synaesthesia" may have a great impact upon the visual representation of sonic data both in all its forms.

While there are perhaps more "evolved" means of analysis/resynthesis and algorithmic spectral composition[30], the works discussed here like Ablinger's *Quadraten* series, embrace an aesthetic that encompasses the deliberate engagement with methods that generate greater and lesser degrees of fidelity and precision, in order to explore the aesthetic implications of (mis)representation and (mis)interpretation.

7. REFERENCES

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