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The Interrelation of Technology and Creativity in the Analysis of Electroacoustic Music: A comparative study of Barry Truax's Riverrun and Trevor Wishart's Imago

The Interrelation of Technology and Creativity in the Analysis of Electroacoustic Music: A comparative study of Barry Truax's *Riverrun* and Trevor Wishart's *Imago*[1]

Michael Clarke, Frédéric Dufeu, Peter Manning[2]

1. Introduction

Technology and creativity are often closely bound together in electroacoustic music. It is the technology that facilitates, perhaps sometimes even inspires, the musical creativity and, conversely, creative goals can stimulate new technical developments. In order to fully understand an electroacoustic work it may therefore be necessary to investigate the technology which was used to create the music as well as the completed composition itself: music analysis may need to be informed by technical analysis. It is precisely this connection that is being explored by the TaCEM project of which the research reported in this article is a part.

TaCEM – *Technology and Creativity in Electroacoustic Music* – is a 30-month project (2012-2015) funded by the United Kingdom's AHRC (Arts and Humanities Research Council). It is asking "How far have new technological developments led to new creative possibilities for composers?" Eight Case Studies, key works from the repertoire, in which new technology has led to new musical approaches (two of which are Barry Truax's *Riverrun* and Trevor Wishart's *Imago*), form a central part of TaCEM. Each Case Study is being examined in terms of its technical context, the hardware and software resources used in the production of the work and in terms of musical structure. Making comparisons across a range of works helps not only to illuminate aspects of the specific works concerned but also facilitates the development of a broader understanding of the relationship of technology and creativity in the electroacoustic repertoire.

A key feature of the TaCEM project in exploring this interrelation of technology and creativity is the use of software. On the one hand, software enables us to emulate the techniques used by the composers and approximate the user interface used in the composition of the work. This makes it possible both for us in our research enquiries and for our readers[3] to engage with the processes used by the composer and the context in which they were used so as to understand the potential of these technologies and their limitations. Software is also used to investigate the finished work by employing interactive aural analysis techniques[4] to study the musical

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[1] This article is a translation from French of the journal article: Michael Clarke, Frédéric Dufeu, Peter Manning, "Les relations entre technologie et créativité dans l'analyse des musiques électroacoustiques : une étude comparative de *Riverrun* de Barry Truax et *Imago* de Trevor Wishart", *Musurgia*, vol. XXII, nº 1, 2015, pp. 27-44.

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[3] The software developed within the TaCEM project is made freely available online.

[4] See in particular Michael Clarke, "Jonathan Harvey's *Mortuos Plango, Vivos Voco*", in Mary Simoni (ed.), *Analytical Methods of Electroacoustic Music*, New York, Routledge, 2006, pp. 111-143; Michael

structure. This means being able to engage with the music as sound, rather than relying solely on verbal descriptions or attempts at visual representation. Finally, software is used to bring together other resources associated with each Case Study, for example, interviews with the composers, and source materials for the works.

This article describes our approach and shows how contrasting technological paths relate to different creative outcomes in two of our Case Studies: *Riverrun* (1986/2004) by Barry Truax and *Imago* (2002) by Trevor Wishart. A more detailed study of these works and the other Case Studies, together with the associated software, will be available as part of the final outcomes of the TaCEM project and information will be available on the project website.[5]

Superficially, it might appear that Barry Truax and Trevor Wishart are very similar in their approaches to the composition of computer music. Both composers are highly skilled in developing software and both have designed personalised systems for their own compositional purposes (although both have also been prepared to make their systems available for use by others and have indeed encouraged such use). In each case a single software system, designed by the composer, was used to create the work. However, in terms of musical style and aesthetic approach they are very different and this is reflected not only in their compositions but also in the detail of their working methods.

2. Comparison of the technologies

2.1. The GSX software

Barry Truax developed his GSX software in the 1980s for a PDP 11/23 computer controlling a DMX-1000 digital signal processer. It was the first real-time granular sound synthesis system ever to be created – Curtis Roads was developing non-real time programs around the same time[6]. To develop a granular synthesis program capable of working in real time at this stage in the development of music technology was a significant achievement. The coding had to be fully optimized, fitting the algorithm into a limited number of instructions, and consequently there were limitations in what could be programmed. The GSX program allowed for the synthesis of a single strand of grains with up to 19 voices at any one time (8 if frequency modulation synthesis was used), all shaped by the same parameter settings. Voices (grain streams) in a strand were divided, alternating between two output channels to enrich the texture and spatial experience. Strands were recorded onto an analogue multi-track tape recorder, subsequent strands being added successively. The final mix of *Riverrun* is in eight channels with the stereo pairs for each strand allocated between eight channels so that the listener, surrounded by eight loudspeakers, is immersed in the evolving textures.

With granular synthesis, sound is formed out of many grains, usually extremely short[7], merging together to create timbres or textures. With GSX this is in real-time.

Clarke, "*Wind Chimes*: An Interactive Aural Analysis", in Évelyne Gayou (ed.), *Denis Smalley: Polychrome Portraits*, Paris, Ina-GRM, 2010, pp. 35-57 ; Michael Clarke, "Analysing Electroacoustic Music: An Interactive Aural Approach", *Music Analysis*, vol. 31, n° 3, 2012, pp. 347-380.

[5] http://www.hud.ac.uk/research/researchcentres/tacem/ (last visited November 29th, 2014).

[6] See for instance Curtis Roads, "Automated Granular Synthesis of Sound", *Computer Music Journal*, vol. 2, n° 2, 1978, pp. 61-62.

[7] Typically, with a length of 1 to 100 milliseconds. GSX does not allow grains shorter than 8 ms; in *Riverrun*, some grains can occasionally be very long, up to 3 seconds.

So once the system is started, GSX produces a continuous succession of grains and the user's task is to shape the sound by changing various parameters as the sound evolves. Parameters that can be controlled include the frequency of the grains: this is specified in terms of a *central frequency* and a *frequency range*. The frequency for a new grain is chosen at random by the program within the given range around the central frequency – so a range of zero means a fixed pitch, that of the central frequency. Likewise, grain *duration* and *duration range* can be set to determine the length of each grain, either a fixed duration or randomly chosen within the specified range. To this is added a *delay*, the length of time between successive grains in a stream, which helps shape the sparseness or density of the texture. Other parameters include selecting whether grains are based on fixed waveforms or created using frequency modulation; this also determines the maximum total number of voices (the number of overlapping grain streams to be synthesised using the parameter data) to be used (maximum 19 in the fixed waveform model, or 8 in the frequency modulation one). The GSX program was operated from a terminal without a mouse. Individual parameters could be selected using the keypad and adjusted one at a time. In addition parameters could be given increment values (positive or negative) and an automated ramp set in motion to change some or all the parameters at once. A *ramp* parameter determines the duration between each step in the ramp; this ramp duration parameter can be incremented and decremented by the ramp itself, allowing for acceleration or deceleration of parameter evolution. Figure 1 shows our emulation of the GSX software, closely imitating the original interface, allowing users to try out the synthesis method, recreating the settings used in *Riverrun* or exploring alternative possibilities.

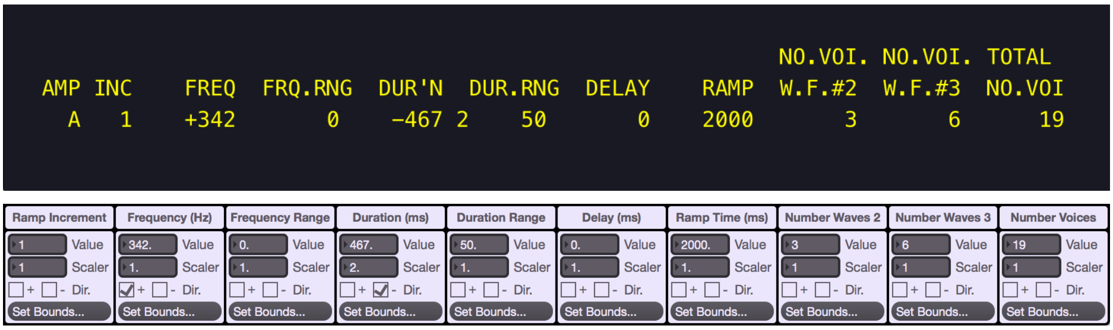

Figure 1a. TaCEM emulation of the GSX software (fixed waveform synthesis). At the bottom is a panel representing the same set of values on a mouse accessible panel.

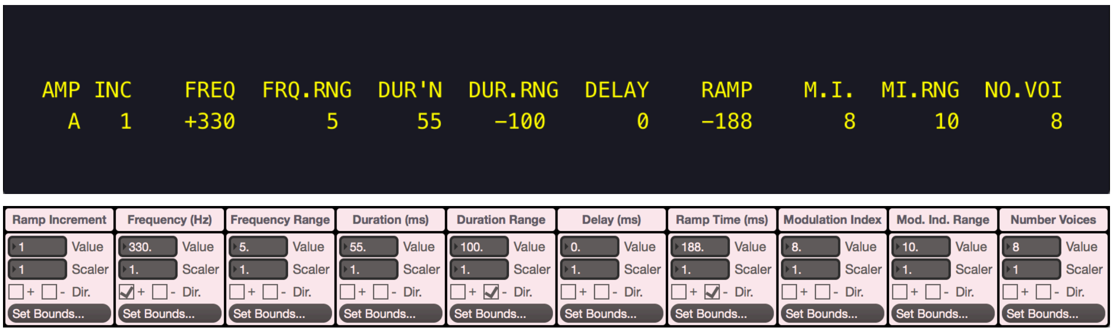

Figure 1b. Emulation of the GSX software (frequency modulation synthesis)

2.2. Sound Loom

Trevor Wishart's Sound Loom software differs from Truax's software in a number of significant ways. One basic difference is that GSX, at least in the form used in

Riverrun, only works as a synthesis program deriving sounds from basic waveforms: it does not process sampled sound. By contrast, Sound Loom is primarily designed to process pre-recorded sound files. Another major distinction is that unlike GSX, Sound Loom does not operate in real time. This is not a question of computing speed. Indeed Wishart, composing *Imago* some 16 years after Truax developed his system, had far more potential to develop software that worked in real time. Nor, for the most part, is it a matter of the algorithms he is using being inherently non-real time. It is more a question of the composer/programmer's preferred working method. This is linked to another difference between the programs: whereas the GSX system essentially employs just one synthesis algorithm with parameters that can be altered[8], *Sound Loom* offers users a wide range of different algorithms for processing sampled sounds. These range, for example, from transposition and time-stretching, to looping and repetition, to amplitude variation, to more complex techniques such as brassage[9]. Even the mixing of the work can be undertaken within Sound Loom, as it was the case for *Imago*. The program is designed so that each of these processes is applied separately and not in real time. A sound file is selected, a process identified and parameter settings entered. The program then generates a new sound file which can be played once the processing is complete. The result is a very different approach to working with sound materials with GSX. Barry Truax could listen to textures being created and perform the transformations in the studio in real time, interacting with what he could hear as it was being generated. Complete strands of a section of *Riverrun*, often lasting several minutes, would be generated in a single take and recorded onto the multi-track analogue tape recorder ready for mixing with subsequent strands. The final component sounds of Trevor Wishart's *Imago*, by contrast, would often be the result of a whole sequence of processes, each applied separately. In fact, all the sounds in *Imago* originate from a single source recording made from the clink of two whisky glasses, a sound borrowed from Jonty Harrison. This brief source is processed in very many different ways, a complex network of different threads of processing branching out from the original. Our software includes interactive charts of this network of materials, enabling users to see the interrelations and to hear the sounds at each node in the network. In selected cases, we have also recreated the techniques used for the transformations. One of these charts shows the chronology of the creation of the materials leading to the final work.

It is an important part of Trevor Wishart's working method that he can explore the potential of his source by processing it in a particular way (e.g. transposition) and then hear the result, trying out alternative parameter settings in successive renditions if necessary, before extending this potential by adding further layers of processing to the result. Often a succession of processes produces a short gesture, but larger textures are also generated and sometimes, such as in the "gamelan" section discussed below, a single process is used to generate an extended passage of sounds. This way of working results in a large number of sound files: the composer's archive comprises well over 1000 files. Sub-mixes of sections were then made followed eventually by a mix of the final work – all this once again using Sound Loom. The software may not

[8] When Truax pursued his developments after *Riverrun*, he developed a new alternative of the GSX algorithm allowing for the granulation of short prerecorded sounds. This alternative was incorporated in another program, named GSAMX.

[9] Brassage makes multiple copies of fragments of the source sound and rearranges these, after possible additional processes, in a different temporal order than that of the original. Re-arranged fragments may overlap, leading to, for instance, the creation of massive textures from short samples. Thus, brassage is in fact a form of granulation.

operate in real time, but this does not mean that listening is unimportant to Wishart. To the contrary, he is keen to listen at each stage in the formation of a sound and fine tune settings in response. Nor does a non-real time approach indicate lack of experimentation; in our discussion with the composer, he has indicated that exploring the sound materials plays an important part in his compositional process.

3. Comparison of the musical outcomes

3.1. Riverrun

The musical structure of *Riverrun* comprises five clearly defined sections. Although there is occasionally a short overlap between sections there is no doubt about the sectional divisions (and this is confirmed by the composer's own documentation) and each section is clearly defined in terms of musical material. Each of the sections (which last between about 2 and 5 and a half minutes) is shaped in terms of complex multi-layered textures which evolve slowly over time. These textures comprise between two and four *sequences* (a term used by the composer), and each of these sequences is in turn made up of 4 stereo *strands* (our terminology), which in turn have a variable number of *voices* or grain streams. Figure 2, a screenshot from our interactive software, shows the strands that make up each of the five sections in the work, with time on the horizontal axis. The software enables users to solo out particular streams or strands using the original component sound files kindly provided by the composer[10].

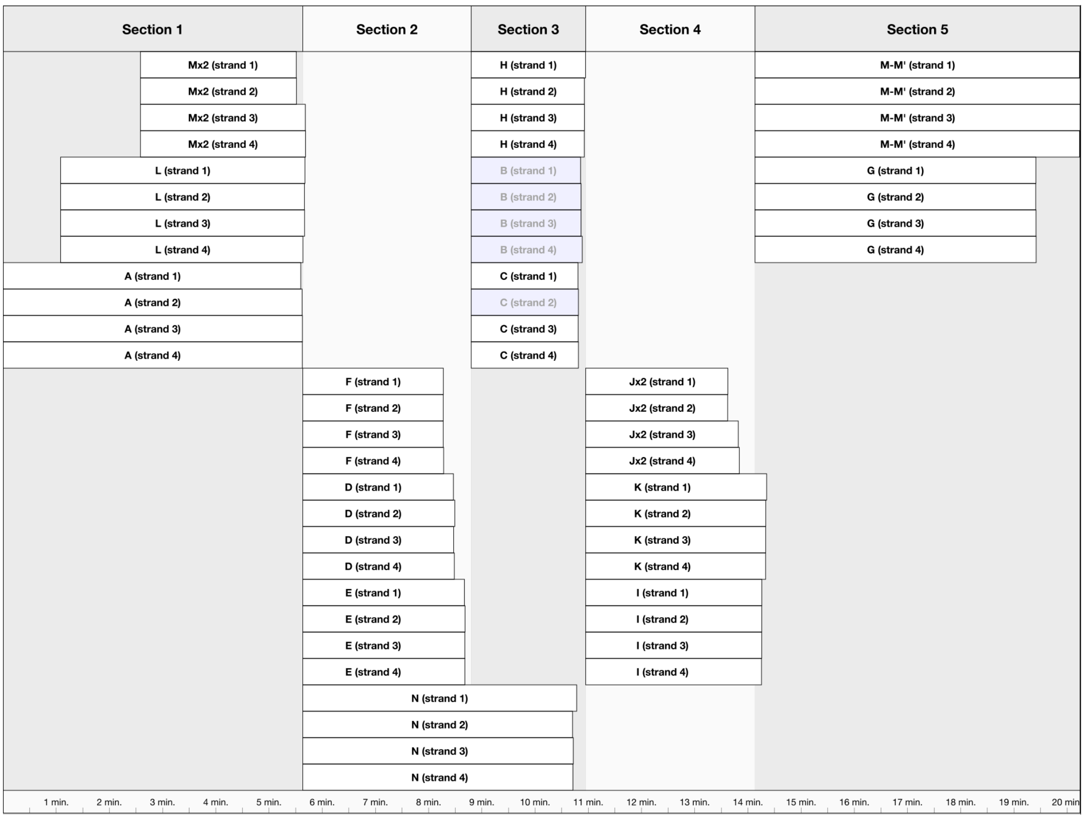

Figure 2. TaCEM software representing the strands making up *Riverrun*

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[10] These files are available in Barry Truax, *HTML Documentation DVD-ROM*, nº 1, *Riverrun* (1986/2004) and *The Shaman Ascending* (2004-2005), DVD, Burnaby, Cambridge Street Records, CSR-DVD 0801, 2008.

As already discussed, the strands were recorded as single takes, shaped in real-time on the GSX system. Musically, this means that the structure of the work was created not in terms of individual gestures sculpted separately and then put together but rather in terms of processes, whose evolution was performed by the composer as the sound was playing. In shaping the parameters of a strand he could therefore adjust settings in response to what he was hearing. This is not to say that no planning was involved. Indeed many of the strands follow some type of overall symmetrical form and strands that are superposed to form sequences often follow very similar trajectories, the richness of the overall texture arising from the simultaneously playback of subtly different variations. So clearly the performance of strands was planned in terms of overall shape and intention but with the added richness of these plans being realized through "live" performance by the composer in the studio with the subtle variation that this implies.

Musical shape in *Riverrun*, therefore, is in terms of evolving processes, the changing textures of individual strands and the ways in which these strands are combined to form larger textures. Often superposed strands within a sequence work together to reinforce and enrich each other, and this is also sometimes the case between superposed sequences though at times they counterpoint each other with contrasting materials or trajectories. A number of shaping devices, in many cases directly related to the opportunities afforded by the design of the software, feature prominently in the work. For example, a significant feature of the design of the GSX system, in contrast to those designed by Curtis Roads and others, is that although random variation plays a crucial role in the synthesis process, this randomness is applied to an underlying regularity. So for example, in terms of pitch, the parameter is initially fixed but a random range can be added. So it is possible for pitch elements in the work gradually to come in and out of focus, sometimes a clearly pitched strand dissolving into a texture of grains of randomly varying pitches, or conversely a clear pitch focus emerging from what initially seemed a noisy, chaotic cloud. All the strands in sequence H, in the third section of *Riverrun*, for example move from a high pitch at the beginning to a granular texture (by increasing the initially narrow frequency range) before the pitch reforms at the end of the section (by reducing the range again). Figure 3 is a graphic representation of the data used by the composer, the central line showing the central pitch and the shaded area around it the frequency range.

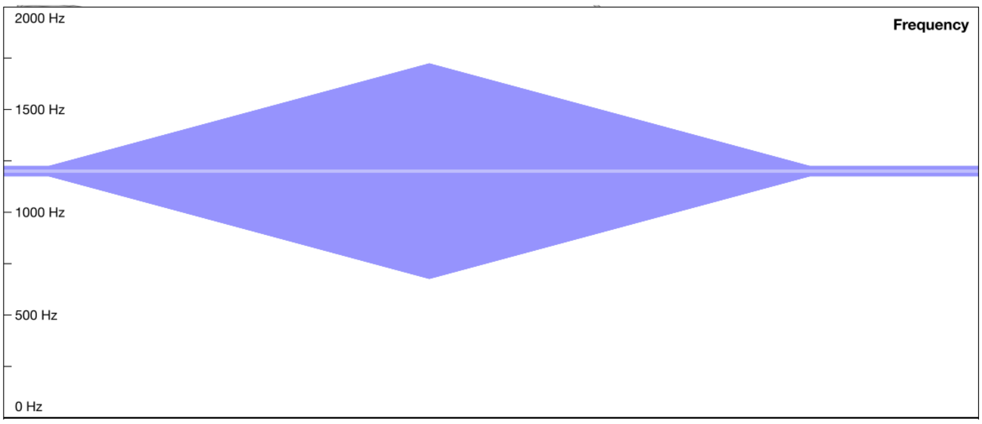

Figure 3. Frequency and frequency range across sequence H of *Riverrun*. The central light horizontal line is the central frequency (constant at 1200 Hz). The darker shading represents the possible values for actual frequency, as the frequency range increases and decreases through the sequence.

Likewise, in terms of the timing of grains, the range parameter allows random variation within a prescribed range to be added to what would otherwise be a regular stream of pulses. This feature enables Truax to move from regular synchronised pulses towards textures involving much more complex patterns of irregularly timed grains with different voices out of synchrony due to the random variation in duration that has been applied. Through sections 2 and 3, the strands of sequence N illustrate this movement from synchronised pulses to a complex desynchronised granular texture. They all begin with a duration range set to 0 and this value is then gradually increased through the section. Figure 4 shows a graphic representation of the duration value, the duration range and the delay between grains. Although the system does not allow the reverse to happen – once grains have become desynchronised it is not possible to bring them back into line even if the random variation is reduced to zero – Truax is able to achieve this effect in the work by recording a passage moving from regularity to irregularity and then playing it backwards on tape.

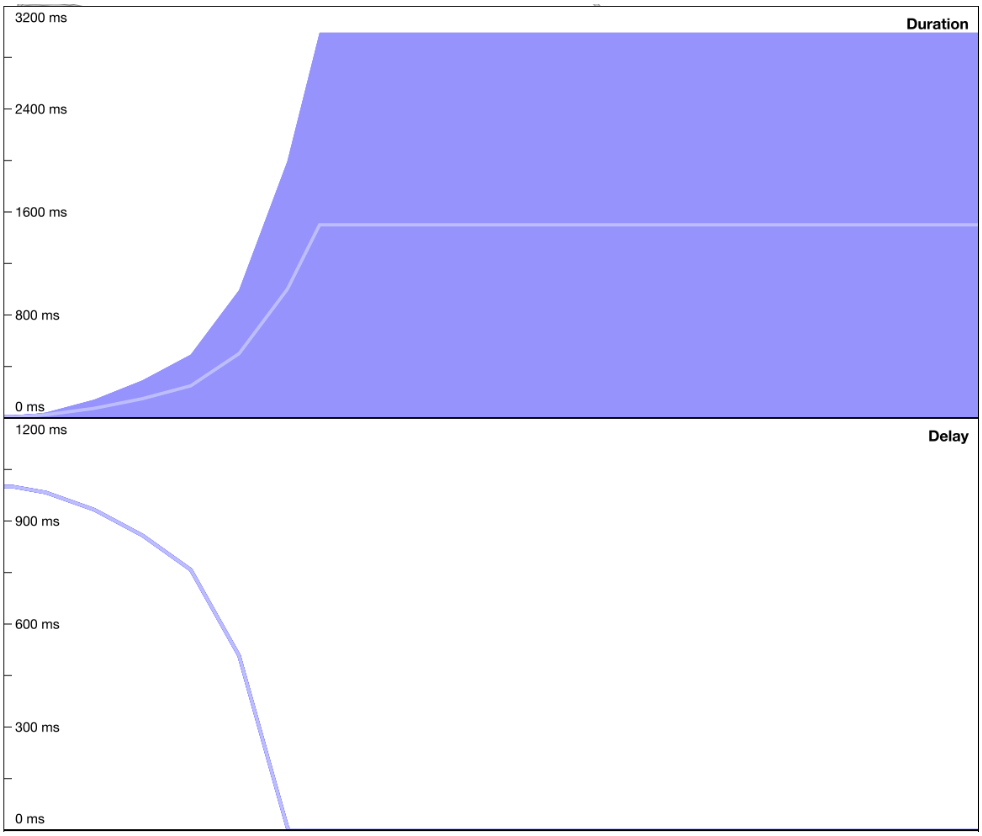

Figure 4. Parametric movements in sequence N of *Riverrun*. Upper part: duration (light line), duration range (blue shading). Lower part: delay between grains (blue line).

Spatialisation plays a significant role in *Riverrun* but not in terms of spatial movement: there is no dynamic movement of sounds between loudspeakers in this work. Rather the 8-channel playback of *Riverrun* is used to enrich the timbral experience of the work. Strands are stereo and given a fixed allocation to two of the eight channels. The individual grain streams or voices that make up a strand are allocated alternately between these channels but again fixed in position. The result of the similar but de-correlated grains streams distributed in space is a deepening of the textural and spatial experience.

A more general shaping device found in much granular music and not so dependent on specific features of the design of GSX is variation in textural density. An obvious example of this can be found at the start of the work in which the sound emerges from a few sparse grains and grows slowly to a dense texture, representing the evolution of a great river from individual drops of water. This is achieved in part by increasing the density of individual grain streams but it is also emphasized by the staggered entry of different streams at the start of the work. And since the different (stereo) streams are placed on different pairs of loudspeakers around the audience, this also has the added effect of the sound gradually spreading through the performance space to immerse the audience.

Other features are used to shape details within textures. For example, the synthesized grains can be created from a number of different waveforms, some having a wider range of partials than others. When as is often the case a stream is made up of multiple strands whose parameter settings and evolution are very similar, variety and richness of texture can be created by giving the strands different but harmonically related partials. In the context of complex textures with much random variation of parameters, the decision to use harmonically related frequencies might seem strange. But, although the result is not normally harmonic in any traditional sense, the outcome is that different frequency ranges within the texture are opened up, and again because these strands are all distributed to different speakers there is also a spatial dimension to this.

3.2. Imago

Imago is structured very differently from *Riverrun*. This reflects an almost opposite design of the software, which in turn reflects the contrasting aesthetic and compositional aims of Trevor Wishart. *Imago* is entirely constructed out of a single brief source recording – the two whisky glasses clinking together. From this source, Wishart gradually developed a rich and varied sound world by applying a succession of transformations to the original sound. The sounds that appear in the final work are often the result of several different processes. These sounds might be thought of as the top branches of a tree, originating from the same trunk but bifurcating in many directions as different processes are applied. Distinct groups of related sounds, resulting from similar sequences of processes, can be detected and help to characterize different parts of the work. Many of the gestures or textures resulting from the processing recur at different points in the work and this is one of the ways in which the music is shaped and formed. Although there are sections with distinct characteristics in *Imago*, and the composer's writings and score annotations for this work allude to these[11], the formal structure of the work is not as unambiguous or clear cut as is the case for *Riverrun*.

As already noted, the Sound Loom software does not operate in real time. Each process, whether applied to the original source or a subsequent stage in the sequence of processing, generates a new sound file that can then form the basis for further transformation or be used in the work in its own right, or both. Each of these sound files is date stamped by the computer and, in some cases, files containing the parameter data used in the processes can also be saved and date stamped. The composer has kindly given us access to his archive of files, which is to a large extent, though not entirely, complete – there are more gaps in terms of data files than sound

[11] See Trevor Wishart, *Sound Composition,* York, Orpheus the Pantomime, 2012.

files. This has opened up intriguing possibilities for our research both in terms of analysing the musical structure of the work and relating this to technical processes, but also, due to the date stamping, in terms of following the evolution of the work through the period of composition. In our software we have been able to depict this: the user can operate a slider to move through time and focus on different elements of the work emerging as the compositional process develops. Linked to this, the software also enables readers to listen to these component sound files. In terms of the evolution of the sounds from one stage of processing to the next, readers can access emulations of the processes and can try out the transformations for themselves, experimenting with alternative settings if they wish.[12]

Imago is a long work, over 25 minutes, and the archive contains over 1000 files contributing to the formation of the work. It is not possible in the context of this article therefore to examine in detail the whole work. Instead we will take a few examples to illustrate how the sound material is developed and how this relates to the ways in which the work is structured.

The opening of *Imago* begins with the original sound source. It comprises a sequence of short events gradually developing this source sound in different ways. From a technical perspective it might almost seem didactic in nature, illustrating a range of techniques that will be developed further and expanded upon later in the work. From a musical perspective it introduces a number of sounds and gestures that will play an important part in the often larger, more continuous textures later in the work.

The archive shows that the opening phrase of the work is a mix of 13 sound files or musical events. Figure 5 is the mix file for this phrase as found in the archives (with the addition of event numbers, from 1 to 13). The filename is followed by the start time (in seconds) and further data (number of channels, amplitude, spatial positioning) for the mixing process.

1	ttballmf.wav 0.0 1 1 C
2	ttbtwice.wav 6.0 1 1 C
3	a1aaaa_upam.wav 11.73 1 1.33 C
4	ttballf_cop.wav 26.0 2 1
5	ttbtwice_cop.wav 30.2 1 1 C
6	a3msemp.wav 34.37 2 1.4
7	ttballf_cop2.wav 41.2 2 1
8	ttbtwice_cop2.wav 45.7 1 1 C
9	startercextr.wav 50.13 2 1
10	from_tbr.wav 55.43 2 1
11	ttbtwice_cop4.wav 60.7 1 1 C
12	chromwej_a.wav 65.7 2 1
13	tt_to_airnu.wav 73.7 2 1

Figure 5. Mix file for opening phrase of *Imago*

The names Wishart gives to the component sound files often give some indication of the processes by which they were derived and of their interconnection. For example

[12] As for all the Case Studies of the TaCEM project, the software dedicated to the interactive aural analysis of *Imago* is being made freely available on the project website: http://www.hud.ac.uk/research/researchcentres/tacem/ (last visited November 29th, 2014)

‘ttbtwice’ derives from the original source sound ‘ttballmf’ played twice. The labels were however originally intended only for the composer’s own use and their precise meaning is often obscure. By listening, sometimes aided by the filenames, the 13 events in this opening passage can be grouped into five categories (A to E) according to their technical derivation and their musical characteristics:

A: three of the events, events 1, 4 and 7 are the original source sound underlying the whole work (‘ttballmf’, ‘ttballf’).

B: the simplest processing of this sound results in a gesture in which this source sound is played twice in quick succession. This gesture occurs four times in the opening phrase: events 2, 5, 8 and 11. It is the only one of the five categories which is entirely invariant and as such it might be heard as an anchor point for the passage.

C: a slightly more complex transformation which involves successive transposed repetitions of the source sound following a pitch contour. Different versions of this occur as events 3, 6, 9 and 10. The first of these, event 3, follows a rising contour, an anacrusis leading back to the original pitch of the source. Event 6 follows a more complex shape, rising then falling, slowing and decaying as it does so. Event 9 is again a rising anacrusis but rapidly accelerating and leading to a decaying resonance. This is terminated by event 10, a close variation of the initial anacrusis in event 3.

D and **E**: in the final two events of this phrase the initial tentative developments of the source sound are exceeded giving a sense of the work beginning to evolve towards more elaborate transformations. **D**, event 12 anticipates material that will feature strongly in some later sections of the work, which is there labeled ‘gamelan’ by the composer. It is a fast sequence of repetitions of the original short source sound following a pattern of pitches randomly picked from a chromatic scale, within a growing range. This leads directly into **E**, event 13, which comprises a mix of 4 sound files. The main sound file is a process in which fast repetitions of the original source at the same pitch fade in and out leading to a noisy resonance derived through granulation and time-stretching and ending with time-stretched granulation of the source in reverse (creating an effect like playing an attack/decay morphology backwards) followed by a resonance. This final gesture is then echoed more quietly by the three other sound files in the mix.

The 13 events in this first phrase follow this pattern:

A B C A' B C' A' B C'' C''' B D E

Within this sequence the following distribution pattern can be found:

A	**B**	**C**		
A'	**B**	**C'**		
A'	**B**	**C''**		
		C'''		
	B		**D**	**E**

Technically, the opening phrase can be seen as developing from the original source sound through a succession of progressively more elaborate transformations. Musically, the listener is being introduced to a range of different types of musical events which will become important as the work progresses. The foundations of the work are being established, firmly rooted in the original source, emphasised by frequent return to it, but gradually opening out into new musical territory.

In contrast to the opening phrase, the second passage we will examine appears towards the end of *Imago* and illustrates the more complex and continuous textures that often occur in later parts of the work. This section of the work (from 20’12” to 21’46”) is dominated by the gamelan material. Although sonically more complex than the first passage we examined, this section again comprises a mix of sound files each representing the result of processes applied to the source sound. And again the mix file from the composer’s archives provides a useful starting point for examining the structure of the passage. Figure 6 is derived from the original mix file. It has been reordered since the files did not all appear in chronological order in the original file. Data other than the file name and start time has been removed for clarity and an additional column showing relative start times, discussed further below, has been added. Indentation has been added to show relationships between files and shading to highlight groups of files.

The section is in two parts each underpinned, respectively, by the sound files ‘gamelda’ and ‘gameldv’. These files, like event 12 of the opening section, comprise fast successions of transposition of the slightly transformed original source sound, following algorithmically determined pitch sequences. A short silence at 20’58” separates the two parts. Superposed over these files in each section is a variety of other material which enriches and varies the texture.

The yellow shading in Figure 6 highlights a repeating pattern of material between the two parts – where file names have ‘_cop’ appended they are in fact exact copies of the original. The relative timings indicated in the figure between the start times of successive files shows that it is not just the order of events that is repeated but often also their timing that is repeated. The numbering of the files indicates their ordering in the original mix file. This may indicate the order in which the composer decided to add them to the mix.

The indentation in Figure 6 aligns the file names with five categories of material which can be defined as follows:

A: ‘gamel’: this is the rapid ‘gamelan’ material already discussed. In fact it already comprises a mix between different gamelan passages counterpointing each other in pitch and rhythm.

B: ‘gam’: a metallic granular texture with a crescendo followed by a diminuendo. Different files vary in length but retain the same focal pitch class.

B2: ‘gamtex’: closely related to B but without the crescendo, starting from a sudden attack followed by a granular decaying texture.

B3: ‘gam2up’: similar in morphology to B but transposed up.

C: ‘descender5’: a sort repeated sound falling in pitch.

D: ‘chromwejaccel’: a very rapid variation of the original source sound, widening in pitch range and increasing in speed with events merging into a texture towards the end (this is a close relative of the sound found in the opening phrase).

D2: ‘wejacclstakrise’: taking up where D finishes, a rapid granular texture.

E: ‘risernue’: a texture growing out of an initial gong-like attack.

A	B	B2	B3	C	D	D2	E	Start times (s)	Relative
Phrase 1									
1 gamelda.wav								0.00	
	2 gam-2.wav							0.48	
					14 chromwejaccel.wav			0.95	
	3 gam.wav							2.48	
	4 gam-4.wav							5.48	
		5 gamtex4.wav						8.48	0.0
		6 gamtex3.wav						17.48	9.0
						15 wejacclstakrise.wav		20	2.52
			7 gam-2up2s_str.wav					29.00	9.0
			8 gam-2up4s_str.wav					31.381	2.381
						16 wejacclstakrise_b.wav		31.4	0.019
		9 gamtex2.wav						31.90	0.5
						17 wejacclstakrise_a.wav		41.7	9.8
				10 descender5.wav				42.2	0.5
	11 gam-8.wav							44.45	
	12 gam-8e_str.wav							44.45	
Phrase 2									
13 gameldv.wav								47.321	
							18 risernue3.wav	48 2	
					25 chromwejaccel_cop.wav			48.27	
		19 gamtex4_cop.wav						55.7	0.0
		20 gamtex3_cop.wav						64.8	9.1
						26 wejacclstakrise_cop.wav		67.32	2.52
			21 gam-2up2s_str_cop.wav					76.32	9.0
			22 gam-2up4s_str_cop.wav					78.701	2.381
						27 wejacclstakrise_b_cop.wav		78.72	0.019
		23 gamtex2_cop.wav						79.22	0.5
						28 wejacclstakrise_a_cop.wav		89.02	9.8
				24 descender5_cop.wav				89.52	0.5
	29 gam-8e_str_cop.wav							91.77	

Figure 6. Mix file for 'gamelan' section, annotated and adapted

By default, because of the way that the whole work is derived from one source sound, all the material is related. But this analysis also shows different groups of family relationships. Although a more dense and continuous texture, this section is constructed according to the same principles as the opening of the work: processing of the original source sound and then combining the resulting sound files. There is a clear sense of structure and order, both in the relationships between the different sounds and in the ordering of the materials.

4. Conclusions

Truax and Wishart represent very different ways of composing with technology. The software systems they devised are also contrasting, reflecting their own working methods and aesthetics. The music they produced, *Riverrun* and *Imago*, is a result both of the different technological approaches taken and their contrasting aesthetics. Truax works in real time, hearing sounds as they are formed and adjusting the parameters as he is listening. He produces relatively few component sound files and these are all rather long passages comprising slowly evolving transformations. Listening is also important to Wishart but after the processing is completed. The final result is not produced immediately but often comes from several stages of processing and very many component files are generated, many of them very short. A selection of these are then mixed together to create phrases and sections. Truax's approach to musical form is concerned with evolving process and development of textures over long periods. Wishart's approach is in many ways closer to a traditional work on motivic repetition and variation, and layering contrasting materials.

For all their differences, there is a sense in which both pieces are formed out of a single short sound. In the case of Truax this is the grain, the synthesis parameters of which are varied to produce a wide range of timbres and texture. With Wishart it is a recorded sound to which a wide variety of processes are applied. This commonality makes all the more striking the significant differences between the composers in terms of their technical approach and their musical outcomes.

In terms of research methodology, this study illustrates the significance of technical investigation for deepening the understanding of individual works and for illuminating the relationship between technology and creativity in electroacoustic music. The use of interactive software is vital in a context where verbal descriptions and diagrams cannot hope to fully communicate the nature of the sounds and the techniques used. By presenting the technical analysis accompanied by emulations of the processes used by the composers and the musical structures in terms of interactive aural charts, we seek, through the TaCEM project, to facilitate closer engagement with the approached resources and aesthetics and so deepen our readers' understanding of both the music and the technology.

5. References

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