A model for the conservation of interactive electroacoustic repertoire: analysis, reconstruction, and performance in the face of technological obsolescence

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This paper presents a three-stage model (analysis, reconstruction and performance) for the conservation of interactive electroacoustic works for which the original technology is now obsolete or otherwise unavailable. The first stage, analysis, is a detailed documentation of the electronic processes and effects required for each work in a format that is independent of any specific device or system. The analysis provides a blueprint for future realisations using available technology. The second stage, reconstruction, provides a working performance resource, as well as a test case for the validity of the analysis. Reconstructed systems are then tested and refined through the third stage, performance. With repeated performances, compositions gain wider exposure and may be evaluated by listeners on their musical merits. To date, the author has analysed, reconstructed and performed several works for clarinet and interactive electronics. Each performance has informed the continued development of the newly reconstructed system, and has in some cases led to corrections to the underlying analysis. As a classically trained clarinettist and computer musician, the author's approach to the conservation of electroacoustic repertoire comes from a desire to find performable works and to keep them viable and accessible for as long as possible. Four works for clarinet and interactive electronics (by Musgrave, Pennycook, Kramer, and Lippe) are presented as test cases for this model.

1. INTRODUCTION

This paper is concerned with the long-term conservation of electroacoustic works that combine live performance with interactive electronic systems. It should be noted from the outset that my work is informed primarily by what one could describe as the 'conservatory' model, in which a musical work is treated as an historical object to be preserved, repeated, interpreted, and ultimately owned by the performers, audiences and musicologists who deem it important enough to perform, listen to, and discuss. In this model, works enter the 'standard repertoire' after a process of repeated performance and evaluation by an asynchronous and widely distributed pool of interpreters. Works that enjoy a consensus opinion of concert-worthiness appear again and again on concert programmes. Where technological obsolescence (or simply the rarity or relative complexity of the required system) becomes a barrier to this process, diffusion of a musical work among performers (and therefore to audiences) may be hampered without due consideration of its musical merit, since issues of mere feasibility take precedence.

At present, it would be difficult to argue that there is such a thing as a 'standard repertoire' of interactive electroacoustic works. This is precisely my motivation for pursuing this research. As a clarinettist looking for good pieces to perform involving live electronics, technical requirements have often been the determining factor in my decision to play or not to play a particular work. In many cases, the composer requires a unique (and often very expensive or completely inaccessible) list of equipment for performance. As a performer with limited resources, I have therefore avoided many intriguing works on this basis. I can only assume many other performers have been deterred likewise. How is a repertoire to survive, much less standardise, if performers interested in interactive electroacoustic music are unable to assemble and maintain the necessary arrays of equipment?

In the case of interactive electroacoustic music, therefore, it may be necessary to separate the music from its original instrumentation in order to ensure its long-term survival. For each new work, not only will the technology used at the time of composition become unavailable, but eventually so will the composer. Preservation of the original technology itself has already proven difficult if not impossible, due to the lack of clear standardisation of equipment that constitutes an 'interactive system'. Musicians who wish to perform these works should be armed with the best possible tools for realisations that are faithful to the composer's intentions, while using the technology at hand.

As a solution, I have developed a model for the preservation of interactive electroacoustic works based on analysis, reconstruction and performance. My aim is to develop resources for the continuous renewal of these works, even in the face of rapid technological change. As an illustration of my model for conservation in action, I present my work to date on four compositions for clarinet and interactive electronics for which the original equipment or systems have become unavailable

Organised Sound **11**(3): 273–284 © 2006 Cambridge University Press. Printed in the United Kingdom. doi: 10.1017/S1355771806001555

or outmoded. Each work tests the analysis model in different ways since the technical requirements and musical effects are quite different from piece to piece, as are the available source materials. This paper is an extension of the ideas and topics discussed in my 2004 doctoral dissertation at the University of Arizona (Wetzel 2004b). In that document I first laid out my formula for the analysis and reconstruction of older interactive electroacoustic works. In the intervening years I have had further opportunities to test these analyses through concert performances and continued development of software-based reconstructions. My own realisations of these four works are in various stages of development, and have in some cases been subject to considerable refinement due to their use in concert performance. I anticipate that future technologies may make possible (or even preferable) formats for implementation quite different from the type of software reconstruction I have used to date. The point of this work, however, is not to focus on particular tools used for performance, but rather to gain a better understanding of the music itself and to establish the most authoritative possible guide for interpretation which can be adapted to technological changes while honouring the musical intentions of the composer.

2. A MODEL FOR CONSERVATION: ANALYSIS, RECONSTRUCTION AND PERFORMANCE

I have taken a three-stage approach to realising older works that were originally based on now-obsolete technology. The first stage is an analysis of the required electronics which details the functions and effects of the interactive system in as 'machine-neutral' language as possible. The second stage is a reconstruction or emulation of the original system using current technology. The third stage is testing of this reconstruction through rehearsal and performance. A diagram of the model is seen in Figure 1. The analysis is based on consideration of multiple sources of information about the system, its operations, and its musical purpose. The reconstruction and performance stages may also provide valuable insights leading to revisions of the analysis or the reconstructed system.

2.1. Sources

A thorough analysis of the electronic elements of a complex interactive work will almost always require reference sources beyond the musical score. To date, I have based my analyses on five categories of source material:

(1) Musical scores with accompanying technical documentation
(2) Direct experience with the original technology (and relevant technical manuals)
(3) Available recordings
(4) Updated versions of system software
(5) Post-compositional commentary

This last source may include correspondence with the composer and/or performers involved in the creation of the work, journal articles on various technology components, and other performers' solutions to performance problems posed by adapting to new technology.

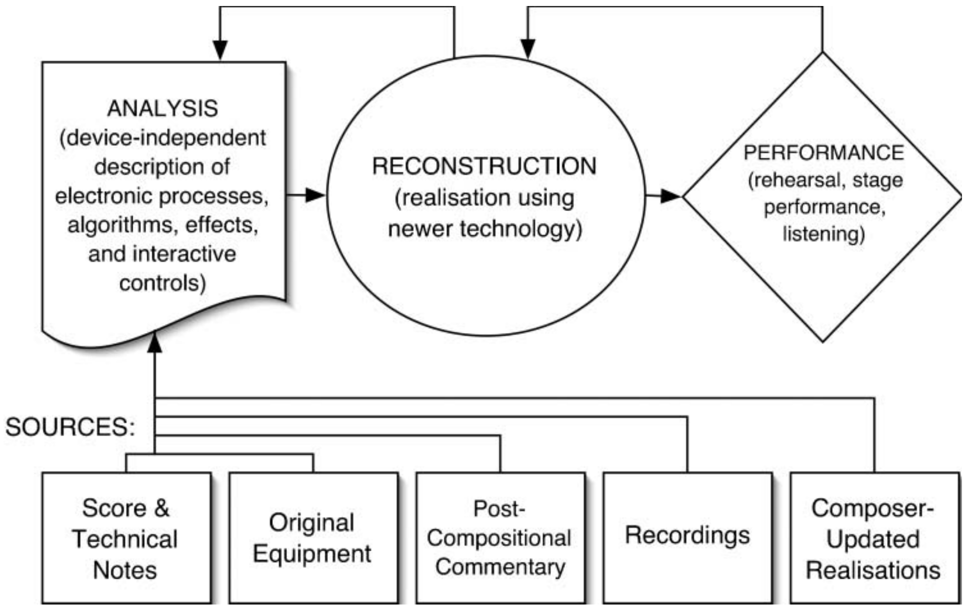

Figure 1. Diagram of the author's model for the conservation of interactive electroacoustic works based on analysis, reconstruction and performance.

2.2. Analysis

The result of the analysis is a text document that describes in detail the functions, human-machine interactions, interactive and automated controls, synthesis and processing algorithms, and musical effects of the interactive system. Although such an analysis document is potentially useful for musicological study, its true value from a performer's perspective is its function as a blueprint for reconstruction of the interactive system using available technology.

Description of the interactive system should be given in general terms, independent of any particular devices or software. Every effort should be made to use standard units of measure and widely accepted terminology in describing signal processing and synthesis techniques. Where more technical detail is necessary and mere prose is insufficient, mathematical equations, pseudo-code, and block diagrams should be used. Sampled sounds, if required, in many cases may be recreated. In such cases, complete instructions for regenerating the required samples would be a critical part of the analysis. In cases where the required samples are unique and not reproducible, the sounds themselves must be preserved in a reliable open-source format.

It is important to note that this analysis is not the same as a 'transcription' or 'port' from an outmoded system to a newer one. Such a strategy would indeed result in a functional realisation of the required interactive system, but one that is itself subject to the possibility of technological obsolescence. Furthermore, future realisations, if based on transcriptions rather than the original system itself, will begin to depart from the original as system functions are adapted to the specific architecture of each new technology. The analysis model proposed here is analogous to an authoritative *urtext* edition from which multiple individual interpretations and implementations may be generated without corruption resulting from serial retranslation. Therefore, it is theoretically possible for an interactive electroacoustic work to be faithfully reconstructed and performed far into the future, regardless of even the most radical changes in available music technology, so long as an authoritative technical analysis and score are preserved.

2.3. Reconstruction

The best test for the analysis of an interactive system is an actual attempt at reconstruction using newer (or alternate) technology. Under ideal circumstances, one would compare the reconstruction side by side with the original system. The composer, if available, may then also provide verification that the reconstruction produces the originally intended result. Reconstruction of an obsolete system may in some cases also serve to correct the analysis, since solving the problems of implementation will sometimes provide new insights that even the most careful study of the original system won't reveal immediately. This is especially true if the process of reconstruction is carried out while the original sources are still available for independent verification by other researchers.

Another useful test for the validity of the analysis is the simultaneous reconstruction of the interactive system using different yet contemporary technologies. Though academically interesting, such a situation may actually occur for purely practical reasons, as in the case of two performers who have invested significant resources and energy in competing computer music platforms (e.g. Max/MSP and Kyma), which may be quite different in their architecture, but equally capable of realising a particular piece. If the interactive system can be reconstructed satisfactorily using a variety of platforms (software and/or hardware), then not only is the analysis that serves as the authoritative source validated, but the long-term prospects of the work's survival in the repertoire are enhanced.

The most practical benefit of a working reconstruction is that it may make a previously unplayable work available for performance. With refinement of the analysis, it becomes possible to reconstruct the interactive system periodically as technology changes and the reconstructions themselves become obsolete. If the primary source for a reconstruction (whether implemented in software or hardware) is the device-independent analysis, then theoretically each new implementation will be just as close to the original as any other reconstruction, no matter what technology is used or at what point in the future it is created.

2.4. Rehearsal and performance

Working reconstructions of obsolete interactive systems must be tested by performers through rehearsal and performance. It is through the rehearsal process that the performer becomes acquainted with the functions of the system and develops an understanding of the opportunities for musical interpretation and expression within the bounds of the composition and accompanying electronics. This is a critical point in the development of useful reconstructions (which in turn serve to validate the underlying technical analysis), since redundancies in the system or flaws in the interactive control structure may be exposed. Rehearsal is also a critical juncture for the performer, who at this stage will develop an opinion as to the work's worthiness for continued inclusion in his or her repertoire.

Concert performance plays an important role in testing the stability and functionality of a particular reconstructed interactive system. It is also the forum in which judgements regarding a composition's place in a 'standard repertoire' are formed. Successful reconstructions that result in nuanced, convincing performances by interpreters who fully understand not only the music but the interactive electronic system as well, are more likely to focus the audience's attention on the musical value of the work, rather than the difficulty of its execution or the complexity of the system.

The process of analysis, reconstruction and performance is ultimately aimed at enabling realisations of interactive electroacoustic works that are unhampered by technological limitations, and allow the performer to focus on the musical issues of presenting works that combine traditional performance with interactive electronic instruments. Therefore, reconstructions must be made available that take the needs of the performer into account, including such features as 'user-friendly' interfaces and controls, plain-language explanations of the system and its musical and interactive elements, technical and performance notes for set-up and execution in a variety of situations, and user feedback elements that put the performer in control of the system during performance to the greatest extent possible. In this regard, I view my work as an attempt to make interactive electroacoustic music more accessible to performers who may not be electroacoustic music specialists, so that this music might begin to receive a broader hearing.

3. CASE HISTORIES: RECONSTRUCTION FROM A PERFORMER'S PERSPECTIVE

This model for analysis was developed through the process of analysing four works for clarinet and interactive electronics. I chose these compositions in consideration of several factors: (i) prominence (each work received a relatively high-profile premiere and some attention in the academic literature), (ii) obsolescence or general unavailability of the original technology, (iii) varying degrees of complexity, (iv) diversity of technical features, and (v) my own desire to perform these works.

This last point is not so trivial as it may at first seem. Performers must be willing to play a piece repeatedly and devote considerable time and energy to its study and interpretation. My understanding of each piece presented here is the product of many years of study and performance (fourteen in the case of Kramer's *Renascence*). To date, I have designed new reconstructions of interactive systems of three of the four works analysed, and tested them in concert performance. Plans for completing and expanding the cycle in the near future are, of course, in progress.

3.1. Thea Musgrave's *Narcissus*

Thea Musgrave (b. 1928, Edinburgh, Scotland) wrote *Narcissus* in 1987 for flute and digital delay in response to a National Endowment for the Arts (USA) Consortium Commissioning Grant for flutists Wendy Rolfe, Harvey Sollberger, Patricia Spencer and Robert Willoughby (Spencer 1994: 47). Musgrave later transcribed this work for clarinet as a gesture of thanks to clarinettist F. Gerard Errante for his help in designing and testing the interactive digital delay system (Errante 2004).

Narcissus was written for a very specific device: the Vesta Koza DIG 411 Digital Delay. The composer acknowledges in the technical notes that performers will undoubtedly need to use other equipment (Musgrave 1987: 1). Although the electronics required for performance are relatively simple, there are several effects called for in the score that are not adequately explained in the accompanying technical notes or in any other previously published source. The score gives knob positions and settings specific to the Vesta Koza DIG 411. In many cases, such as delay time ('512 × 2'), Vesta Koza notation is easily translated. Other effects such as delay feedback, expressed in values from 1–10, suggest straightforward solutions based on reasonable conjecture (e.g. 0–10 = 0%–100% feedback). One case in particular, a score indication of 'Mod to 1', is especially mysterious, since 'Mod' or 'Modulation' is never defined in the score as to how or what it is to modulate. Nor is the meaning adequately explained of a modulation depth value of '1', or a modulation speed, as indicated, of '0'. Errante described the modulation effect as 'a gradual, "undulating" pitch transformation, like a slow, wide vibrato' (Errante 2000: 09/03). Desiring more precision in my analysis, I tracked down the composer's original Vesta Koza DIG 411, which was lent to me very kindly by Dr Wendy Rolfe, one of the flutists involved in the commissioning and premiere of *Narcissus*.

Working directly with the DIG 411, I was able to model a software-based reconstruction directly on the functions of the composer's original system. For effects such as modulation (LFO-controlled delay time modulation, as it turns out), I was able to define a processing algorithm with precise values for such parameters as modulation, speed and depth. It was extremely helpful to observe first-hand other important features of the original system, such as the delay hold and bypass, in order to construct software emulations that had the same responsiveness and functionality the composer had expected. The full analysis, including complete descriptions of each effect and its parameters, plus an overview of the control system used in my implementation, are given in my earlier work (Wetzel 2004). However, the delay system implemented in Max/MSP, shown in Figure 2, gives a fairly concise description of the core system.

Of the four works analysed for this study, my efforts on behalf of *Narcissus* have had the most exposure to performance testing and review by other musicians. My software reconstruction of Musgrave's delay system was first used in performance as part of my doctoral

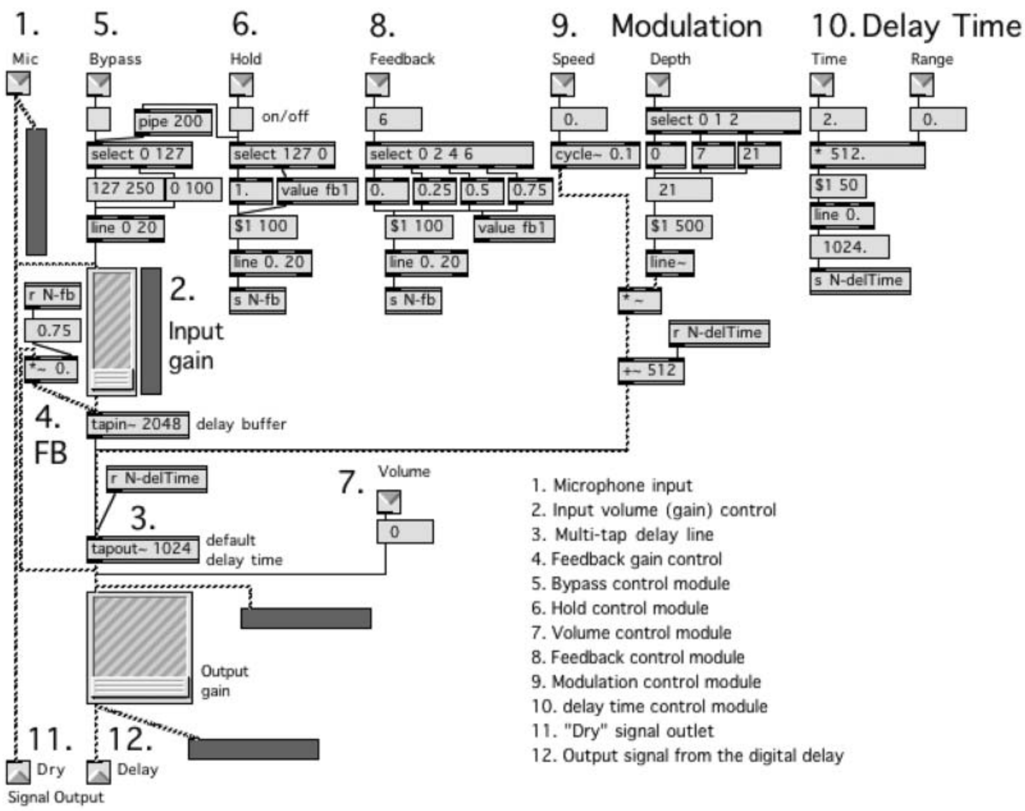

Figure 2. The digital delay system for Thea Musgrave's *Narcissus*, implemented in Max/MSP.

lecture-recital in the summer of 2004 at the University of Arizona, Tucson (Wetzel 2004b). A description of the current implementation in Max/MSP was given at the 2004 International Computer Music Conference (Wetzel 2004a). Portions of my software were incorporated by Todd Welbourne for a performance given by flutist Elizabeth Marshall at the 2005 Spark festival of Electronic Music (Welbourne 2005: 23). My own subsequent performances (2005 and 2006) have been very instructive in refining the reconstructed system for ease of use and reliability on stage. For instance, Musgrave emphasises in her technical notes the need for a smooth 'delay hold' feature free of audible 'clicks' when engaged with a foot switch (Musgrave 1987). This feature required considerable refinement in my own software realisation of the delay system. The author's performance software resulting from this research should be publicly available sometime in late 2006.

3.2. Bruce Pennycook's *Praescio IV*

Praescio IV, composed in 1990, was part of a series of compositions written between 1986 and 1993 at McGill University in Montreal which used Pennycook's 'MIDI-Live' system for real-time control of MIDI file playback (Pennycook 1991). The interactive system for *Praescio IV* used MIDI control signals from switch triggers (originally via custom switches harnessed to the clarinet) and pitch tracking data (originally via IVL Pitchrider), to initiate MIDI sequences with variable playback parameters. Pitch-tracking data (pitch and amplitude) were also used to control synthesised 'colourisation' (four-part intervallic doubling) of the live clarinet (Pennycook 1994). Continuous volume of the synthesizer colourisation was controlled by a simple volume pedal. All electronic sounds were generated by an external synthesizer. At the heart of the MIDI-Live system was an 'Event List' that contained data for each cue point indicated in the score: event trigger (switch or MIDI pitch number), sequence number, output channel, transposition (in semitones), harmonisation, velocity scaling, and tempo scaling (Pennycook 1991: 23–4).

Because the original 1990 MIDI-Live system was no longer available by the time I became interested in the piece in 2003, the composer provided me with a version of the control software developed in 1995 using (then Opcode's) Max. This software, my correspondence with the composer, a recording of the piece by clarinettist Jean-Guy Boisvert (1997), and a technical manual for the IVL Pitchrider were my primary sources for analysis of the interactive electronic system.

Variable-parameter playback of standard MIDI files was handled in the 1995 version by a custom Max object, *playSMF*, developed by Pennycook, Dale Stammen and Basil Hilborn in 1993 (Pennycook 1997: 89). This object had not yet been re-compiled for the

Macintosh PPC architecture, so in early 2004 Stammen was kind enough to create a version that was compatible with Max 4/MSP 2 on my Apple G3 PowerBook, running Mac OS 9 (Wetzel 2004: 91). However, this version was not compatible with Mac OS X, which was already in common use by the time of my performance of this work. Newer realisations of *Praescio IV* will either require further updates to the *playSMF* object or will require alternate solutions to the requirements of the MIDI file playback system. In this regard, a device-neutral analysis is most helpful.

My analysis of Pennycook's system divides the electronics into five sub-systems: (i) input controls (pitch tracker, event trigger, sustain pedal, and volume pedal), (ii) input processing, (iii) 'play' event processing (MIDI file playback based on stored instructions in the Event List), (iv) 'thru' processing (synthesised colourisation of the live clarinet based on instructions in the Event List), and (v) a synthesizer (Wetzel 2004b: 93–4). Synthesised sounds are left to the performer to realise according to basic guidelines given by the composer (Wetzel 2004b: 85). Because each of these components is fairly simple in itself, the entire system could be easily reconstructed from my analysis using a variety of computer music platforms, provided the performer has the clarinet score, the complete Event List, and a full set of MIDI sequence files, all of which are easily preserved in durable, human-readable media.

My 2004 realisation of *Praescio IV* was based on a Max/MSP patch provided by the composer, but included many of my own modifications. Pitch tracking functions (based on Miller Puckette's Max/MSP object *fiddle~*) were now incorporated into the software, eliminating the need for an external device. Trigger switches and foot controls were handled with a MIDI foot controller (DigiTech RP-20). Synthesised sounds were produced by an external Proteus 2000 sound module under MIDI control. My other contributions included additional graphical system indicators and access links to various control panels and internal processing modules.

My newest realisation of *Praescio IV* (used in performance at the Sonic Fusion festival in Edinburgh, Scotland in May 2006) represents a complete re-thinking of the interactive system software. I have created this software reconstruction without direct assistance from the composer, using only my previous analysis and the *Praescio IV* Event List as a guide. An important feature of the new system is a module for asynchronous multichannel MIDI file playback that uses only standard Max/MSP objects (avoiding the need for another port of *playSMF*). Figure 3 shows the main user interface window for my 2006 realisation of *Praescio IV*.

The new software system functions more like an instrument than as an embodiment of a particular composition, since all settings specific to the piece are loaded into the program from external text files. Theoretically, other works with similar technical requirements could be performed using the same software. Only the external files would have to be changed. I believe this approach is valuable mainly because it draws a sharper distinction between the composition and the instrument used for its execution.

I have streamlined my current performance set-up further by replacing the external sound module with a software synthesizer. The entire hardware system therefore consists of a laptop, a foot controller, a sound interface, a microphone, and loudspeakers. These requirements are now the standard set-up for all works in my electroacoustic repertoire.

3.3. Jonathan Kramer's *Renascence*

Jonathan Kramer (1942–2004) was a noted American theorist, composer, and music critic with a particular interest in the problem of musical time (Kramer 1988). *Renascence* was written in 1974 for clarinet, pre-recorded tape, and tape delay system. It was commissioned by the University of Redlands and dedicated to Phillip Rehfeldt and Barney Childs (Kramer 1977). The premise of the piece is the periodic repetition and layering of previously played material, using a long delay.

The original interactive system requires three open-reel tape recorder/players. The first is used for playback of the pre-recorded tape, supplied by the publisher, G. Schirmer. The other two tape machines are used for the delay system: the live clarinet is recorded by one tape deck; the tape then travels across the stage (bypassing the take-up reel) to the second tape deck, which plays it back. The time delay between recording and playback is determined by the physical distance between machines. Also required for performance is a 3×3 matrix mixer to control audio routing from the microphone and delay outputs to the speakers and delay inputs. The matrix mixer is operated by a technician who must follow very precise instructions in the score for switching audio connections during performance.

The composer specifies a delay time precisely equal to thirty-four measures in 2/4 time at a tempo of 200 beats per minute. Synchronisation between the live performer and the return of the delay is accomplished through the use of a click-track, which is to be recorded onto the tape on one channel (monitored in headphones but not played back over the loudspeakers) and re-circulated via tape feedback every thirty-four measures until no longer needed. This ensures that slight irregularities in the length of the delay (due to placement of the machines) does not gradually build up into 'a major lack of synchronisation' (Kramer 1977). The problem of setting such a precise delay time between two bulky machines, nearly four metres apart (tape speed at 19 cm/sec), posed serious difficulties for set-up and performance.

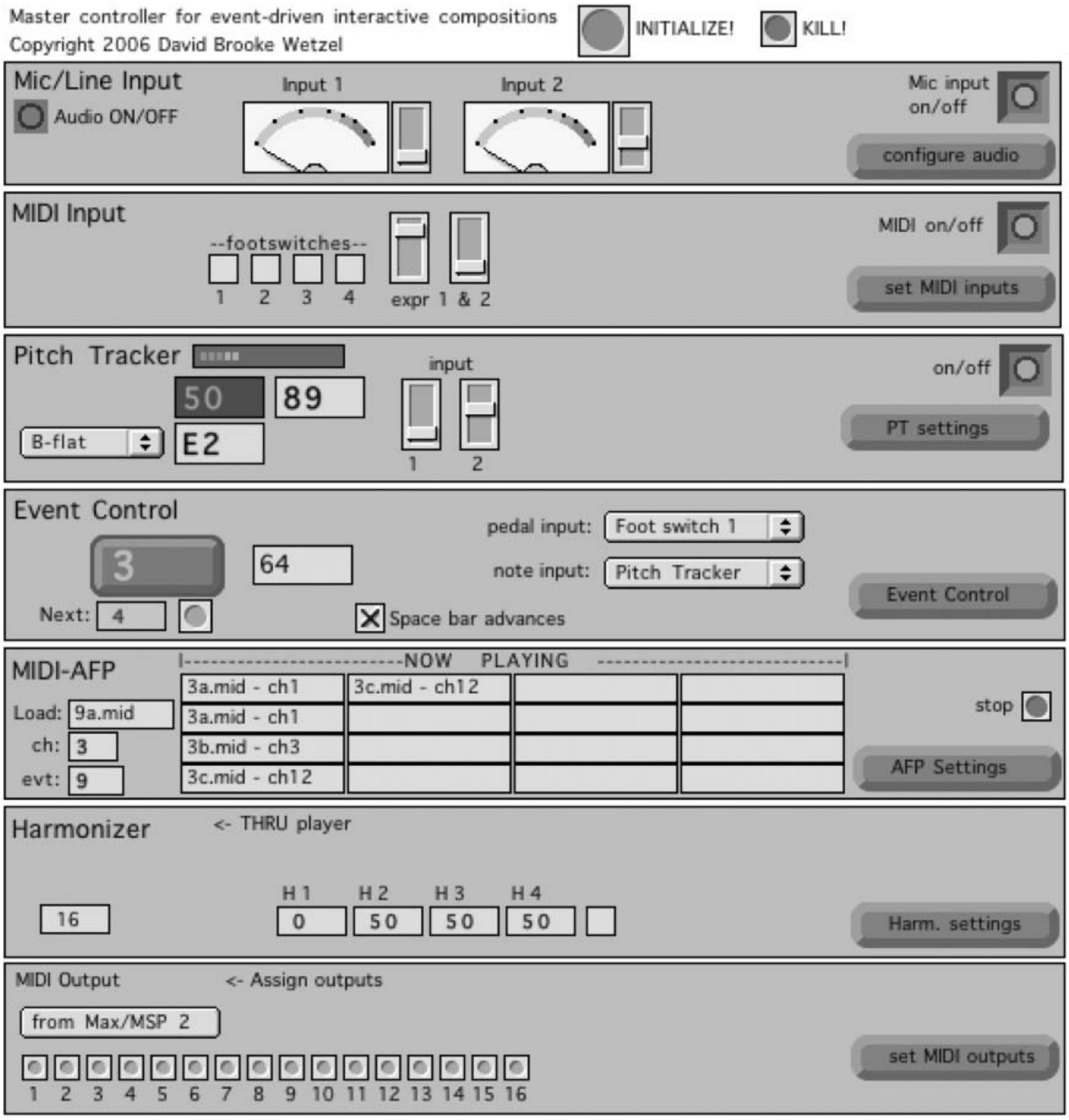

Figure 3. Main user interface window for the interactive system used in a recent performance of Bruce Pennycook's *Praescio IV*. Interconnected modules for audio i/o, MIDI controller set-up, pitch tracking, event control, file playback, and harmonisation allow for flexibility and future expansion. All information specific to *Praescio IV* is loaded into each separate module at run-time from text files.

According to Kramer, early performances using the original equipment suffered from inaccuracies in the delay time, and were never completely satisfactory (Kramer 2004). Therefore, the composer revised *Renascence* in 1977 as a work for clarinet and tape, with the interactive elements reduced to a single pre-recorded tape part. However, the live version was preferred by Kramer, and he strongly encouraged the development of accurate new interactive implementations of this work (Kramer 2004).

The analysis of Kramer's interactive system was very simple and straightforward, since, in the abstract, his system is quite basic and the technical notes accompanying the score are very clear. Delay time is described in terms of tempo (200 bps), metre (2/4 time), and a set number of measures (34), with detailed instructions for setting up the tape delay system to achieve the desired delay length. In an alternate delay system, such as a software-based digital delay, all that is required is a delay time. This can be easily calculated based on the values given in the score (34 m. / 200 bpm * 2 * 60 = 20.4 seconds). The matrix mixer is described in even more abstract terms, since the composer did not specify any particular model of mixing console, only that it have at least three inputs and three outputs with switchable routing.

The interactive system is only one part of the soundscape for this piece. A pre-recorded tape also runs in the background during performance consisting of recorded clarinet sounds (a drone and a series of phase-loops based on a score excerpt). The original tape was created by the composer in 1974 using analogue equipment and recordings of clarinettist Phillip Rehfeldt. Since a digital implementation of the delay system is not likely to match the sound of the original tape, the composer was kind enough to share with me the procedure for re-creating the pre-recorded tape (Kramer 2004). Thus each performer now has the option of creating a tape part to match his or her own personal style and clarinet sound.

The complete analysis of the technical components of the delay system and instructions for re-creating the pre-recorded tape are given in my dissertation (Wetzel 2004b: 95–117). More recently, I have had the opportunity to create a new software implementation of this work and perform it at the 2006 Spark Festival of Electronic Music and Art at the University of Minnesota in Minneapolis. An accompanying technical paper given at the Spark Festival describes the digital implementation of Kramer's system using Max/MSP (Wetzel 2006).

My implementation was built for practicality and reliability from a performer's perspective. Realisation of the core elements of the delay system were fairly simple using Max/MSP: a delay line set to 20,400 milliseconds and a matrix mixer controlling audio routing gave me a functional model of the system within a few minutes of programming. However, even a simple system used in performance requires careful programming and testing of a number of interrelated systems. Other components of my performance software include controls for setting up microphone inputs and levels, an internally generated metronome (for click-track synchronisation with the delay), automation of the matrix mixer, controls for automatically balancing delay feedback levels, output routing controls for configuration in different playback environments, headphone monitor mixing, automation of pre-recorded 'tape' playback, and user-interface controls and indicators to provide as close an interaction with the system as possible during performance. The main user interface window is shown in Figure 4.

With my current set-up, I am now able to start up the system, run an initialisation sequence (one-touch

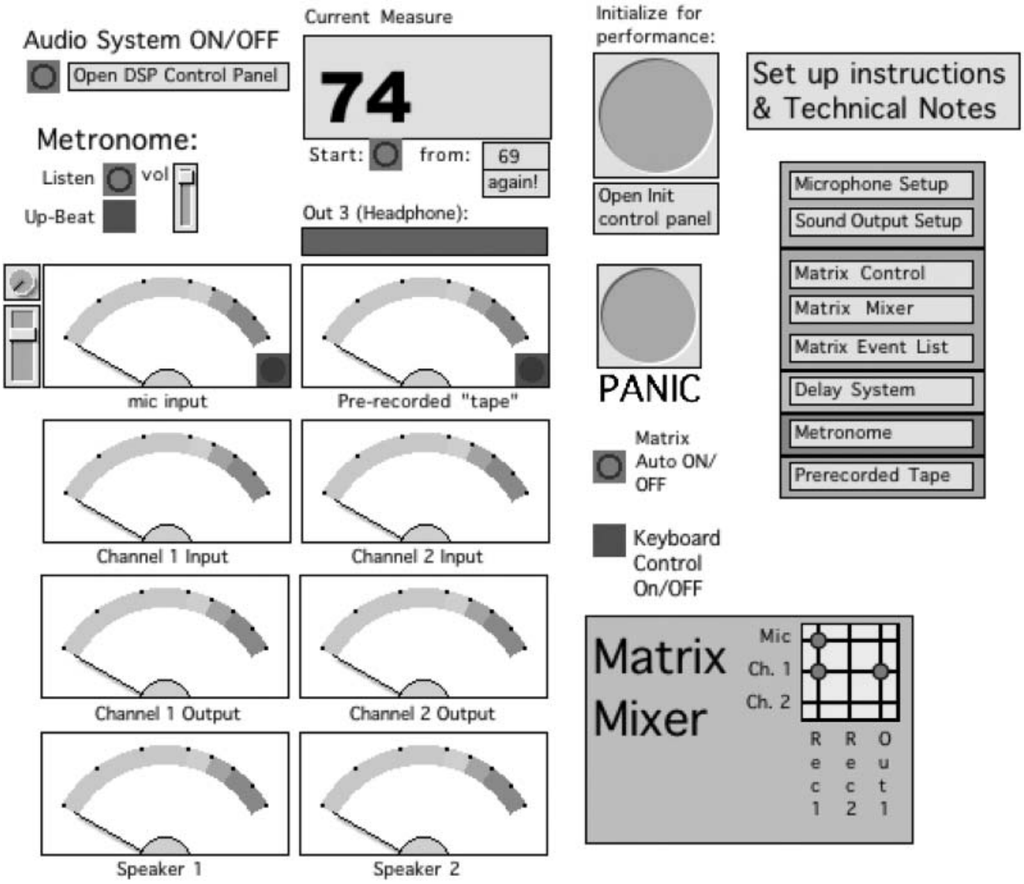

Figure 4. User interface for the delay system used in a recent performance of Jonathan Kramer's *Renascence*. Indicators and controls are included for current measure number, audio system on/off status, metronome control, rehearsal number start points, microphone and delay system audio levels, and matrix mixer status. Access is provided for important set-up functions and viewing of core system components (audio i/o set-up, metronome, matrix mixer automation, pre-recorded sound file playback, etc.).

operation), check the microphone input, and run the piece from start to finish. The reliability of this system allows me as a performer to concentrate fully on the musical aspects of the piece. It also allows me to isolate and rehearse short sections and to listen critically to the system output, activities that were not practically feasible with the original equipment. Therefore, from a performance practice standpoint, the new implementation represents a marked improvement over the original. My performance software is still under development, but I am hopeful that it can be made available soon for public distribution.

3.4. Cort Lippe's Music for Clarinet and ISPW

Cort Lippe composed *Music for Clarinet and ISPW* at IRCAM, Paris and at the Center for Computer Music and Computer Technology, Kunitachi College of Music in Tokyo, Japan, where it was commissioned in 1991 (Lippe 1992). This piece was developed using Max-FTS software running on the IRCAM Signal Processing Workstation (ISPW), a real-time digital signal processing system (a forerunner of Max/MSP), hosted by a NeXT workstation computer (Lippe and Puckette 1991: 533). I included this work on my graduate recital in computer music at the Peabody Conservatory. Since neither the Peabody studios nor I had an ISPW system, the composer was kind enough to bring his own, set it up, and run it for my dress rehearsal and concert. Previous rehearsals had taken place with the composer at the Hiller Computer Music studios in Buffalo, NY. Since that time, ISPW/Max-FTS systems have fallen out of use, supplanted by their descendants, Pd, jMax and Max/MSP. In 1999, Lippe created a Max/MSP version of this piece, which became the primary source for my 2004 analysis (Wetzel 2004b: 118–47), summarised here. Because Max/MSP is a proprietary system (currently maintained by Cycling74), I am treating Lippe's current implementation as an 'obsolete' system, even though at present it is quite functional.

Lippe's interactive system is hugely complex, yet it can be broken down into basic components which can then be described in standard synthesis and audio signal processing terms. In general, the system consists of (i) a synthesis and signal processing instrument, (ii) a set of sound and control sources (pre-recorded samples and live input), (iii) a set of instructions (a 'cue list') and discrete algorithmic functions for controlling the system at specific points in the musical score, and (iv) a score-following system.

The synthesis and signal processing instrument is made up of eight discrete audio processing units: (i) a sample playback engine (with granular sampling functions), (ii) harmoniser, (iii) reverb, (iv) 'noise modulation' (a sort of randomised amplitude modulation), (v) frequency shifter, (vi) flange, (vii) frequency/amplitude modulation (a specialised application used to transform the live clarinet sound), and (viii) a spatialiser (controlling left-right placement of sound output within the stereo field). Each of these modules (before output to the spatialiser) may be combined in any order for compound effects. In my analysis of the various system components for this piece, I found that my prose was occasionally inadequate for explaining the intricacies of Lippe's signal processing routines. Therefore, I supplemented the text descriptions of each audio processing module with block diagrams, pseudo-code renderings of algorithmic processes, and mathematical equations where necessary. An example of one of my block diagrams is seen in Figure 5.

All electronic sounds in *Music for Clarinet and ISPW* are generated from the clarinet sound, either live or from a set of eight pre-recorded samples. The pre-recorded sounds are excerpts from the score that are stored on disk as ten-second sound files. The sampler manipulates these sound files using various playback techniques (variable speed, direction, granulation), and further transformations are achieved by complex signal processing. The live clarinet sound is also transformed at several points in the score, but is used primarily as a control source. Multiple system variables are controlled directly by clarinet pitch (as both MIDI note number and as continuous frequency in Hertz) and its continuous amplitude. In the original version, a score-following algorithm was used to progress the system through its list of score 'events', or system cue points. This system compared incoming note data against a stored version of the clarinet part in order to track with the player through a performance (Puckette and Lippe 1992). The composer's latest recommendation is to abandon this approach in favour of direct human intervention either by the performer on stage (via foot switch), or by an assistant at the computer console (Lippe 2003–2004).

The entire system is driven by the event list, which stores variable parameter values for each system event found in the score. When a cue point in the event list is triggered, a series of system variable changes is initiated. Parameter values for signal processing modules may be changed in this manner on the fly or algorithmic processes may be triggered with variable arguments set by the event list or via live input sources.

My 2004 analysis of Lippe's software system required some thirty pages of text and two lengthy appendices of block diagrams and tables to adequately explain. I have not as yet attempted a new realisation of this piece, but I plan to do so in the near future. I hope that my detailed analysis would be sufficient to guide another performer to a realisation that is extremely close in function and effect to the original, even if the original version or its creators are no longer available. Lippe's software is still current as of this writing, and it is quite usable for performance. I would argue that even though it may not seem absolutely necessary (and is indeed somewhat

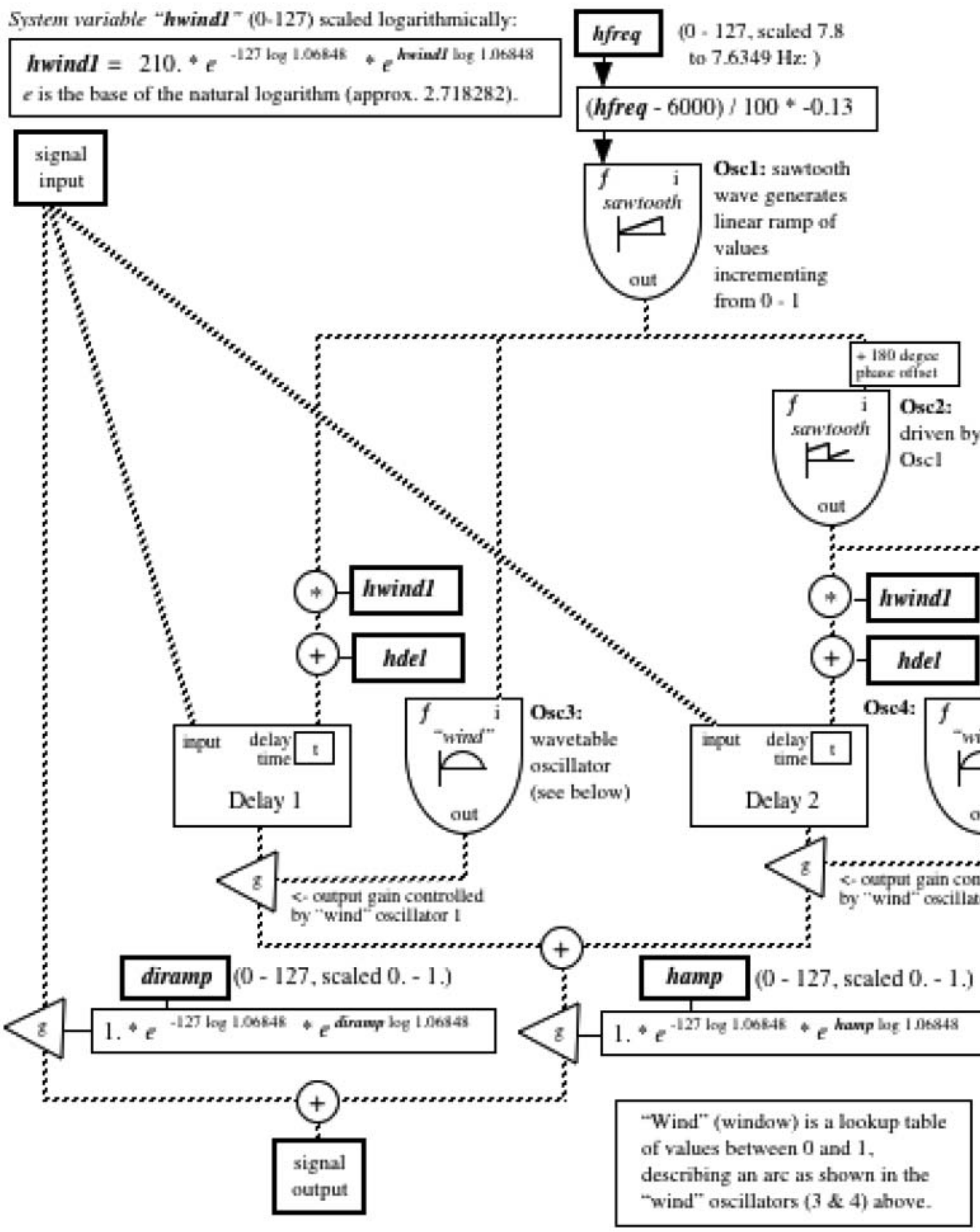

Figure 5. Block diagram of Cort Lippe's Harmoniser used in *Music for Clarinet and ISPW* (1992). Two delay lines are set in parallel with delay time increased at a constant linear rate (from its base delay time, *hdel*, to an offset, *hwind1*). Delays are synchronised by osc1, but delay time increments are out of phase by 180 degrees. Amplitude window ('wind' oscillators) controls envelope for delay output, cross-fading between the two delay lines. The effect is the pitch-shift that results from changing a delay time, used instead to alter playback speed without affecting duration.

daunting), now is actually the perfect time to attempt such an experiment, since a working version of the composer's software and the composer himself are still available for consultation. A reconstruction for alternate technology at this time is therefore perhaps the only way to test the validity of my analysis and correct any errors that may exist in it. It would be especially interesting to see what results might be obtained by another researcher working with only my analysis and a printed score. A realisation of this work using one of the open-source systems closely related to Max/MSP (pd or jMax) may offer some additional insulation against technological obsolescence, at least in terms of preservation of its underlying computer code. However, my concern is more with preservation of the composer's musical intentions for the piece. I do not believe that simply recompiling software for alternate systems is sufficient, since in my opinion it is the renewal of a work through fresh interpretation that keeps it alive and interesting. On a more practical level, an understanding of how to implement a work in the absence of the source code is potentially more useful in the event of the emergence of future technologies that may make a simple software port problematic or impossible.

4. IMPLICATIONS

The model for analysis I have presented here seems to be a natural reaction to the state of computer music today, since I am clearly not the only performer-researcher to stumble upon a similar need for preservation of electronic music by freeing it from its original technology. Regarding the need to conserve our 'electronic musical heritage', Carezza and Vidolin had this to say about interactive electronic works:

> The patches must be documented in an abstract form or in other terms in an independent manner by the system used, since the machines have an extremely brief life.
>
> The values assumed by the patches parameters must not be documented in a unit of measurement of a particular system but in a standard unit. In this way they can easily be transferred from one system to another. (Carezza and Vidolin 2001: 290)

My work, therefore, seems to be a response to this call to action. In fact, I arrived at the same solution by another route: from the entirely practical problem of finding accessible repertoire for my instrument, and from the frustration that arose when trying to assemble a half-dozen specialised systems for a single concert. In this regard, again, I am not alone. Increasingly, performers are taking matters into their own hands when it comes to creating practical realisations of existing interactive electroacoustic works. Percussionist Robert Esler (2004) has created a new realisation of Phillipe Boesmans' *Daydreams* using Max/MSP, considerably streamlining the technical requirements in the process. Christopher Burns (2002, 2004) has created new realisations of classic electronic works by Lucier, Stockhausen, and Cage (using Max/MSP and Pd). Likewise Joel Chadabe (2001) has created new realisations of works by Cage and Tudor (using Kyma and SuperCollider). Benny Sluchin (2000), working at IRCAM, developed realisations of Stockhausen's *Solo* using Max-FTS (ISPW/NeXT system), and later with Max/MSP (Macintosh). Miller Puckette (2001) led a group of researchers at the University of California, San Diego in creating a series of 'reference realisations' (in Pd) of works by Stockhausen, Manoury, Boulez, and Saariaho. Surely there are many more similar efforts being made on the part of technically savvy performers too numerous to mention. Perhaps it is time to begin organising the broader community of performers involved in this activity.

If an organised effort at conserving interactive electroacoustic works were initiated, what form would it take? We are certainly in a precarious situation with the sheer quantity of material that requires attention. As Canazza and Vidolin presciently point out:

> It may seem absurd, but today, as we finally are able to record and memorise almost all sounds, gestures, images and sequences, and are therefore able to deliver more information to the future nowadays than in the past, we discover that the conservation of this enormous data quantity constitutes a very serious problem. That cannot be realised by the individual but must be done by an institutional structure equipped with funds and specialised personnel. That makes our society much more vulnerable than its precedents, because a catastrophic event or a period of long recession that stops the preservation activity could delete many years of Music History. (Canazza and Vidolin 2001: 289)

An institutional response indeed seems necessary. At the same time, the very technology that forces this situation upon us also places tremendous power in the hands of individuals. I believe that it is time for performer/specialists to take the lead in developing a viable electroacoustic repertoire. We seem to be at a point where the technology has matured sufficiently to allow the music to finally leave it behind. Progress, however, will depend on the efforts of dedicated and insightful musicians who have the combination of technical skills and musical judgement to rescue one work at a time from technological oblivion.

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