Interconnecting forms of expressivity as a compositional process: the evolution of an interactive practice with specific reference to the Bodycoder System.

Mark A Bokowiec

A Portfolio of original compositions and commentary submitted to
The University of Huddersfield in partial fulfilment of the
Requirements for the Doctor of Philosophy

January 2011

Interconnecting forms of expressivity as a compositional process: the evolution of an interactive practice with specific reference to the Bodycoder System.

Abstract

The main focus of this commentary is the examination of the *Vox Circuit Trilogy* (2007) consisting of *The Suicided Voice* (2003/2007*), Hand-to-Mouth* (2007) and *Etch* (2007). The innovative use of interactive technologies and the architecture of the Bodycoder System in terms of its software, hardware and human-computer interface will be examined.

Kinaesonics will be discussed in relation to the coding of real-time one-to-one mapping of sound to gesture and its expression in terms of hardware and software design. The compositional processes will be discussed, in particular: the use of performance simulations, workshop collaboration with the performer and the negotiation of creation, composition and performance in the final work. Rehearsal processes will be examined with particular reference to *The Suicided Voice.* The notion of expressivity will be interrogated and how four principle forms of expressivity are interconnected, modelled and realized to generate a totally integrated performance modality.

Contents

Works submitted:
The *Vox Circuit Trilogy: The Suicided Voice, Hand to Mouth, Etch.*
The Navigator (Interactive extracts)
Zero in the Bone
Lifting Bodies
Spiral Fiction (extract)

1. Introduction – Early Context

The early impetus for the development of the Bodycoder System was concerned with closing the gap between dance and electro-acoustic music performance through the use of interactive technology that facilitated a more immediate and intimate relationship between the movement of the body and the processing and articulation of electronic sound. This creative impulse stemmed from my long-standing collaboration with dancer Julie Wilson-Bokowiec. The drive toward a greater integration of dance and music through the use of interactive technology was at the time seen as a means by which we could more actively engage each others skills – mine as a composer and technologist and Wilsons's as a dancer with a classical music training. Moreover, it was our interest in the physicality inherent in both sound and movement that prompted discussions about how such physicalities could be conjoined and integrated in real-time. In terms of the physicality of sound I saw this as embodied in the design of the sound material itself: evident through the spectral evolution and spatialization of the sound and a result of the live manipulation of this in terms of processing and mixing which was central to my studio based compositional practice. How to conjoin the movement and manipulation of sound with the movement of the body became the premise of the work and, in retrospect, was a radical starting point that immediately set our work apart from other performance artists[1] who were beginning to explore the potential of interactive technologies to create dialogues between existing arts practices but who were not intentionally seeking the kind of intimate real-time integrations that would perhaps lead to new performance practices. This was not a consequence that we, at the start of our project, fully appreciated, although we acknowledged in our journal articles at the

[1] Some of whom will be discussed in more detail in the Context section of this commentary, see p. 15.

time the possibility that such work might, through practice and historical necessity, force us to look at new ways of working. Concerns that were expressed in a number of joint journal articles through the late 1990s:

> …with the collapse of geographic boundaries with the increased power of telecommunications and the internet…artists must begin to question whether it is within the spirit of the age to hang onto, and vigorously defend, their own art genre boundaries, or whether it would be more fruitful to relax their grip… and allow them to hybridise and perhaps give rise to other creative disciplines and forms… more appropriate mediums through which to articulate the concerns and creative impulses of the 21st century. [2]

The bringing together of the body and computer-bound processes inevitably threw up a number of technical challenges (more fully examined in the following sections of this commentary) and aesthetic problems. Early aesthetic concerns centred on the identification of an appropriate practice methodology (a means of making and collaborating), the identification of a language of interaction, and considerations as to how audiences might be introduced to and perceive interactive performance. Discussions within artistic and academic circles at the time were dominated by concerns for the status of individual art forms within interactive performance. These concerns, energetically discussed on social network sites such as the *Dance & Technology* Zone,[3] centred on the preservation of established arts practice and the outward aesthetics of dance and music. Much of the criticism levelled against early dance and technology work focused on the manner in which both dancers and choreography seemed to be constrained by the interaction with technology.[4] It was frequently noted that dancers were unable to dance freely while encumbered by

---

[2] Wilson-Bokowiec, J., and Bromwich, M. (1999). 'The Bodycoder System: Intensifying the Collaborative Process Through the Use of New Technology', in: Enders, B. & Stande-Elbe, J. (eds.) *Global Village – Global Brain – Global Music*, Osnabruck, Electronic Publishing, pp. 361-369

[3] http://art.net/~dtz/ accessed 5/2/10

[4] A similar kind of constraint was noted in the relationship between musicians and "first generation live (and 'mixed') electronics" who were "often severely disempowered. The electronics were pretty much in charge. It was common to hear the frustration of the live performer, straight-jacketed by a tape part, unable to hear the overall effect of the electronics and clearly unable to influence many aspects of the performance." Emmerson, S. (2007). *Living Electronic Music*. Ashgate Publishing Limited. Hampshire & Burlington VT. p. 95

technology or the responsibility to interact with it. The unsophisticated nature of available technologies at the time, particularly the limitations of 'wired' systems, justified some of the criticism. However, the overwhelming feeling within interactive dance performance was that the individual art forms were weakened and that practitioners were compromised by the use of technology. From a musical point of view, there was the added problem that dancers were not musicians and could therefore only be expected to control small and relatively superficial aspects of a sound composition. In most instances the dancer's live control of sound was confined to triggering pre-recorded or pre-defined music events. In more advanced interactive works the dancer's body was used as a site of data acquisition either from sensors generating data on the body or via off-the-body sensing such as video - the beauty of this being that dancers need not be aware of the data they were generating. Passive data acquisition meant that choreography could be freely executed and dancers could get on with dancing unencumbered and free from the responsibility of having to think about what they were interacting with. Such pieces looked, for all intents and purposes, like traditional dance works with an accompanying electronic sound score and in this respect communicated a confused or misleading performance aesthetic. Interactive dance and video works were more effective since the 'evidence' of the interaction, seen as visual effects, could be integrated into the overall stage picture. However, passive forms of dance and sound interaction seemed inane because an explicit physical language of interaction was missing from the outward performance aesthetic. This is not to say that early experiments, including our own, were not without value, since they did draw attention to the need for aesthetic innovation along side of advances in technology and performer skills.

Our co-authored journal articles throughout the 1990s document our concern for the development of a new interactive performance aesthetic that acknowledged that the innate qualities of technologies and the effect of interaction should figure strongly in any new aesthetic formulation.[5] Our growing discomfort with the use of a specifically contemporary dance vocabulary as the primary physical language through which interactive articulations were executed can also be traced through these early journal articles. My discontent growing from a lack of finite control that only seemed to be able to be attained when movement was constrained and Wilson-Bokowiec was able to more easily focus on the gestural manipulation of sound. Wilson-Bokowiec's frustration was in having to maintain a demonstrative level of dance proficiency in order not to sublimate the status of the dancer. At the same time Wilson-Bokowiec was asking for more finite control of sound, but the kind of focus required and type of physicality that such control demanded seem incompatible with an established contemporary dance vocabulary. In 1999 we took the decision to abandon the physical vocabulary of contemporary dance and seek instead a more fundamental vocabulary that arose directly out of qualities of physical interaction. Various early publications evidence our efforts to locate within the practice what might be identified as an authentic gestural language and a more holistic understanding of the physicality of our particular interactive system. Although we[6] persisted for a number of years in the use of a contemporary dance vocabulary, it was decided that only by taking the radical and brave decision to abandon completely this type of movement vocabulary could we begin to find a language that was specific to the type of interaction

[5] Wilson, J., and Bromwich, M. (2000). 'Lifting Bodies: Interactive Dance – Finding New Methodologies in the Motifs Prompted by New Technology – A Critique and Progress Report with Particular Reference to the Bodycoder System', in: Landy, L. (eds.) *Organised Sound*, 5:1, pp. 9-16

[6] During this period Wilson-Bokowiec's role was as choreographer and dancer whilst my role has always been as composer and technologist. In later years Wilson-Bokowiec's role would expand to include the design of visual content and telematic elements in works such as *Spiral Fiction* and later the *Vox Circuit Trilogy.*

embodied and specific to the sound composition and system configurations. Moving away from a pre-conceived dance vocabulary removed the responsibility to choreograph and operate (if only partially) within a dance aesthetic. In terms of creating a new work, we also took the decision not to place sensors on the lower limbs (the lower torso and legs) thereby relinquishing the need to 'travel' the body. The next work created outside of a dance aesthetic would be stationery with the gestural vocabulary situated in the upper torso. Such a radical re-think of the practice also gave me time to implement a number of technical upgrades and developments to the Bodycoder System. It also provided me with an opportunity to explore the range of Wilson-Bokowiec's vocal expertise and the possibility of developing an entirely live and acoustic piece (in terms of vocal input) that would ultimately result in the *Vox Circuit Trilogy*.

2. Early Compositional Influences and Practice

As a qualified electrical engineer, my early experiments with electronic music were firmly rooted in a hands-on approach to building simple sound generators and signal processors using analogue technologies. Working with discrete components from transistors to the early 74x family of operational amplifiers, my early sound compositions were the products of the technology that I was constructing. This included the construction of synthesiser circuits following the recently discovered principles of analogue voltage control.[7] As a composer my sonic preferences have been shaped primarily by my interest in sound processing and the mixing and layering of evolving soundscapes as opposed to the construction of melody. In my early practice I used custom-built technology in combination with tape techniques such as looping and live sampling on two-track Revox machines to create multiphonic layers of sounds.[8] I became interested not only in pure electronically generated sound, but also in how natural sounds subjected to processing and re-processing evolve and can be layered slowly over time to create dynamic and dimensional soundscapes. My early interest in durational sound processing has informed my current practice and thinking particularly in relation to sonic expressivity: as the physical movement of

[7] The use of voltage control was pioneered by designers such as Peter Zinovieff who formed EMS in Putney, East London, producing formative designs such as the EMS VCSIII and AKS synthesisers. Voltage control was a reliable and repeatable method of accurately controlling the modular elements intrinsic in an electronic music synthesiser, these elements would generally consist of one or more voltage controlled oscillators, a voltage controlled filter and one or more voltage controlled amplifiers. Zinovieff employed pin-matrix patching on his designs so enabling signal and voltage control routings to be achieved simply by the insertion of pins into a small matrix board. The use of this type of audio and control patching meant that a wide range of possible timbres and sounds could be produced. It was this possibility of being able to produce authentic and original sounds that convinced me to purchase the components to construct an early voltage controlled synthesiser.

[8] The Revox G36 valve stereo tape machine had a sound-on-sound facility that allowed a user to record on to one of the stereo channels and then combine this 'live' with a source recorded on to the adjacent channel. This recording could be mixed and 'bounced' to the first track whilst re-recording onto the second track. This could be done several times but levels had to be carefully monitored as a build up of noise was unavoidable as the process was repeated.

sound through timbral evolution and various forms of spatialisation. In my compositions it is the transition and transformation of sound that is in itself considered expressive.

When I began composing in the late 1970's there were a small number of left-field bands that were beginning to explore the potential of analogue technology such as *Can* and *Hawkwind.*[9] Holger Czukay,[10] a founding member of *Can,* used banks of oscillators, UHF radio receivers and 8 track tape players to create sound collages combined with an early form of 'live' sound sampling.[11] In my own experiments I used two Revox tape recorders set to operate as a record/playback pair so that variable delays could be used to process live instruments. I discovered that by carefully controlling the signal from the playback machine, fed back to the recording machine, long echoes could be built up from the live material. Robert Fripp famously exploited this technique to process his live guitar, Brian Eno and friends later dubbed this as *Frippertronics.*[12] The technique, carefully used, could result in quite beautiful, slow evolving textures and was an ideal structural platform over which to extemporise with other more virtuoso sounds. This remains a favourite compositional structure that I frequently use both in my later electro-acoustic music pieces and in works for the Bodycoder System, particularly the *Vox Circuit Trilogy.*[13]

---

[9] *Hawkwind's* debut album release *Hawkwind* (1970), where the track: *'Seeing It as You Really Are'* featured processed voices using echo, reverberation and sweeping oscillators.

[10] Holger Czukay studied with Stockhausen from 1963 to 1966. Czukay used tape processing techniques that he learnt whilst studying and working at Stockhausens' studio - West Deutscher Rundfunk. *Cans'* first album release *Monster Movie* (1970) was recorded at Stockhausens' studio. Schmidt and Czukay had first met while studying with Stockhausen, both were classically trained musicians who wanted to 'break away' from the conventions of traditional ways of making music.

[11] See 'Aumgm' from *Tago Mago* (1971) that features the use of tape echo on instruments, the use of bowed bass and heavily processed vocals. 'Oh Yeah' also from *Tago Mago* that features reversed vocals and cymbals.

[12] *Electronic and Experimental Music: Technology, Music, and Culture*, Thom Holmes Taylor & Francis, 2008, p. 133

[13] This process can readily be heard in 'Etch' and described in Appendix B, p. 51.

In the mid 1970s it was extremely expensive to purchase sound processors, but there were a growing number of published DIY designs available in monthly journals such as *Practical Electronics*. Electronic components were relatively affordable and I had the practical skills to be able to construct various electronic sound processors such as phasors, filters, distortion units and also to construct sound generators such as variable frequency oscillators, and an early Theremin. What is important (for this commentary) is that most of these custom-built devices were in essence simple controllers with knobs and faders that afforded a level of expressive real-time control.

Few experimental bands of that period could be said to be more characterised by a particular piece of technology than *Throbbing Gristle* (1979-1981)[14] who routinely fed a portion of their live sound through what they affectionately refer to as their *Gristlizer* – an amplitude modulator and variable filter built by Chris Carter, a founding member of the group, from a design sourced in *Practical Electronics.*[15] Custom-built effects units were notoriously 'individual', indeed it was not uncommon for designs sourced in popular electronics magazines not to work as expected (due to publishing mistakes or variation in the quality of components). As a result these early processing devices were frequently one-offs, something that, in my view, made them more interesting. I often augmented published circuitry to make a basic unit more flexible in terms of user control such as adding a substantial modulation section to an early analogue delay line, employing five different low frequency oscillators and a

[14] *Throbbing Gristle* used conventional instruments played in non-conventional ways combined with hand built effect units made by Peter Christopherson and Chris Carter who also played banks of 8 track cassette players that had been customised to enable the triggering of tracks from a home built keyboard.

[15] In 1997 I was invited by Genesis P-Orridge to build a *Gristlizer* to replace the original TG one that had been lost in a house fire. Even though it was built to the same design P-Orridge commented that it "didn't sound the same."

randomization function. Similarly adding an amplitude modulator and state variable filter to a basic distortion module. This was an early form of *circuit bending* long before the term became fashionable. This ability to 'tweak', enhance and modify analogue designs - an important part of my early practice - has been carried into my approach to sound processing in my digital practice particularly with the Bodycoder System.

In terms of my own work with live bands, I experimented with the use of hardware oscillators designed for electronic testing in laboratory settings.[16] Oscillators with external input connections could be controlled by a second variable frequency oscillator to produce frequency and amplitude modulation resulting in interesting timbres.[17] By controlling the waveform shape, strength and frequency of this external modulation, combined with additional processing such as an analogue delay unit produced some unique sounding textures that I began to use in live performance with bands such as *Counterdance* (1978 - 1981).[18]

At this time music synthesisers were in their infancy and were extremely expensive so I investigated a newly published design for a small, stylus-operated synthesiser based on a sound 'chip' that had just become available and used in 8 bit microcomputers such as the Commodore 64. The integrated circuit had an oscillator, a low frequency oscillator, a white noise generator and a flexible way of cross modulation via hardware switches - this was a cost effective way into the world of generative multi-timbral synthesis. I designed a multi-channel interface for this unit so that I could use

[16] From 1977 - 1979 I worked in the University of Leeds sound research lab in the Department of Psychology.
[17] I later discovered on a visit to the BBC Radiophonic Workshop that resident composer Paddy Kingsland used a similar setup in his studio.
[18] www.myspace.com/counterdance - accessed 17/12/10

it with a custom built drum machine to work as a rudimentary eight-note step sequencer. By using the drum machine, sequencer interface and the small monophonic synthesiser I could automate backing sound sequences and percussion – there were no personal computer music systems available at this time and commercial synthesisers with sequencers were only just appearing on the commercial market. My studio set-up at that time was an integrated hybrid environment that included both analogue and fledgling digital technologies. Tape was still the only recording medium so analogue tape machines remained central to my studio practice. Sound processing, by necessity, was real-time which meant that composition was hands-on (the pragmatic manipulation of tape, switches, faders etc.) and 'live' which added a certain level of risk and a heightening of focus that made the act of composition feel like a high-stakes activity. The studio, in essence, functioned as both an instrument and performance environment – an idea that was proposed as early as the 1940s by Pierre Schaeffer in describing his own practice in his then pre-tape *musique concrète* studio.[19] In *Living Electronic Music* Simon Emmerson describes a particular approach to studio-based composition that could be said to be characteristic of early tape-based and *musique concrète* practice observing:

> in effect one rehearses *actions* which produce the right *perceptions.* The finished work instantiates an idealized *performance* – only one which did not happen at one particular time.[20]

This very clearly draws a distinction between the approaches adopted by such composers as Denis Smalley, Trevor Wishart and Jonathan Harvey[21] for whom studio based composition is a meticulous process of manipulating a small range of sound

[19] Emmerson, S. (2007). *Living Electronic Music*. Ashgate Publishing Limited. Hampshire & Burlington VT. p. 25
[20] Ibid, p. 26
[21] All of who were highly influential figures in terms of my own education as an electro-acoustic composer (see Discography)

sources, subjecting these to particular processes, rehearsing and refining before committing finally to tape.[22] While artist collectives such as *Can* and *Hawkwind* worked in real-time and committed to tape as they were performing and interacting with live processes in the studio. For them improvisation and the possibilities of performance producing chance sonic events were integral to their live compositional practice. This is an important distinction, although to a certain extent it is hypothetical since most composers did not strictly conform to an *either/or* of live or pre-composed construction in terms of analogue studio practice. Both approaches were formative in terms of my own studio practice. Meticulously constructing sounds using tape-techniques (similar to those utilised by Smalley and Wishart) to create a number of tape loops running on several machines, I would then mix these in real-time while subjecting them to live processing such as pitch change (using multiple vari-speed controllers[23]) filtering, spring reverberation, distortion, ring modulation, and analogue delay using a range of custom-built processing units. The results were committed to a master tape without further editing. This way of working was highly performative in terms of the nature and status, within the creative process, of real-time physical control – a characteristic of the analogue studio noted by Simon Emmerson:

> In an analogue studio the operation of tape machines and mixing desk faders required physical movement over a footprint up to the size of the studio itself. [24]

The primacy of the physical associated with work within the analogue studio, and my continuing interest as a composer in working with audio processing and the construction of compositions using real-time processing of live (or pre-composed)

---

[22] Denis Smalley has described this in the programme note to *Wind Chimes* (1987) as "taking a single sound source and getting as much out of it as possible has always been one of my key methods for developing sonic coherence in a piece." in *Computer Music Currents 5* (1990), CD, Wergo WER 2025

[23] I also employed customized variable speed controllers that enabled multiple tape machines to be controlled individually or synchronized together in various combinations.

[24] Emmerson, S. (2007). *Living Electronic Music*. Ashgate Publishing Limited. Hampshire & Burlington VT. p. 26

material, has been carried forward into my practice with the Bodycoder System. While as Emmerson suggests, the movement from analogue to digital has reduced the size of the studio to:

> a footprint the size of a qwerty keyboard and mouse mat, possibly retaining fader and other accessory input control. Hence any residual idea of 'physical' performance is severely constrained.[25]

In terms of my own practice, working within the digital domain has facilitated access to more finite levels of audio processing which has allowed a greater degree of controlled expressivity across a broader array of active processes. While I have retained my taste for classical analogue forms of audio processing. I have also held onto the primacy of the real-time in my compositions for the Bodycoder System. Real-time processes can be customised and tuned to a much higher degree within a Max/MSP environment. Further, qualities of audio processing, released from hardware constraints, become more flexible and distinct entities that can be programmed as unique forms of expressivity. More importantly, the primacy of the physical (a fundamental mode of performative operation within the analogue studio) has not been reduced, but retained in my current practice: encoded as programmed and sonic expression within Max/MSP and embodied as explicit gestural (kineasonic) expressivity.

---

[25] Ibid., p. 26

3. Contextualising the Bodycoder System

There are many artists today working in the field of live interactive composition and performance, however, there are comparatively few artist/composers who are working in the field of 'on-the-body' sensor systems and mechanisms. This section will therefore concentrate on looking at the work and systems of artists who are most closely related to my work with the Bodycoder System.

At the time of the initial development of the Bodycoder system there were three active artists/composers of whom I was aware that had developed sensor mechanisms that enabled on-the-body control and manipulation of audio processes. These practitioners were:

- Mark Conglio and the *MIDI Dancer*
- Michael Waisvisz and his *Hands* interface
- Wayne Siegel and Jens Jacobsen and the DIEM *Digital Dance System*

Further developments in the field include:

- The *Mimburi* system developed by the Yamaha Corporation in 1994.
- The *BodySynth* created by Ed Severinghaus and Chris Van Raalte, notably used by composer/performer Pamela Z.

I will look at these systems in order to locate my own technical and compositional developments in this emergent field of interactive art practice.

3.1 MIDI Dancer

Mark Conglio and his partner Dawn Stoppiello formed their dance company, Troika Ranch in 1994, pioneering work in the field of dance and new technology. The first *MidiDancer* system was built whilst Conglio and Stoppiello were both students at the California Institute of the Arts. Regarding the development, Stoppiello states:

> The first MidiDancer system was built for a collaborative project at CalArts in which Mark and I took part. The original device was quite primitive. It was made from radio controlled car transmitters. Attached to each transmitter were two sensors in the form of metal levers that we taped (at the loss of much body hair) to our arms and legs. Each sensor measured the flexion of a joint, and sent that information via the radio transmitter to a computer where it could be used to control music synthesizers.
>
> The piece we made was for four performers, each of whom was wearing two sensors, one on the elbow and one on the knee (four individual MidiDancer systems in all). The idea was to give each dancer two sounds to control, one on each sensor, that would stay the same during the course of the piece. Our hope in keeping this fixed relationship was to create a kind of sonic identity for each dancer that the audience could recognize. After creating material separately, we came together to work with the dancers and quickly realized that this one to one relationship, one gesture producing one (and only one) sound, did not make for a rich composition either as dance or music. We came to call this technique the "bleep-bloop" method, as this is all that the first attempt ended up being, i.e., a series of bleeps and bloops in conjunction with the robotic choreography required to trigger the system. We were disappointed that the piece lacked the kind of complexity and subtlety that we had envisioned and knew right away that we were going to have to try again.[26]

Conglio and Stoppellio were embarked on a parallel research path, a couple working together and collaborating to produce dance pieces using technology to enable new forms of artistic expression. The experimentation with radio-controlled car transmitters mirrored my initial experimentation with radio controlled aircraft transmitters and receivers. In fact the mention of taping metal levers to body parts paralleled my early experimentation with using model aircraft servomechanisms as sensor elements, however, these were seen as too intrusive and basically unworkable in practice.

Conglio and Stoppellio were not using real-time processing of audio but they were

[26] http://www.troikaranch.org/pubs/FleshMotor_MIT_Press.pdf accessed 05/02/10

simply triggering preset sounds via MIDI sound modules requiring little, if any, musicianship from the performer. Triggering sounds in this way makes it possible for choreographic actions to be 'tagged' to the sound itself so therefore no deep interaction with the audio is required. A keen sense of timing is, however, required of the dancer but there is no sense of interacting within an electro-acoustic process or aesthetic. Performances using the *MidiDancer* system tend to inhabit the area of Music Theatre, a most important aspect being the integration of telematics in to the repertoire of the company using multiple video cameras and displays.

Conglio went on to develop a more refined, eight-channel system which used flexion sensors to transmit joint flex information to a host receiver, generating MIDI data as the interface protocol. At this time, a seminal piece that used the *MidiDancer* system was *In Plane* (1994) - a piece for solo dancer and Laser Disc player in which the performer controlled the playback of pre-recorded footage of Stoppellio's dancing, stored on the video disk and responding to information sent via the *MidiDancer* system. Talking about *In Plane* Stoppiello states:

> On a technical level, we wanted my gestures to control the musical score, the playback of images from a LaserDisc, the movement of a robotic video-projector, and the theatrical lighting for the piece. We realized that this was ambitious, but we wanted to see how far we could go. We wanted to find out how much one performer could play. We began our work by collaborating on choreographic and musical materials that echoed the traits of the two bodies. The music, representing the electronic, was comprised solely of sampled sounds of machines while the choreography, clearly representing the corporeal side of the equation, was constructed from a fundamentally human movement vocabulary consisting of running, jumping, falling, and rolling.[27]

This concept of having one person in total control of all aspects of the performance was strikingly similar to the original concept of my music theatre piece *The Navigator* (see p. 38 of this commentary). The *Navigator* (1995) featured a sensitized

---

[27] Ibid., p. 4

performance space and not an on-the-body system. However, this model was to become a defining requisite for all future pieces conceived and subsequently written for the Bodycoder System.

Conglio and Stoppellio continue to write and perform and occasionally use the *MidiDancer* as an interface element but the company has since focused on using video and robotics rather than music as the main interactive elements in their performances. Conglio employs the software program, *Isadora*[28] as the controlling package to interface with MIDI/OSC hardware and computer systems - in particular digital video playback and control.

Of course real-time control of computer-generated and manipulated video graphics has been an important element in a high percentage of pieces written for the Bodycoder System. From the early days of working as beta-testers for the XPose system we have strived to find an equal dialogue between audio/video processes, however, the use of projected visuals has not been a primary focus in the creation of pieces for the Bodycoder System. Indeed I would consider that this is a main departure from similarities between the two systems in that my work has been predominately concerned with sound, in particular controlling the texture/timbre of the sound produced in performance, whether the sound is being generated acoustically, as with the voice in the *Vox Circuit Trilogy* (2007) or being generated electronically, as for example in *Lifting Bodies* (1999). In addition, although Conglio and I both collaborate closely and intensively with our respective partners, the work I create for Wilson-Bokowiec takes into consideration the fact that she is a highly

[28] Isadora: a graphic programming environment created and written by Mark Conglio for real-time manipulation of digital video.

trained musician as well as a dancer/choreographer. I believe that having a strong musical perspective and being able to interact intimately with increased sensitivity to real-time audio processing is what uniquely positions my work in this field. The concept of the on-line/off-line[29] practice, enabling facilitation of complex navigational structures whilst being able to control finite timbral and aural processes, further locates my work in a unique position in this field of interactive art.

3.2 The Hands

Although Michel Waisvisz's *Hands* (1984) is not strictly a full body control mechanism it is important to mention it in this commentary for two reasons. Firstly that my piece *Hand to Mouth* (2007) was written to use only the hands of the performer as the controlling elements and secondly that Waisvisz has performed pieces using only the voice as the sound source material.

The Hands project was created at STEIM[30] and was the result of a major collaboration by staff members at the institute working both on the hardware mechanics and the software resident in the Sensor Lab interface.[31]

The mechanical construction of Waivisz's system changed over the years as sensor technology developed in line with new developments in software architectures. However, the sensor hardware has always integrated tactile and non-tactile elements into the physical construct. Ultrasonic transducers have been the mainstay of the non-tactile elements of the system with a transmitter being situated on one hand and its

[29] The ability of the performer to physically select which sensor elements are enabled/disabled, i.e. 'on-line'/'off-line', is described in Appendix A, p. 19.
[30] STEIM - the Studio for Electro-Instrumental Music based in Amsterdam.
[31] Sensor Lab – a wired analogue sensor to MIDI interface developed at STEIM in 1981 using 'SPIDER' - a custom designed programming language running on a Macintosh computer.

corresponding receiver element being located on the other hand. This enables a large range of expressive control by simply moving each hand closer or further away from each other but it does mean that the hands do have to operate in the same physical plane. The other primary non-tactile sensors used on *The Hands* are mercury 'tilt' switches that simply enable a pair of switch contacts to be activated when *The Hands* are tilted or raised above a certain angle. Finger switches and bend sensors feature as the tactile elements in the *Hands* system both enabling utilitarian functionality and expressive control respectively, but the system has always remained as a 'tethered' interface, relying on the cable connection between the Sensor Lab interface and the receiving hardware hosts. This is obviously quite unlike the Bodycoder System in which one of the main premises was that the performer had to be free from any physical constraints to a particular location. *The Hands* can be more readily regarded as an '*instrument'* compared with the Bodycoder System as a 'system' due to the fact that the sensor architecture is fixed and cannot be re-configured without major work on the physical hardware. [32] Conversely the Bodycoder System is uniquely flexible in the way that sensors can be utilized, in any combination, to any bend area of the body, such as torso, knee, elbow neck, wrist, ankle and finger. Also, the Bodycoder System can comprise any combination of switched and/or bend sensor elements simply by connecting these elements to its custom sensor interface module.

Waisvisz does, in fact, refer to *The Hands* as an 'Instrument*'* and explaining the premise for its origin he states:

> MIDI suddenly allowed me to think of mini-keyboards, fitted to my hands and littered with various movement sensors to translate hand, arm and finger movements immediately into sounds. It would make it possible to trigger and manipulate sounds, but also to conduct streams of sounds. Also I would be able to walk, move and even

[32] The use of 'system' and not 'instrument' is explained on p. 52 of this commentary.

> dance while making electronic music. This was such a liberating prospect after having had to work with big chunks of unmovable analog electronica tied up in the early electronic music studios. Also I experienced that the early synthesizers didn't bring the real grip of electronic sound. Beautiful promising electronic sound worlds were hidden in these instruments, but fitted with traditional organ/piano keyboards they seemed better suited for melodic music than for 'sound-music'. At that time I was on a quest to create electronic music in it's purest sense. With it's own sonic rules and a narrative purely expressed through sequences of flow, rhythm and sound. What was needed was an instrument that would allow you to 'touch' sound. I wanted to operate, navigate, compose, mold and play sound in a sensible, refined and even sensual and groovy way! Something that was, at that time, not associated with electronic music at all![33]

This is an interesting quotation and sits closely with my original ideas of enabling a performer to have total utilitarian and expressive control over all aspects of an electro-acoustic performance but in my case this was to include dance, music theatre, instrumental and vocal performances.

Waisvisz was fortunate to be able to draw on the expertise of the staff working at STEIM and indeed it is doubtful whether the instrument could have originated without the input of colleagues resident at the institute, particularly Johan den Biggelaar who designed the prototype instrument and Bert Bongers who, with Waisvisz, designed and built the final version of the instrument. In terms of performance software, Waisvisz was again fortunate to be able to draw on the design expertise of staff working at STEIM such as Frank Balde and Tom Demeyer.

Balde designed the software code for The Sensor Lab interface as well as the code for The *Lick Machine* that Waisvisz used extensively in his work to enable triggering and real-time control of preset sequences of MIDI events. *LiSa*, another piece of software developed at STEIM and used extensively by Waisvisz, enabled the user to sample live audio into a computer’s memory and access variable portions of the sample in different ways. This highly specialized performance software was an ideal tool with

---

[33] http://www.crackle.org/TheHands.htm accessed 05/02/10

which Waisvisz could create dynamic real-time sample based material based on any live input source including his own voice. Of course this type of software can now be written using Max/MSP but the close integration with the Sensor Lab ensured that compositions based on this software could be realized in quite short periods of time. Although Waisvisz's *Hands* is limited in its being physically 'bound' to a location and its reliance on using MIDI it can nevertheless be seen as an extremely performative instrument and, in the hands of its originator, capable of producing works of great import and of musical interest.

3.3 Wayne Siegel and Jens Jacobsen and the DIEM Digital Dance system

In 1997, working at the Danish Institute for Electroacoustic Music, Wayne Siegel headed a project to create a radio sensor interface for 'digital dance'. In their 1998, co-authored paper, *'The Challenges of Interactive dance: An Overview and Case Study'*[34] Siegel and electronics engineer, Jens Jacobsen describe their system in detail and also look at pieces specifically written for the system. Due to the physical similarities between the Bodycoder System and the DIEM DDS it is therefore useful to interrogate this paper in order to locate the two systems in their historical context, particularly as the works created for the Bodycoder System in 1997 used a dance vocabulary.

The DIEM Digital Dance System consists of a sixteen channel, body-worn sensor interface using a standard, European licence exempt frequency with an indoor range of up to thirty metres. The receiver unit translates a PCM signal into MIDI information as fixed controller data, i.e. controller numbers 71 – 86 on MIDI channel

[34] Siegel, W., and Jacobsen, J. (1998). 'The Challenges of Interactive Dance: An Overview and Case Study' in *Computer Music Journal 22, No. 4*, pp. 29-43.

1. Bend sensors are used as the sensor elements that are effectively 'live' whilst the system is in operation. As the gating of sensor signals has to be controlled by the host software, this action removes a primary level of control from the performer. This suggests a number of questions: firstly, is the performer incapable of taking primary control of the system and secondly, is the composer unwilling to relinquish full control of his composition to the performer? In either case one has to ask why is the work being realised in this way? For me, the practice of on-line / off-line working is a fundamental tenet of my practice with the Bodycoder System and affirms the real-time nature of the work.

In their chapter headed 'Mapping Motion to Music' Siegel and Jacobsen state that:

> generally speaking, extremely simple mappings tend to be immediately understood by the observer, but are considered trivial.[35]

I have to disagree with this statement. Is the bending of a note played on a violin by expressively deflecting a string trivial? Why should there not be an immediate and identifiable correlation between cause and effect in interactive performance practice? There has always been a dichotomy of aesthetic viewpoints on this subject but my practice has fundamentally been about enabling absolute control for the artist and ensuring that gestural expressivity is totally visible.

In Siegel's *Movement Study II* the authors explain that in the first section of the piece:

> The first section of the piece gives the dancer direct control of two very perceptible parameters: volume and brightness. However the dancer does not make choices related to pitch or rhythm. This gives the dancer a certain amount of freedom of movement as well as expressive control of the music, without requiring excessive concentration on instrumental performance.[36]

[35] Ibid., p. 31
[36] Ibid., p. 37

In each dance piece written for the Bodycoder System it has been an absolute requirement that the performer is focussed on every aspect of the compositional and musical process and has the physical and mental dexterity to take musical and choreographic decisions as each piece evolves. An acute aural awareness and sensitivity to changes in the compositional structure must be retained for the duration of each performance. For example, if a sensor was to miss-trigger a patch-change the performer should be able instantly to recognise this and be able to navigate to the correct part of the piece. Working intensively and collaboratively with my partner as choreographer, dancer and musician guarantees that there is a fluid integration in pieces created for the Bodycoder System. This ensures a focus of energy and concentration enabling the creation of authentic and expressive work.

There are many ways in which a composer can integrate and codify movement to audio and compositional processes.

In *Movement Study II* (1996) Siegel and Jacobsen go on to state:

> The harmonic structure is determined by a set of simple compositional rules. There are seven subsections, each with a different set of harmonic structures or pitch aggregates. In any one subsection for any one voice there are a limited number of pitches (usually two to six) that might be chosen, but only one note per voice will be played at any time. Choices within these aggregates are made according to a set of predefined probabilities for the occurrence of each possible pitch. The choices made by the compositional software are thus narrowly limited random choices. On the one hand, no one can predict exactly which pitches will be played at any given moment within a particular subsection; but on the other hand, it is certain that the pitches chosen will lie within the harmonic structure defined for that subsection. The makeup of these seven harmonic structures cannot be influenced by the dancer. The dancer, can however, influence the pace at which the piece progresses through the seven subsections before finally reaching the second section.[37]

Siegel and Jacobsen go on to explain how the dancer can influence the pace of this progression:

[37] Ibid., p. 37

> Progression from one subsection to the next is based on the number of new note events triggered by the dancer. The more often the dancer's limbs are placed in the closed position, the faster the work progresses to the next subsection. If a limb is never completely closed, the voice associated with that limb will remain within the current subsection, allowing the dancer to manipulate the volume and brightness of only a single pitch. It is, for example, possible for the voice associated with the right elbow to remain in subsection 1, while the left knee has reached subsection 2, and the right ankle has reached subsection 5. This would mean that the pitches chosen by these various voices would not lie within a single harmonic structure. This incongruity will be corrected by software in the course of the performance.[38]

As can be seen from this statement Siegel has written a piece that is not being totally controlled by the dancer. In fact I would go as far to say that the performer's role is more of a puppet dancing to a choreography which, although the computer enables parameters that can be affected by expressive functionality i.e. filtering and volume changes, the overall structure is fixed and immutable. Siegel and Jacobsen go on to state:

> To smooth unwanted abrupt changes in volume, a software lag function is applied to the sensor data in this section. Slow changes of angle are unaffected by this modification, whereas sudden changes of angle are slowed down slightly. This allows the dancer more freedom of movement without disrupting the musical idea.[39]

This statement clearly indicates an important difference between the design and implementation of the two systems. Firstly, the Bodycoder System enables the dancer/performer to select whether they are 'on-line' or 'off-line' with respect to sensor data transmission, and secondly, that as previously stated, it is a fundamental premise of the system that the performer remains in total control of all aspects of the musical and indeed visual structure of each work from start to finish. This is not the case in the DIEM system where solutions have to be found in software to restrict the data from the sensor elements in different ways, the performer being unable to take 'control' of the process, the prime concern being that the 'musical idea' does not get 'disrupted'.

---

[38] Ibid., p. 38
[39] Ibid., p. 38

In Siegel and Jacobsen's conclusion they state:

> Dancers are usually not musicians with specialized training in performing or interpreting a musical work. If a dancer is asked to perform as an instrumentalist in the context of a dance performance, the effort required to control the music may make it difficult or impossible for the dancer to concentrate on dancing.[40]

The expressive interpretation of music is, most definitely, part of the craft of dance although dancers are not normally required to also be musicians. Music and rhythm is present in all aspects of a dancers training, indeed I have sought to exploit this synergy of expressivity in the interdisciplinary works I have created for the Bodycoder System.

In Siegel's *Sisters* (1998) for dance and Digital Dance Interface the choreography was created first with the composition created to fit the choreography.

In explaining the piece Siegel states:

> The music composition was created for two dancers and interactive computer music system. Both dancers wear a DIEM Digital Dance interface with bending sensors on their elbows and knees. About fifty sound files are loaded into the computer's random-access memory (RAM), and these sound files are played back in various ways and altered in real time using comb filter and resonance filter algorithms. The dancers control playback and filter parameters in various ways during the course of the piece.[41]

Fitting a piece of interactive composition to existing choreography is, of course, an entirely valid way of creating a piece of work. However, this methodology prioritises one artform over another and suggests a lack of interactive synergy – an interest in the collaborative collision of practice languages - between dance and music. In my interactive dance piece *Lifting Bodies* (1999), I similarly use pre-recorded soundfiles but the dancer is required to realize physically the composition in its entirety and retains total control of both the choreographic and compositional process.

---

[40] Ibid., p. 41

[41] Siegel, W. (2009). 'Dancing the Music: Interactive Dance and Music' in *The Oxford Handbook of Computer Music*, Oxford University Press, England, p. 207

Furthermore, the choreography was improvisational and took the physicality of kineasonic interaction as the starting point for the physical performance of the work. The dancer/ performer in this work is also a musician who must possess a keen sense of musicality. Siegel goes on to state:

> The work consists of twenty-eight sections that are changed manually by the computer operator. Automation of section changes was not used because the specific breakup into sections was not decided until after rehearsals had begun.[42]

Working with a computer operator in charge of the navigation and structure of the piece is an entirely valid way of working. In contrast, the basic premise of all my interactive works in that the performer must retain total control of all aspects of the performance. Effective collaboration has been a key issue here having absolute trust in the ability of the performer to realize faithfully compositions 'in performance' is paramount in my work.[43]

Working collaboratively with a performer to develop interactive dance works such as *Lifting Bodies* is about developing expressive possibilities and tapping into new performance skills. The primary skill is the ability to be able to construct the piece musically, at the same time as performing the choreography. This requires an intense aural and physical skill as the performer is required to be musician and dancer at the same time. A pre-requisite for this type of working is an ability to be flexible about the authoring of the work. The 'disruption' of a musical idea might actually lead to more interesting sonic and expressive ideas. Because my compositional processes has always been concerned with 'playing' with sonic material, I am perhaps more willing to share that process with a performer. The flexible nature of the Bodycoder System means that it can be constantly re-configured to access different types of gestural

[42] Ibid., p. 208
[43] See section 6 of this commentary, p. 80.

expressivity. This adds to the scope of what can be explored both in terms of the means and manner of interactive performance.

Because of the interdisciplinary nature of my work, and the sophistication of the current Bodycoder System, it is impossible for choreography, hardware development, sonic/visual composition or any form of substantive programming to be undertaken independently. The *Vox Circuit Trilogy* was formed out of long periods of intensive collaboration in which all aspects of the performance were simultaneously in development. Because it is the syntax of the physical that forms the basis of the interactive work, the articulation of the physical in the making process requires the performer to be present. Judgements concerning the mapping, scaling or response within the software impact upon the physicality of the performer and vice versa: thus the making process involves the slow movement-by-movement configuration and negotiation of the physical at all levels. This is not a hindrance to the making of work, rather the often slow and laborious composition of physical interaction: Kinaesonic practice, albeit through a collaborative process with a performer, is nevertheless an extension of compositional studio practices I established in the early 1970s with the hands on manipulation of analogue technologies.

3.4 The Miburi

The Miburi was a sensor suit, developed and introduced by the Yamaha Corporation, and subsequently only made available in Japan. To this date the Miburi is the only available sensor suit to be produced commercially and is thus worthy of documenting in this commentary. Six flex sensors were located on a shirt (see Figure 1, p. 29).[44]

[44] http://www2.yamaha.co.jp/manual/pdf/emi/japan/port/MiburiR3J.pdf accessed 17/11/2010

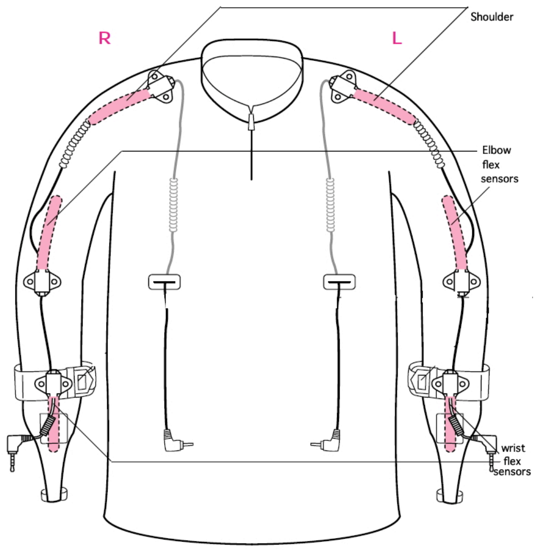
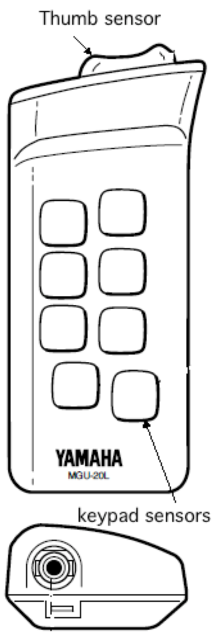


Figure 1. Miburi R3 shirt

In addition, two MGU-20 hand mounted pad controllers, featuring velocity-sensitive buttons for thumb control, were included that importantly allowed selection of sensor elements in a similar way to the Bodycoder System's on-line/off-line protocol (see Figure 2, p. 30). A pair of MFT-20 shoes were also included with the system that had piezoelectric sensors mounted in the toe and heel areas (see Figure 3, p. 30).



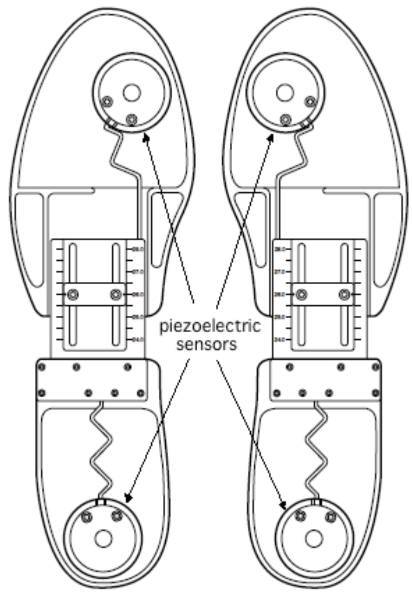


Figure 2. MGU-20 hand controller

Figure 3. Miburi MFT-20 shoes

The control and sensor elements were connected to a pair of MBU-20 belt-mounted interface units that were in turn connected to an MRX-20 transmitter unit operating at a frequency of 259.55Mhz. Between two and four MRX-20 receiver units could be placed on the performance floor, ideally around the dancer/performer, ensuring complete radio coverage of the performance area (see Figure 4, p. 31). This does indicate a weakness in the system in that the radio system had to comply with Japanese regulations and had therefore to operate at quite a low power, hence requiring more than one receiver unit to ensure accurate and reliable reception. The receiver units connected to a MSU-20 AWM2 sound module that enabled various preset and programmable sound sets to be used in performance (see Figure 5, p. 31). A MIDI OUT connector enabled expansion of the system that also included computer processing of the MIDI data.

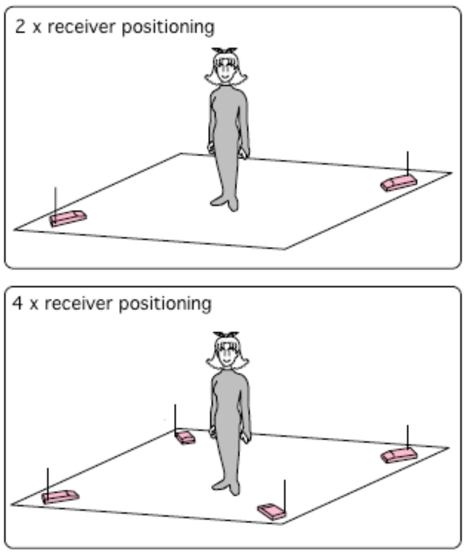


Figure 4. Miburi recommended receiver positioning

The system was designed to be used by a performer triggering sounds, either by using the velocity-sensitive keypads or foot sensors, subsequently controlling these sounds by arm and body movements or by using the variable thumb sensors.

セット ナンバー	ドラムセット名	セット ナンバー	ドラムセット名	セット ナンバー	ドラムセット名	セット ナンバー	ドラムセット名
1	Aerobi1 (エアロビクス1)	9	Std.2(スタンダード2)	17	Swing(スイング)	25	Vibes (バイブ)
2	Aerobi2 (エアロビクス2)	10	Rock 1(ロック1)	18	Samba(サンバ)	26	Timpani (ティンパニ)
3	Dance 1(ダンス1)	11	Rock 2(ロック2)	19	Conga(コンガ)	27	St-Drum (スタンダードドラム)
4	Dance 2(ダンス2)	12	Analog(アナログ)	20	Bongo(ボンゴ)	28	El-Drum (エレクトロニックドラム)
5	Dance 3(ダンス3)	13	Classic(クラシック)	21	Timbale(ティンバレス)	29	Hd-Drum(ハードドラム)
6	TAP 1(タップ1)	14	March(マーチ)	22	Perc.1 (パーカッション1)	30	MbrVce1(ミブリボイス1)
7	TAP 2(タップ2)	15	Waltz 1(ワルツ1)	23	Perc.2 (パーカッション2)	31	MbrVce2(ミブリボイス2)
8	Std.1(スタンダード1)	16	Waltz 2(ワルツ2)	24	Perc.3 (パーカッション3)	32	SFX Set(効果音セット)

Figure 5. Miburi preset voice banks

Performances using the Miburi system were generally quite prescriptive and demonstrative in nature.[45] This was due to the fact that the sensor architecture and preset nature of the system meant that most users simply ended up triggering percussion sounds by, for example, stamping their feet and then subsequently triggering preset AWM sounds to accompany the beat.[46] The limited Japanese market for the system meant that researchers and artists were generally unable to obtain a system so that they could explore and expand the use and application beyond the quite limited area in which the Miburi ended up occupying. The preset voice banks and, indeed, the information included in the (Japanese) manual[47] show the nature of the intended market for the system i.e. aerobic, fitness and light entertainment (see Figure 6, page 32).

[45] http://web.media.mit.edu/~joep/MPEGs/Miburi.mpg accessed 18/11/2010
[46] http://www.youtube.com/watch?v=77bQnSdotDo accessed 18/11/2010
[47] http://www2.yamaha.co.jp/manual/pdf/emi/japan/port/MiburiR3J.pdf accessed 17/11/2010

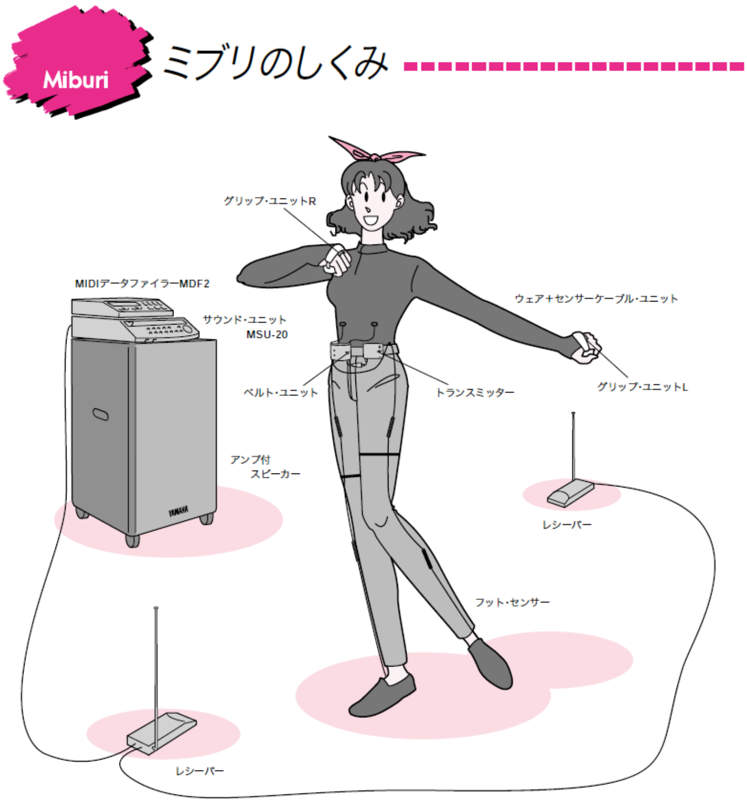


Figure 6. The Miburi

The fixed sensor architecture of the Miburi system further decreased its use by contemporary artists looking at exploring the field of gestural control. The idea of the 'body-suit' was quickly dismissed in my early experimentation at STEIM, resulting in the second generation of the Bodycoder System in use today. The use of MIDI with its inherent seven bits of data resolution is another factor in limiting the use of the Miburi system, this is in common with other contemporary systems such as the DIEM Digital Dance System and Troika Ranch's MIDI Dancer. It is my firm belief that OpenSoundControl (OSC) with its ten bits of data resolution is a minimum with which true sensitive and expressive gestural control can be achieved from any sensor architecture, and it is the OSC protocol that will be a feature of future developments in this field.

3.5 The BodySynth

The BodySynth, developed by Ed Severinghaus and Chris Van Raalte, is an eight-channel wireless sensor system that utilizes muscle sensors, usually worn on the arms, to convey muscle movement information to a receiver and processing unit that contains several DSP functions to decode and process the data. These functions include data averaging, impulse decoding and translation, scaling and various metronomic operators that are then formatted as MIDI controller and note data. The system is still available to purchase today and continues to be used by artists working in interactive performance, notably Pamela Z who uses the system as a vocal performance controller. Indeed as Pamela Z's work is primarily concerned with vocal sampling and control I will locate the work with the BodySynth in relation to my work with the Bodycoder System. Electromyogram (EMG) sensors, used as muscle sense elements in the BodySynth system, cannot produce the accurate, sensitive and expressive control data that is inherent in the Bodycoder System. It has always been a requisite in my work that there is a transparent and localized dialogue between the audience's 'gaze' and the performer's gestural expressivity required for each piece of work. The fact that the BodySynth is always sending data to the processor further isolates the two systems in terms of having physical control of the sensor data. Pamela Z's work necessitates the use of extra control elements for sensor enabling and control such as footswitches and set mounted triggers (see Figure 7, p. 34). In addition the necessity of having to use the computer on stage, visible to the audience and activated and visibly used by the artist goes against the aesthetic of my process whereby the technology is required to be as invisible as possible to the audience.

Figure 7. Pamela Z *Gaiizin* performance set-up

This aspect of Pamela Z's work can clearly be seen in *Nihongo de Hanasoo (from Gaijin)* [48] from 2001, in which the performer vocalizes short fragments of words that are then sampled and looped by the computer whilst the performer reads selections of text from a book. The sampling process and patch selection are initiated by footswitches and keyboard selection that visually detract from the performance and it is obvious that the artist has to locate these elements before activation can take place. In Pamela Z's work *Voci* (2003)[49] Z uses pre-recorded samples and her own voice is used to produce spoken phrases that are, indeed, most prominent in the artist's works to date. There are also elements that are witnessed as being comedic in nature by the audience. It is assumed that this 'humour' is meant to be present in the work and not just an audience's response to the unfamiliarity of the work. *Voci* includes the use of the BodySynth mechanism but it is, as I have previously intimated, extremely difficult

[48] http://www.pamelaz.com/NihongoMov.html accessed 02/04/10
[49] http://www.pamelaz.com/VociMov.html - accessed 02/04/10

to see the correlation of body movement to audio output or to achieve a fluid dynamic. The system is not witnessed as being used as an expressive timbral controller but more of a data acquisition tool, used to initiate various sampling modifiers that are difficult if not, indeed, impossible to appreciate as a member of an audience. The converse is true of all my works for the Bodycoder System where my primary concern is with the one-to-one and real-time manipulation of audio processes and the creation of authentic and sonically expressive textures.[50]

[50] For a definition of sonic expressivity see section 5, p. 74

4. Early Interactive Works – Introduction

In 1994 I was approached by Derek Baker of Dawsons Music, Warrington to join the development team of the MidiCreator Project - a sensor interface prototyped by the University of York and promoted within the music education sector by Dawsons Music. The MidiCreator was a small programmable MIDI interface that had fourteen sensor inputs enabling the connection of switched or proportional sensors working in the range of 0–3.2 volts.

The MidiCreator was supplied with eight pre-programmed presets that enabled the user to trigger various General MIDI[51] sound-sets from the fourteen sensor inputs, (e.g. preset 1 used the fourteen inputs to trigger GM percussion sounds on MIDI Channel 10). This simplicity of its use enabled users with limited technical skills instant access to quite a wide range of MIDI controlled sounds and voices.

The MidiCreator was originally developed for use with special needs groups as an enabling device for creating music using MIDI as the control protocol. My involvement took the form of software and hardware consultant for the design, development, and construction of interface sensors, with particular focus on the use of both tactile and non-tactile sensors that enabled disabled clients with limited mobility access to electronic music making tools and instruments. It was at this time that I was also invited to join the Ensemble Research Group, based at the University of York, hosted by the Department of Electronics and the Department of Music. The

[51] General MIDI (GM) is a standard voice specification for MIDI synthesizers and sound modules that ensures that MIDI data played on different manufacturers devices would operate and essentially produce the same voicing.

Ensemble Research Group was set up to undertake research into enabling technologies for Music and the arts with special needs groups. Experience in both the electronics and music fields enabled my contribution to Ensemble Research Group forums and annual conferences culminating in practical workshop presentations and conference papers.

As a composer, the most innovative aspect of the MidiCreator and one that offered the most potential for my own practice was not in the use of its eight presets but in the fact that an extra set of eight 'user' programs could be programmed on a personal computer. This data could be stored on a PMCIA[52] card which, when inserted into the MidiCreator, enabled the user to program MIDI controller messages in response to up to fourteen proportional sensor inputs. Morphing, controlling and mixing sounds in real-time by the simple use of potentiometers and foot pedals had become an important technique in my computer based compositions. The ability to use MIDI controller data to 'sculpt' sounds in real-time offered some exciting possibilities. With the development of custom designed sensors coupled with the MidiCreator interface there was now the possibility of producing a control mechanism for live digital performance. In order to achieve this, a reliable and robust computer music hosting program was required that could translate and route the MIDI data produced by the sensor interface into meaningful and 'musical' data to be used live in performance. Opcode's StudioVision Pro software provided a solution in the form of a software routine entitled 'MidiKeys'. MidiKeys enabled external MIDI controller data to be routed in real-time to any track in any music sequence or sub-sequence. This track could contain pre-recorded MIDI note data or function as an empty track

[52] PCMCIA Personal Computer Memory Card Association: an international standards body set up to define the protocol for computer memory and related digital hardware.

and simply route the external controller data to an external synthesizer or digital audio processor. In addition to the routing of live MIDI data MidiKeys allowed sub-sequences to be triggered by any MIDI event such as a simple note-on signal. The concept to produce a stage based interactive theatre piece that could be dynamically realized and performed in real-time could now be achieved. Combining a number of MidiCreator interfaces with a range of custom made sensors, coupled with Opcode's StudioVision Pro, running on a Macintosh computer, meant that it was now feasible to embark upon the composition of a full-length interactive performance piece.

4.1 The Navigator

The Navigator (1995) is a music theatre piece for solo performer. The primary intention was to create a robust and reliable interactive environment that would enable a performer to have absolute control over every aspect of the audiovisual environment. This would include the triggering of pre-recorded aspects of the electro-acoustic score and initiation and live interaction with various digital audio processors and lighting controls. It is important to state that, even at this early stage of working with interactive technologies, it has remained a defining ethos that this level of control is entirely given up to the performer with absolutely no off-stage intervention. In order to achieve this a ‘sensitized performance space’ was designed using a variety of sensors (see Figure 8, p. 39).[53] The performance space was physically wired with multiple types of sensor elements and their accompanying network of cables and wiring.

[53] See Appendix C, Recordings: *The Navigator* Interactive Examples.

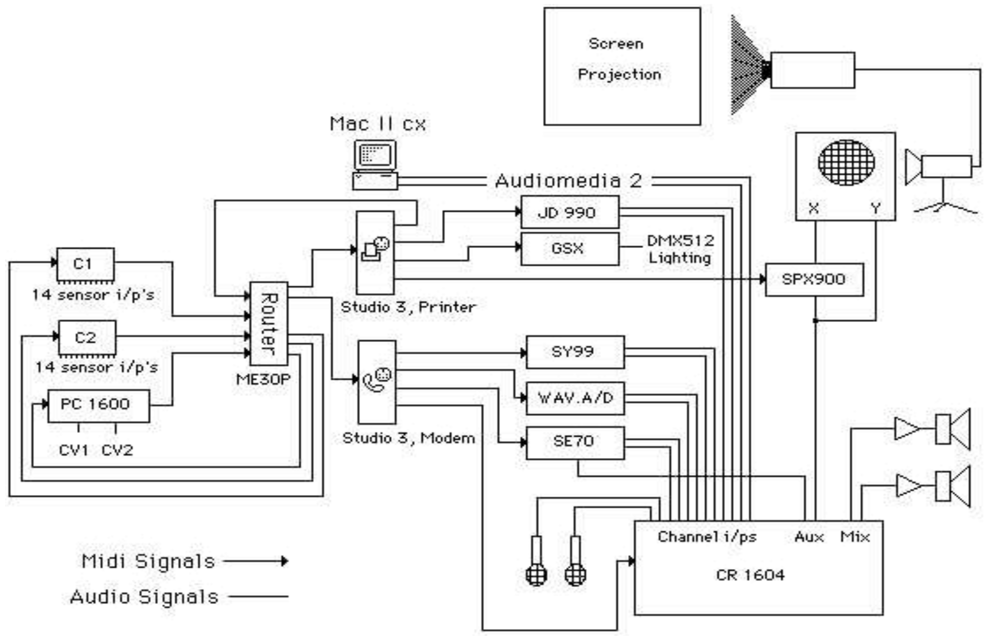


Figure 8. *The Navigator* performance setup

Two MidiCreator interfaces with pre-programmed PCMCIA cards were employed to receive data from twenty-four sensor elements positioned inside the performance space.[54] Sensors were fixed in their respective positions in and around the stage. This meant that the performer had to locate themself physically and accurately in certain positions, at the required time, to perform and interact with various sensor elements as dictated by the composition. At the time this was not seen as a limitation or a constraint on the physicality of the performer. Interaction with the computer system via the sensor elements seemed like a massive breakthrough in the shaping of a dynamic and expressive real-time electro-acoustic music theatre environment. It became clear, during the rehearsal process, that this type of real-time interactive performance called for a very particular set of skills and sensitivities on the part of the performer if they were to be able to translate accurately and deliver the scored

[54] For a full description of this work see, Bromwich, M. (1995). 'A Single Performer Controlled Interface for Electronic Dance/Music Theatre' in *Proceedings of the International Computer Music Conference*. International Computer Music Association. San Francisco, CA. pp. 491-492.

performance that reflected my compositional ideas and processes. If a switch contact miss-triggered or a program change was misread it would be ideal if the performer had the musical experience and aural sensitivity to detect this as it happened, and to be able to take actions to rectify the situation, allowing the piece to continue without external intervention.

The performer chosen for *The Navigator* was a proficient dancer and performance artist in his own right, however, he was not a musician and subsequently found it difficult to make decisions with regard to the quality of sound his physical actions controlled and initiated. For example, responding and interacting with sensors controlling vocal pitch changes were particularly difficult if the proximity sensor elements were even slightly off axis – a person with a trained musical ear should hear the pitch discrepancy and adjust their physical position to compensate. It became very clear over the course of making *The Navigator* that this type of interactive performance practice required a range of very specific interdisciplinary skills on the part of the performer. It was evident that intensive collaboration with a performer in the making of work was key to ensuring the development of their physical and musical sensitivities and skills in relation to real-time interactive practice.

4.2 Zero in the Bone

In 1996 work began on creating an interactive performance work for the trombonist Barrie Webb. The piece entitled *Zero in the Bone*[55] originated around the idea of creating a 'meta-instrument' - a term used by Jonathan Impett to describe a trumpet

[55] For a full description of the piece see: Bromwich, M. (1997). 'The Metabone - An Interactive Sensory Control Mechanism for Virtuoso Trombone' in *Proceedings of the International Computer Music Conference*. International Computer Music Association. San Francisco, CA. pp. 473–475.

augmented by the addition of a various sensor elements which connected to the STEIM 'Sensor Lab' interface. In the case of *Zero in the Bone*, the meta-instrument is an enhanced trombone: a *Metabone*. Various sensors are situated in the performance space with a custom designed reactive plate mechanism attached to the trombone to facilitate interaction with fixed sensor elements (see Figure 9, below). Placing sensor elements within the soloist's immediate performance was a continuation of the practice established in *The Navigator.* Much of what had been learnt with regard to the gestural control of sound processing in relation to proximity sensors was applied in the development of *Zero in the Bone.* This included, for the first time, fully scoring the physical gestures of the performer, and providing the performer with a visual cue system. The inclusion of both these elements was a major consideration in the actual composition of the piece and was perhaps, the first acknowledgement of the importance of the Kinaesonic score: the heightened and accurate qualities of one-to-one gestural control of real-time sound processing that I was seeking.[56]

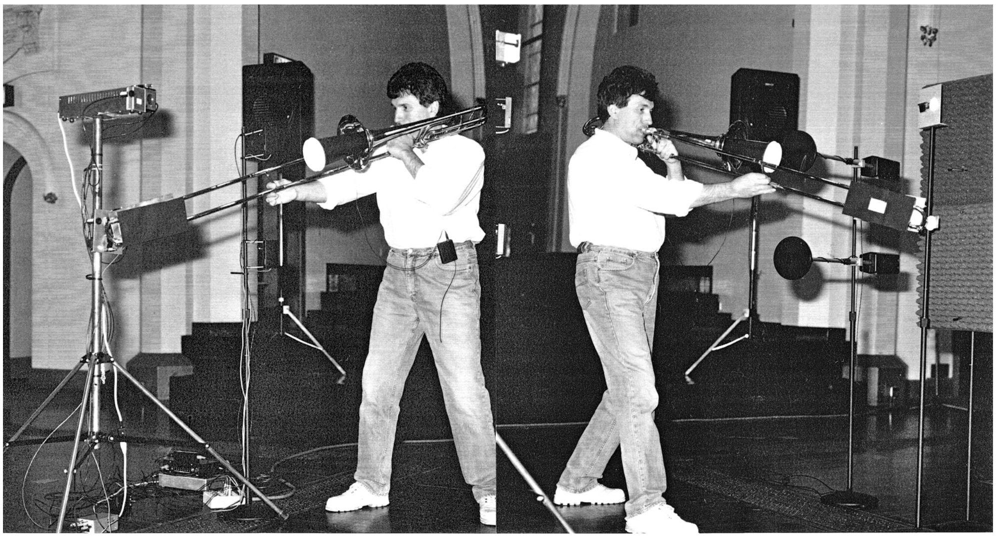


Figure 9. *Zero in the Bone* in rehearsal

[56] See Appendix D, *Zero in the Bone* performance score and Appendix C: Recordings – video and audio recordings of the piece.

The trombone is a sonically rich acoustic instrument and provides great potential as live material for digital processing, timbral enhancement and modification. Rather than composing a classical electronics and trombone piece, I wanted to create an entirely unique work using the energy and rich acoustic resonances of the instrument but not the acoustic sound. The fundamental premise being that the audience should not hear the natural acoustic of the instrument, only the processed sound.[57] However, in practice, this was only partially achievable. An anechoic mute was designed, fitted with a radio microphone, to transmit the acoustic sound to the digital audio processors. The natural acoustic was emitted from an air hole on the mute and also from the actual body of the instrument. However, an acceptable balance was achieved between the processed sound and the relatively small amount of acoustic sound that leaked from the instrument mute.

As in *The Navigator*, *Zero in the Bone* employs two MidiCreators to interface sensor elements to a computer system, again using Opcode's StudioVision Pro as the host program. Digital audio processing of the trombone is achieved by using two Roland SE70 digital multi-effect units that allows real-time timbral control via its comprehensive use of MIDI control data (see Figure 10, p. 43).

[57] This ideal could only be achieved in the confines of a recording studio. It is interesting to compare the two recordings (live and studio) see Appendix C for both recorded versions of the piece.

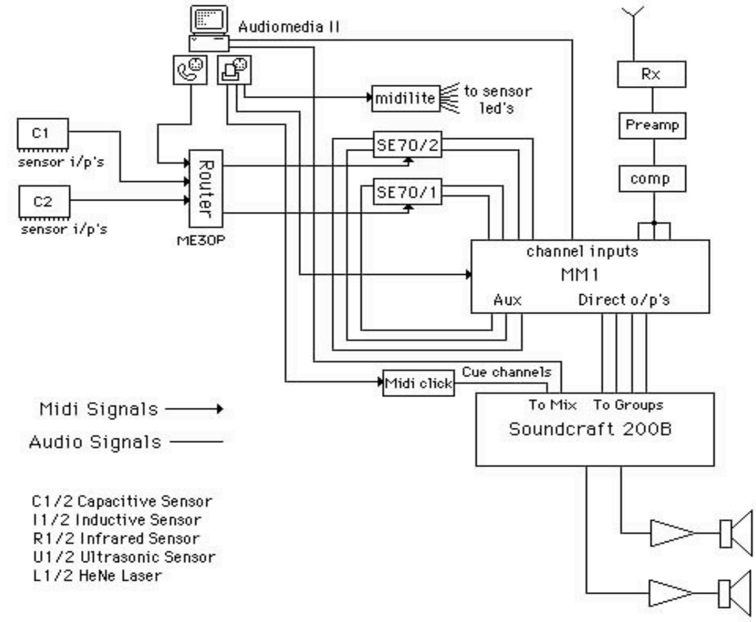


Figure 10. *Zero in the Bone* performance set up

A series of sound processing 'presets' were written using processes such as vocoding, filtering, ring modulation, delay and harmonization. These processes are controlled by the performer, interacting with the various sensor elements placed around the periphery of the performance area (see Figure 11, p. 44).

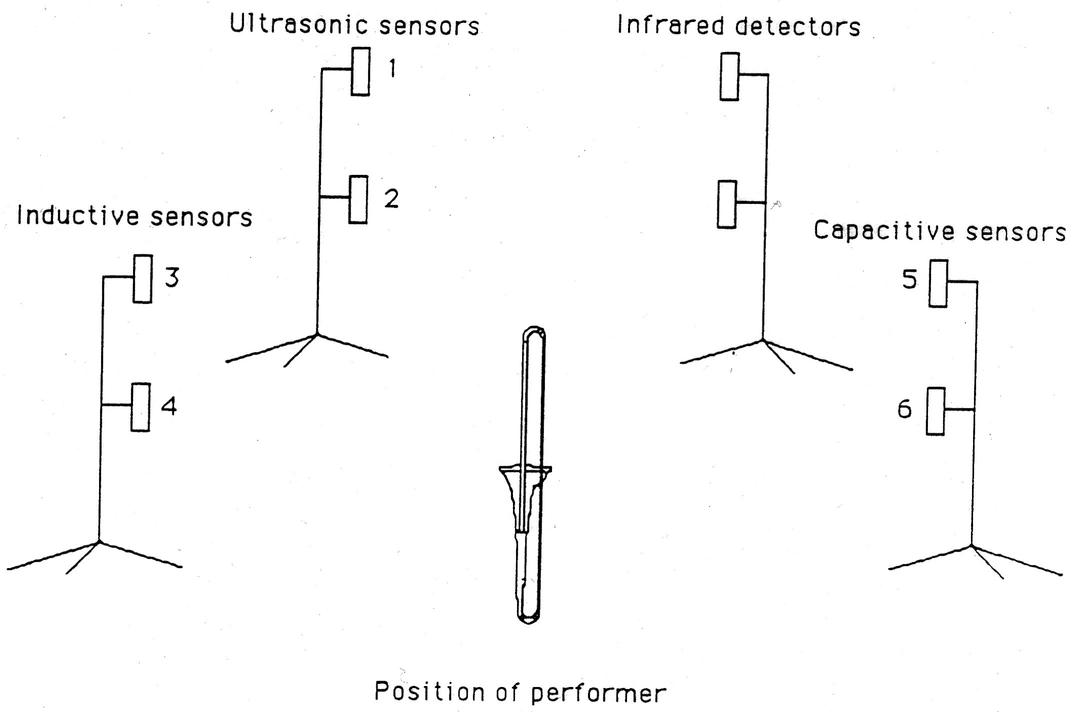


Figure 11. *Zero in the Bone* sensor positioning

The Compositional Process

The compositional process began with a series of workshop sessions with the trombonist Barrie Webb in which the range and timbral qualities of the instrument as well as Webb's particular skills as a soloist were explored. The performer's ability to sustain a note by circular-breathing for extended periods of time offered interesting possibilities for developing long sequences of evolving organic material. Several recording sessions were subsequently undertaken enabling the recording of instrument samples, allowing experimentation in the studio without the need for the performer to be present. During one of these recording sessions samples were taken of Webb playing sustained Didgeridoo-type voicings. This enabled experimentation, using these samples as 'carrier' material in a vocoder process I had first explored during the development of *The Navigator*.

Composing *Zero in the Bone* then took the form of extended periods of 'playing' with pre-recorded trombone samples on a Yamaha SY99 keyboard synthesizer and processing improvised phrases utilizing various DSP programs previously created and stored into presets in the two digital effect processors. Experimenting with various DSP algorithms and controlling various effect parameters with external controllers resulted in the creation of musically interesting material. Finally these experiments were recorded on to a computer sequencer, i.e. the audio samples together with MIDI note and controller data. It was then necessary to analyze the results to see what worked musically. This way of working with sound, particularly the live and controlled processing of audio material in real-time, is similar to the way composer Brian Eno creates original works. In describing his composing Eno states:

> Sometimes there will be a melody at the beginning, or a particular rhythmic configuration, but generally there's a sense of, "Well, I'm going to set this process in motion. Where will it lead me?" And furthermore, do I like where it leads me? Because if you don't, you abandon it, you start again.[58]

My compositional practice does not begin with a particular set of musical phrases or melodies in mind, rather I begin with a palette of sounds that may have been selected from a larger bank of promising audio ideas generated out of long periods of improvisation. Improvising with real-time processing results in the construction of recorded 'banks' of sound formed by the mixing of tones and timbres until a particular audio 'palette' of the new piece begins to emerge. This is a process that is to do with exploring the interiority of sound and the movement or organic[59] evolution of sound processes. Similarly Eno states;

> Each thing you add modifies the whole set of things that went before and you suddenly find yourself at a place that you couldn't possibly have conceived of, a place that's

[58] Tam, E. (1995). *Brian Eno, His Music and the Vertical Colour of Sound*, Da Capo Press, Inc. p. 65.
[59] See footnote on p. 74 describing the use of this term.

> strange and curious to you. That sense of mystery, learning to live with it and make use of it, is extremely important.[60]

The recorded notes and MIDI controller data affecting the DSP units (from the improvised sections) were recorded into several sub-sequence tracks in the Studio Vision Pro environment. The sub-sequences were then individually triggered in real-time whilst recording into one master sequencer track, thereby ensuring that there was an organic feel to the transitions between the various sections of the piece. Once the piece had been assembled it was simply a matter of muting the note and controller information and leaving program changes for the digital effect processors intact. Similarly an audio cue and click track, fed to the performer via a headphone bus, was retained to be used in subsequent rehearsal sessions. It was also necessary to retain a pre-recorded MIDI control data track, feeding the MIDI-Light interface that provided visible sensor cues to the LED's (light emitting diodes) mounted on each sensor element. Finally, a digital audio file was recorded on to the computer containing a processed didgeridoo soundfile. This soundfile provided the carrier signal information for the vocoder processing. The piece relied on this 'timeline' of data to run with no facility or requirement for the performer to extemporize or navigate within or away from the strict dictates written into the score. As was experienced in the case of *The Navigator* the performer had to be physically 'in the right place at the right time' for the piece to work. Although the two pieces worked well in practice it was seen as a limitation that this 'binding' to a particular area/space could be constrictive in terms of developing a certain freedom of gestural expressivity. However, the combination of Metabone and Meta-environment proved to be a powerfully expressive medium in which the performer was both challenged in terms of the degree of physical skill required and emancipated by the new virtuosity offered by an interactive environment.

---

[60] Ibid., p. 65.

It was apparent, however, that further research was required into the implementation of a localized and wireless sensor system that would provide a greater degree of physical freedom for the instrumentalist and banish much of the cabling from the performance environment.[61] An on-the-body system might also offer a greater degree of interactive intimacy and therefore a more refined and acute degree of sound processing and control. An effective on-the-body sensor array required a reliable wireless system and the development of sensor technology that could withstand the physical rigors - the extreme twists and pulls of the body. It was ultimately the successful development of a wireless on-the-body sensor array, as manifest in the Bodycoder System that was a major contributing factor towards the creation of the *Vox Circuit Trilogy.*

A result of the experience gained in the development of *The Navigator* and *Zero in The Bone* led to the decision to investigate the Max/MSP environment as the software 'host' for the Bodycoder System. It was evident that Opcode's StudioVision Pro was not an ideal platform because of the inability to re-map and re-structure sensor designations and routings, effectively being limited to one function per sensor element. Using Max/MSP would enable multiple functions to be addressed and controlled. The use of Max/MSP would additionally enable mapping, scaling and calibration processes to be set in the software program. This would minimize the amount of time needed to physically re-calibrate the hardware before each performance and would additionally enable the creation of customized audio processes to extend the compositional palette of sounds and DSP processes.

[61] Bromwich, M. (1997). 'The Metabone: An interactive sensory control mechanism for virtuoso trombone' in *Proceedings of the International Computer Music Conference.* The International Computer Music Association, San Francisco, CA. pp. 473–475.

Another advantage of using MAX/MSP was the fact that mathematical processes could be applied to the data received from the sensor interface that could translate and encode the raw sensor values - increasing the potential for designing creative and expressive gestural control of DSP processes. As well as performing translation and mapping of the received sensor data it was also possible to smooth out sensor data using, for example, the line object (see Figure 12, below). This was to become an essential process when controlling such elements as pitch.

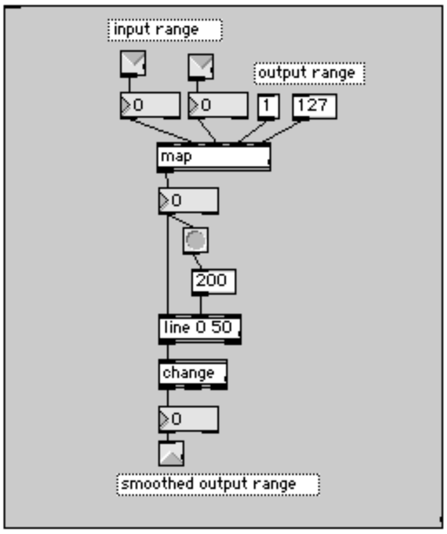


Figure 12. Sensor smoothing using the MAX *Line* object

4.3 Lifting Bodies

The first piece composed for the Bodycoder System and Max/MSP was entitled *Lifting Bodies* (1999) - premiered at the Making New Waves Festival 1999, organized by the Hungarian Computer Music Association and held in Budapest at the Trafo Art Centre. *Lifting Bodies* was the final piece in an evening length program of works that included a performance of *Zeitgeist* (1999) – also for solo dancer and the Bodycoder System.[62]

Lifting Bodies is constructed using two MSP processing patches – providing two musical compositional elements. The first patch utilizes a Granular Synthesis abstraction, originally devised by Nobuyasu Sakonda, to process one of two short, pre-composed soundfiles that can be controlled in a variety of ways by the dancer/performer. Sixteen granular presets are pre-programmed to recall discrete sensor mappings and to set up variable elements within the patch such as pitch, randomization of position, randomization on/off, grain size and loop length. In this way the dancer can recall a patch preset and then control variable elements within the patch. Each patch is thereby optimized to function with the exact amount of control required to achieve a precise and pre-rehearsed system of effect processes. The second of the two sample elements replaces the first sample on the recall of preset patch number nine. The two samples include sonically evolving elements that provide a harmonically rich and dynamically varying sound source that can be processed by the actions of the performer. The real time processing of these elements take the form of the left arm bend controlling 'granular scrubbing' through various preset portions of the sample that can be preset in one of two looping modes – random and fixed. In this way the performer can navigate to a certain point in the granular sample and, using a dedicated finger switch, i.e. switching to 'off-line' mode, continue the performance without alterations being made to the sample loop. Various presets enable the randomization function, this, together with various preset amounts of randomization, result in randomization of the playback position of the sample. As

[62] See Appendix C for an audio and video recording of *Lifting Bodies*.

well as adding an interesting process to the composition this also presents a challenge to the performer who has to integrate these random elements into the musical performance, creating a virtuosic and dynamic dialogue with the computer program.

The second 'generative' patch used in the piece utilizes an abstraction originally written by John Echenseer. *CellSound* uses the principles of cellular automata to generate twenty-five sine wave oscillators, each oscillator being harmonically related to each other. The abstraction was modified to accept external control, using the left arm bend sensor to control such elements as cell updating frequency and random cell period. One of eight preset states can be recalled by the detection of a maximum left arm bend value. This preset recall is programmed to fade out the previous state before fading in a new one with a different set of preset variables. The preset variables consist of harmonic limit, cell change rate, damping rate, diffusion rate, slew rate and random base frequency. An optimized range of variables is sent to each of the controllable functions for each of the eight presets. This is achieved via a system of counters, gates and multipliers.

As three of the finger switches are dedicated to enable/disable each of the three bend sensors with the third, knee mounted sensor controlling the volume of the cellular patch, this only leaves one finger switch for navigation and control. Finger switch four is programmed to start the piece, advance the granular presets - when held for more than 6 seconds and stop the piece if held for more than 25 seconds. This functionality is simply achieved by using a system of counters and *select* objects.[63]

[63] See: Wilson-Bokowiec, J., and Bromwich, M. (2000). '*Lifting Bodies*: Interactive Dance – Finding New Methodologies in the Motifs Prompted by New Technology – a Critique and Progress Report with Particular Reference to the Bodycoder System' in *Organised Sound* (5) 1 Cambridge University Press, pp. 9-16.

Lifting Bodies was composed using a PC1600x to simulate the sensors that would later be used in rehearsal and performance. In this way it was possible to design and construct a piece of interactive performance without the dancer/performer having to be present.[64]

Although *Lifting Bodies* was pre-composed using a MIDI control interface it was only when moving into a rehearsal situation that the piece took on a new and physically expressive form. The collaborative situation, working with a trained and proficient dancer who also had the benefit of having had a musical training, meant that decisions could be made 'on the spot' regarding timing and delivery of the piece that simply could not be achieved in the composition studio using faders and switches. A strong compositional framework provided the dancer with both the freedom to improvise and a structure in which to work with numerous musical and choreographic elements, the parameters of which were negotiated and refined during the collaborative process.

For *Lifting Bodies* it was decided to move away from the 'Body Suit' situation in which sensors were 'sewn in' to pockets in the suit material. The bend sensors are instead mounted into thin pockets sewn into sport bandages that can be worn underneath any clothing as dictated by each individual piece of work. It was an important decision to hide the sensors and associated wiring from the audience's gaze. This was in order that the audience should not be aware of the sensor interface and sensor array. The Bodycoder System was not conceived or designed to provide a

[64] The piece was later recorded and published as part of the compilation '*Sonic Art from Aberdeen, Glasgow, Huddersfield and Newcastle*' on MPS Music and Video, MPSCD013 using the PC1600x as the control surface to realize and record the piece in real time. See Appendix C: Recordings - for an audio recording of this version plus a video recording of the piece performed in Budapest (1999).

‘demonstration’ of new technologies but to enable and produce a new and original performance aesthetic, this was rationalized in the use of the term ‘System’ and not ‘Suit’, ‘Interface’ or ‘Instrument’. The Bodycoder System was to combine the various Bodycoder elements into a single aesthetic comprising of 1/ The Performer, 2/ The Electronic hardware interface, 3/ The Sensor array, 4/ The Software host, 5/ The Max/MSP patches, 6/ The Computer system and 7/ The Sound diffusion system. This idea became extremely important in the formation of the Bodycoder as a ‘System’ and not an ‘Instrument’, an instrument being defined as having fixed protocols and a ‘System’ as being ‘open-ended’ due to the flexibility of its sensor interface and its complete integration into the Max/MSP framework.

The system of on-line and off-line working was key to the success of implementing interactive and non-interactive states within the performance in providing a ‘space’ for the development of a more dynamic and complex interplay of freedom and expressivity. The ability of the performer to take active control of electro-acoustic processes, finding rhythmic and sonic motifs that could be ‘locked in’ so that dance could be extemporized without changing the audio material.

4.4 Spiral Fiction

Spiral Fiction (2002),[65] commissioned by Digital Summer (cultural programme of the Commonwealth Games, Manchester) is an interactive music theatre installation that was premiered at The Green Rooms, Manchester. The piece consists of a large set construction comprising several fixed elements inspired, in part, by Louise Bourgouis’s sculpture work. The main focus of the set is an eight-foot square metal

[65] Bokowiec, M.A., and Wilson-Bokowiec, J. (2003). ‘Spiral Fiction’ in *Organised Sound*. Cambridge University Press. (8) 8, pp. 279-287.

cage that houses various shaped mirrors and telematics. Three data projectors are positioned in and around the performance space providing interactively controlled visuals at various times during the ninety-minute performance.[66] A four-channel sound system surrounds the performance/installation space and the audience was encouraged to move freely within the space. A further four miniature loudspeakers are positioned inside the cage providing localized sound diffusion. A pre-composed soundtrack is variously triggered by the female performer wearing the Bodycoder System, interfacing with various Max/MSP patches, enabling control and positioning of the soundtrack in the performance space.

A male and female performer both wear radio headset microphones, the audio received by the Max/MSP patches are designed to affect the spoken dialogue in various ways and at various times in the performance. The female performer can control and manipulate various processes such as the vocoder carrier frequency for the female voice, and sampling and scrolling of the male voice using a granular sampling process.

Spiral Fiction was an ambitious undertaking comprising many elements integrated into the performance designed to create an immersive environment inside which members of the audience could experience various modes of interaction with the two performers - one of which was in total control of the audio-visual production.

The extensive use of vocal processing in the piece was to signify a direction in which I was increasingly being drawn i.e. using the human voice as the sole element in a

[66] See Appendix C for a video excerpt of *Spiral Fiction*, showing the Bodycoder used to sample, scroll and pitch change the live vocalisations of the male performer.

new piece for the Bodycoder System. This tendency would eventually result in the creation of the *Vox Circuit Trilogy.*

Before considering the *Vox Circuit Trilogy* it is important to outline the particular nature and dimensions of the distinctly interactive physicality that is central to my work with the Bodycoder System. This is critical to understanding how the modelling and composition of the physical is embodied at all levels of the work as forms of expressivity - in hardware, software, gesture and sonic - not simply as an effect, but as an integrated language of interaction. This language is generically described as Kinaesonic.

5. Kinaesonics, Tactility and Expressivity

I devised the term Kinaesonics in 1998 and have subsequently used it to describe a particular form of interactive arts practice associated with the gestural manipulation of real-time processing of electro-acoustic music. The term kinaesonic[67] is derived from a composite of two words: 'kinaesthetic' meaning the movement principles of the body and 'sonic' meaning sound. My defining of the term kinaesonics was prompted by Drew Hemment's[68] description of my work with the Bodycoder System as Kinesonic: his collision of the terms Kinetic and Sonic. Kinetic implies any moving object, not specifically the human body, and this prompted me to clarify that it is the human body in relation to sound that is at the centre of my interactive practice.

The real-time mapping of movement to electro-acoustic sound processing is achieved through the use of an on-the-body sensor array. The Bodycoder System employs sensor elements that provide the performer with two types of gestural control, expressive and utilitarian. Proportional bend sensors, located on any bend area of the body are associated with expressive functions, while switch sensor elements, located on the fingers of both hands, are associated with utilitarian functions. Through intensive work with the system, a convention has arisen whereby right-handed utilitarian functions activate the bend sensor elements thus enabling expressive kinaesonic gestures to be controlled. Left-handed utilitarian functions are designated

[67] Wilson-Bokowiec, J., and Bokowiec, M. (2006). 'Kinaesonics: 'The Intertwining Relationship of Body and Sound' in *Contemporary Music Review. Special Issue: Bodily Instruments and Instrumental Bodies.* London, Routledge Taylor & Francis Group, Volume 25 Number 1+2, 2006, pp. 47-58.
[68] Hemment, D. (1998). 'Bodycoder and the Music of Movement' in *Mute* magazine. Issue 10, pp. 34-39.

for control and navigation of the Max/MSP environment. This is one of the unique and defining protocols of the Bodycoder System that facilitates an on-line/off-line way of working that was first used in *Lifting Bodies* (see p. 48). In the *Vox Circuit Trilogy* navigation of the Max/MSP environment takes the form of the selection of processing patches and subsequent selection of preset states within an active patch. In *The Suicided Voice* there are three primary processing patches, each of these patches are recalled with a dedicated finger switch. One finger switch is always dedicated to the advancement of presets contained in the active processing patch (see Figure 13, below).

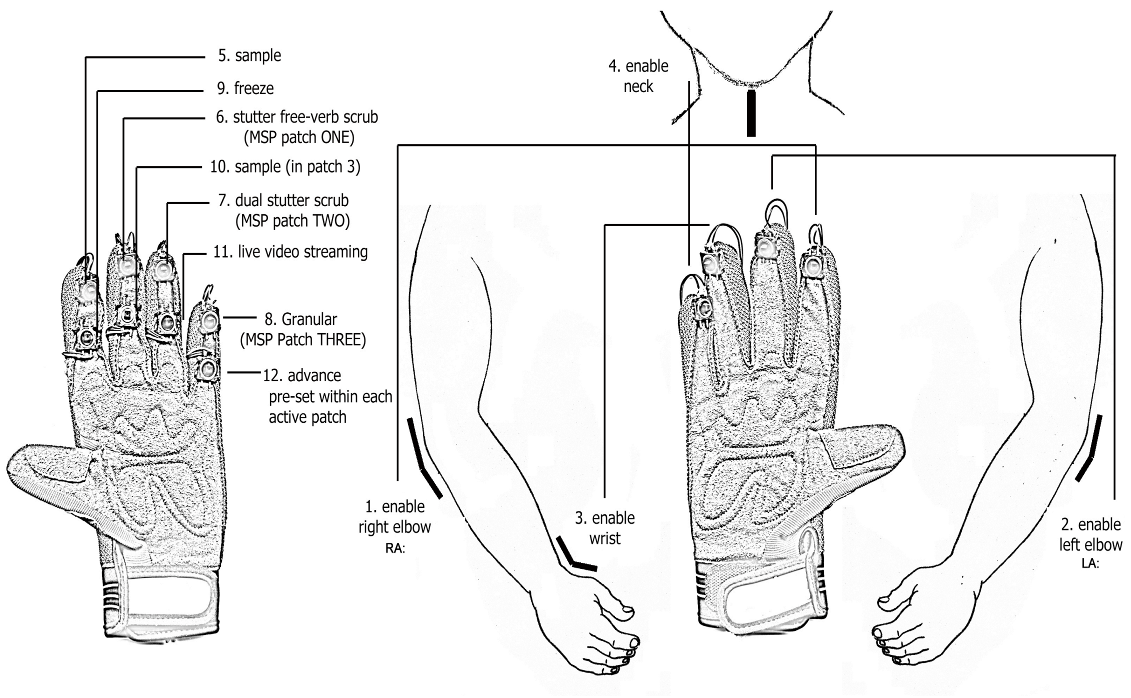


Figure 13. Bodycoder System interface configuration for *The Suicided Voice*

These four, entirely utilitarian, switches cannot be said to be expressive, or indeed defined as performing a kineasonic function, however, the ability to navigate a complex Max/MSP environment is one of the defining elements of the Bodycoder System.

Some utilitarian switch elements can also be said to provide a kinaesonic function, an example would be finger switch five which, in processing patch three, initiates live vocal sampling into a granular buffer that is immediately heard as a manually scrolled sample or as a repeated looped section of the granular buffer. The simple movement of the activating finger is seen as a 'kinaesonic action', resulting in the immediate playback of a vocal, 'sonic', sample. The utilitarian elements can therefore be seen as operating in one of two distinct states: purely functional, as in the advancement of presets, and 'functionally kinaesonic': kinaesonic but with no visible expressivity.

5.1 Forms of Tactility

The two types of sensor elements used in the Bodycoder System can be divided into two categories, tactile and non-tactile. The tactile elements comprise the switch mechanisms, mounted on a pair of gloves. The switches have been sourced to provide the performer with reliable and repeatable sensory feedback in the form of well-defined 'clicks'. These are felt when the units are depressed. This feedback is essential so that the performer is totally confident that switch contacts have been made, the disadvantage being that audible clicks can be sampled with the vocal material. The non-tactile elements comprise the bend sensors that are mounted on various bend areas of the body, for example in *The Suicided Voice* the sensors are mounted one on each elbow, one on the right hand wrist and one on the neck of the performer (see Figure 13, p. 56). It might be surprising that the bend sensors are seen as being non-tactile but the performer does not feel the bend sensor elements in terms of detecting a sense of physical resistance, but instead, they are sensed in the form of audio feedback from the sound system that is, of course, remote from the body. The performer has spoken of the sense of 'feeling sound'[69] and feeling the 'texture of sound' in the area of the body that is performing the manipulation of sonic material. This is a difficult concept to grasp for those who have not had experience of such sensations but it remains an experiential consequence of working with the Bodycoder System and requires further analysis outside the scope of this commentary. It is the combination of expressive and utilitarian, and of tactile and non-tactile sensor elements that provides the performer with multiple simultaneous levels and qualities of both expressive and navigational control that defines and characterises the interface of the Bodycoder System.

5.2 Forms of Expressivity

In using the word expressivity, I am not referring to an aesthetic intention that is to do with the work's reception by an audience: the indication of mood or sentiment through music. Expressivity, in terms of my work with the Bodycoder System, is a pragmatic and tangible compositional practice that is concerned with the construction and manipulation of four interactive and interrelated expressive elements: sonic (electro-acoustic), programmed, gestural (kinaesonic) and in terms of the *Vox Circuit Trilogy,* vocal. It is the sensitive orchestration and control of the changing character of these expressive elements and the choices made with regard to the manner of their interaction and influence on each other that defines the practice and ultimately the individual nature of the resulting works. The focusing on expressive elements particular to the Bodycoder System has emerged directly out of my practice and, I would suggest, constitutes a new methodological approach to the composition of interactive electroacoustic music.

[69] Wilson-Bokowiec, J., and Bokowiec, M. (2010). 'Sense & Sensation: the Act of Mediation and its Effects' in *Intermedialities*. CRI Université du Montréal number 12, p. 137.

With respect to the Bodycoder System, and particularly in relation to the *Vox Circuit Trilogy*, expressivity can be sub-divided into four principle forms.

- Gestural = G
- Sonic = S
- Vocal = V
- Programmed = P

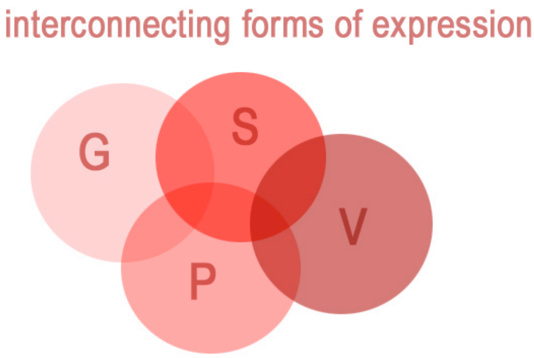


Figure 14. Four principle forms of expressivity

The four forms of expressivity are inter-related and interact with each other in various ways and degrees. An awareness of the interconnectivity of principle forms of expressivity, their interaction and influence on each other, shapes the compositional, development and rehearsal processes. While in the following commentary each form of expressivity will be discussed separately in order to expose some of the technical and creative principles associated with individual forms, it is important to note and understand their interconnectivity and their interactive relationships.

- **Gestural / Kinaesonic**

Gestural expressivity refers to the physical movements made by the performer. Gestural expressivity is intimately linked to programmed expressivity through scaling and mapping within Max/MSP that models the kinaesonic relationship between sound processing and physical gesture. Gestures and their location on the body are largely dictated by the performance demands of the composition and ease of articulation. Real-time gestural control of live electro-acoustic processing requires a high degree of physical skill, musicality and aural awareness. The flexibility of the Bodycoder System's hardware, protocols and functionality means that gestural expressivity can be uniquely configured for a range of physicality that corresponds to different types of kinaesonic expressions from moment to moment within a piece.

- **Sonic**

Sonic expression is concerned with the way in which sound subjected to processing and often re-processing[70] evolves over time and can be layered to create dynamic and dimensional soundscapes. Sonic expressivity in terms of my own compositional practice is founded on this notion of evolution and duration. Such evolutions are considered physical/organic in that they are programmed with a quality of movement (transformation) within the larger sonic landscape[71]. Common to all pieces in the *Vox Circuit Trilogy* is the use of multiple simultaneously active DSP processes, often used in conjunction with sampling and looping buffers, to create multiphonic layers of sound, portions of which may be subjected to live gestural articulation.[72] Equally, such transformations may operate as separate entities that are not subjected to any form of additional gestural articulation by the performer. In this case their programmed, shaped and automated evolution alone and not their live/gestural articulation is considered expressive. Therefore sonic expression can be modelled

[70] This might include timbral and textural development, transformation through fragmentation, the use of randomisation and chance processing, transformation through pitch change, spatialisation and evolution through the use of various mixing and fading techniques.
[71] This idea has some correspondence with the notion of *gestural sonorous objects* expounded by Schaeffer (1966) further explored in Von Nort, D. (2009). 'Instrumental Listening: Sonic Gesture as Design Principle' in *Organised Sound*. Cambridge University Press. (14) 2, pp. 177-187.
[72] see Appendix B - technical description of the *Vox Circuit Trilogy.*

entirely within the DSP processing through the programming of variables to create automated sonic events and/or expression that can be shaped (controlled and articulated) through gesture (kineasonics): the gesture of the performer defining the scale and time-frame of sonic transformation. In both cases the nature of the sonic transformation is programmed and scored.

- **Vocal**

The expressivity of the acoustic voice is important not only with respect to its unprocessed presence within the sonic landscape, as something of a soloist, but more crucially in the manner in which it interacts with live processing.

In the *Vox Circuit Trilogy* the timbre, pitch and energy of the acoustic voice is used to enliven, activate and articulate certain electro-acoustic processes. A key part of the development of the *Vox Circuit Trilogy* was concerned with identifying the qualities of acoustic vocal input that resulted in sonically rich interactions. The same concerns directed the phrasing of melody, the quality of accents used and the use of natural forms of vocal filtering - executed by changing the shape of the mouth and the muscular use of the throat and the larynx: generically known as extended vocal techniques.

- **Programmed**

Qualities of sonic expression are modelled in the Max/MSP environment through the use of mapping and scaling processes to translate degrees of physical gesture to control electro-acoustic processes. Expressivity is tuned through the mapping of different ranges of audio and/or visual processing to, for instance, the bend of the arm, leg, wrist etc. Various mapping ratios, for example the proportion of an arm movement to a particular range of sound/visual manipulation, produce specific physical expressivity. For example, a 45-degree bend of an arm can be physically mapped and scaled to scroll through a definable area of a recorded sound sample (see Figure 15, p. 63).

Different scaling ratios vary from sensor to sensor and can be changed from moment to moment within a piece. The real-time expressivity of kinaesonic actions is established through these mapping and scaling choices during the rehearsal process according to various performance preferences including the ease/difficulty of physical execution and the quality of control required.

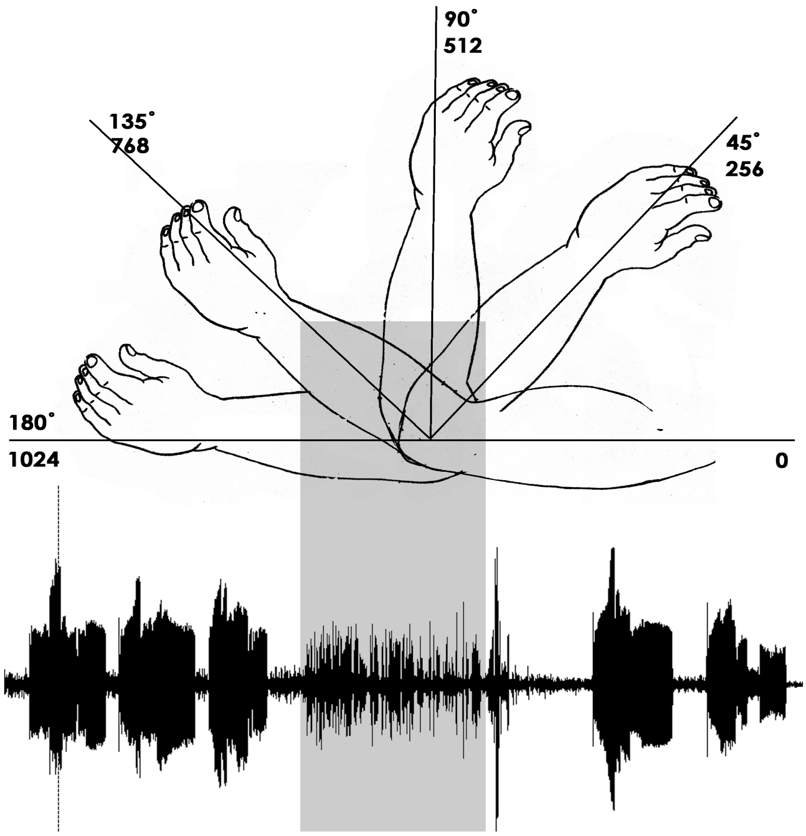


Figure 15. Scrolling a portion of a soundfile using a 45-degree bend of the arm

Interactive expression is therefore achieved through the modelling of gestural, sonic, vocal and programmed forms that are interrelated and combine in various ways.

The following section explores how the four forms of expressivity are articulated within the *Vox Circuit Trilogy* with some specific instances explained.

5.3 Vocal Expressivity

As stated in section 5.2 of this commentary (Forms of Expressivity) the timbre, pitch and energy of the acoustic voice is used to enliven and activate electro-acoustic processes. Vocal expression, within the context of work with the Bodycoder System, is therefore viewed as a form and method of interaction. This kind of interactive 'sensibility' requires a different approach to the more classical perception of acoustic singing that focuses on the precise articulation and consistent production of one vocal score in relation to, but not directly affecting, one or a group of other instruments. In the *Vox Circuit Trilogy* the performer is responsible for the articulation and consistent production of two simultaneously intertwining and interactive sound elements. The first, the acoustic vocal source as well as being a virtuosic presence within a piece also acts as a kind of carrier (raw timbre), catalyst (initiator) and participant (part of a co-existent duality) - to characterise just a few of its roles. The second, the live electro-acoustic soundscape, part of the articulation of which is gesturally embodied by the performer (this will be discussed in a later section), is often multifaceted - constructed out of layers of sonic voices built compositionally through the use of granular samples, pedal notes, multiple live looping recorders, in combination with additional real-time DSP processing. Wilson-Bokowiec has described this as:

> a multi-dimensional dialogue between the acoustic and the electroacoustic which is never really clear-cut in terms of its rules. The qualities of interaction between my acoustic voice and the electroacoustic processes that build into active sonic landscapes is I think, best described as a relationship of ratios. What I mean by this is that there is a kind of live negotiation that goes on between the acoustic voice and the processed. In performance I am acutely aware of what is activating and therefore exerting the most influence over the other. At some point in the work I sometimes have to listen more intently to the electroacoustic consequences of that activation than I do to my own acoustic vocalisation – listening to the other electroacoustic score and adjusting the acoustic voice almost intuitively. At such moments its almost as if my own voice acts as an instrumentalist for the electroacoustic processing instrument as it literally plays the processing. At other moments the ratio flips and I feel the processing working more in counterpoint or as a duality with the acoustic voice.[73]

Such qualities of interaction change from moment-to-moment within each piece, so it cannot be said that a single quality of interaction applies to the entirety of a piece.

With regard to 'playing' and 'adjusting' the acoustic voice in relation to live electro-acoustic processing, what needs to be stated is that this is not improvisational within the finished pieces. Although improvisation is important in terms of the compositional process when it is used as a means of finding sonic relationships. Within the finished pieces it is more a case of what Wilson-Bokowiec has described as a process of tuning, concerning this she says:

> …when I say I'm listening to the live processing and adjusting my acoustic voice – to be more precise – I'm kind of tuning the processing within defined and composed parameters. It's not full extemporisation, you understand, it's more like I'm shaping the sound. For instance, there are episodes in all three pieces when I am, for example, able to open and close the natural filter frequency of the processed sound simply by changing the shape of my mouth. Rather than thinking about how I am changing the acoustic sound of my own voice, which in reality is sometimes quite difficult to hear in performance, I'm listening for the changes I am making in the processing. Depending on the pitch and quality of the voice, these kinds of manipulations affect processed sound in different ways. In some cases the processing is so complex and I guess, dense and dimensional, that it's almost like I can get inside of the architecture of an electroacoustic soundscape and affect small parts of it by executing small changes in my own voice or the physiology of the mouth.[74]

[73] Interview with Julie Wilson-Bokowiec – Dartington College 2010
[74] Ibid.

In *The Suicided Voice* the sung text is, generally speaking, developed out of an interaction with live electro-acoustic processes. It is not formed as a result of wanting to use recognisable pre-defined words. Rather, vocal articulations are derived from explorations into phonic shapes that resonate and interact with live processing. A good example of this is the opening phrases of the first movement which are scored as being sung on single notes, recitative style:

zet-shou-yet-a, zar-ner-zoo

him-me-ya, go-zee-ya, go-zee-ya, gor-zee-ya

Gor[75]

Here it is rhythm coupled with the changing phonic textures of the acoustic voice that resonates and affects the sonic shaping of the live processing. In the third movement, it is pitch coupled with vocal attack and phonic articulations that sculpts a sequence of processed sound which is simultaneously sampled into a looping recorder:

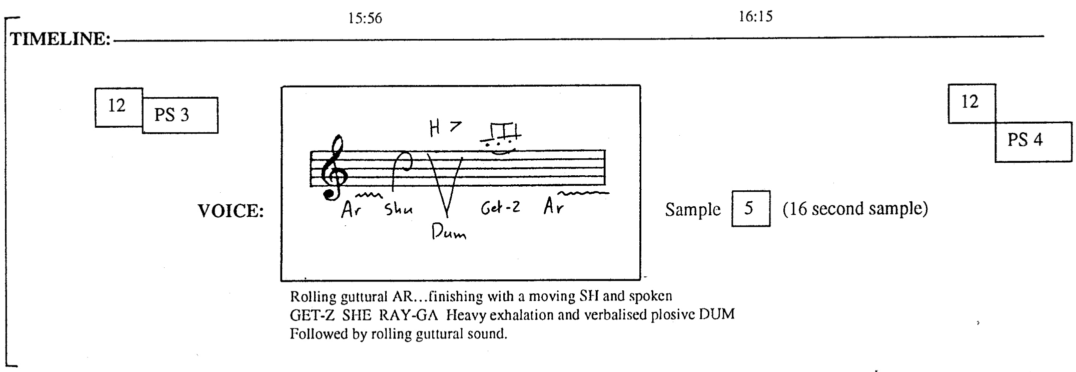


Figure 16. Detail from the vocal score: 3rd movement of *The Suicided Voice*

This combination of pitch movement, attack and phonic articulation is best represented graphically[76] (see Figure 16, above). Although the emphasis in this part

[75] Opening vocal phrases – first movement – *The Suicided Voice*.
[76] Note on the status and function of the vocal score.

of the work is not on precise vocal tonalities, Wilson-Bokowiec's internalisation of the score is such that even the most abstract vocal phrases are the same from performance to performance including their pitch progressions and durations.

> It helps me to memorise the shape and progression of a really abstract vocal phrase if I characterise it in some way – if I attach a kind of dramatic intention to it. By characterising a vocal phrase I am able to engage my imagination, to visualise the shape and quality of the sound. Characterisation helps me to locate the correct physicality I need to manufacture the sound; to shape the mouth, to control the muscularity of the larynx, to create the right breath pressure necessary for some forms of extended vocal articulation and to have a sense of where the sound is being generated from and where it moves to. For example, in the Industrial Movement (third movement of *The Suicided Voice*) I'm vocalising a phrase which is being pitch-changed down several octaves and returning into the auditory space in a twelve second sample loop buffer. I characterise this phrase sequence as Whale – or more precisely Whale song. The idea of the whale helps me to articulate the sound with intention and emotion and to remember the patterns of the phrasing. The manufacturing of the sound requires the voice to move through siren high covered head-tones (located in the upper nasal/temple area of the head) and down into the lowest point of my vocal range – and beyond into deep guttural sounds formed by the breath being pushed into the lower abdomen. Pure tones created by the cover notes are beautifully emulated in the pitch-changed processing that seems to amplify a sense of distance and water-quenched muffle which is very haunting, while the guttural low-register tones sink and rumble into the sub-bass units. The two loop buffers running together; the GET-Z and the WHALE form a really broad and exciting sonic landscape into which other voices are introduced.[77]

The vocal score of *The Suicided Voice* is by no means a complete score of the entire work, rather it is a sketch that has been culled from the performer's working notes and acts as an aide-memoire for the performer in performance and offers 'signposts' and essential technical information with regard to patches and patch changes. The vocal score (included in this commentary) was formalised in 2007 in order that the piece could be submitted to a number of music festivals that required a score to be supplied.

A full performer's score of *The Suicided Voice* that contained all the vocal and gestural annotation, would be of no practical use to the performer in performance since it would contain so much information: technical, notated and graphical. It is therefore more practical to learn and internalise most if not all of the performer's part.

A full score of *The Suicided Voice* and any of the *Vox Circuit Trilogy* pieces would, by its very nature, also have to include the Max/MSP patches, hardware configuration and speaker layout.

[77] Interview with Julie Wilson-Bokowiec – Dartington College, 2010

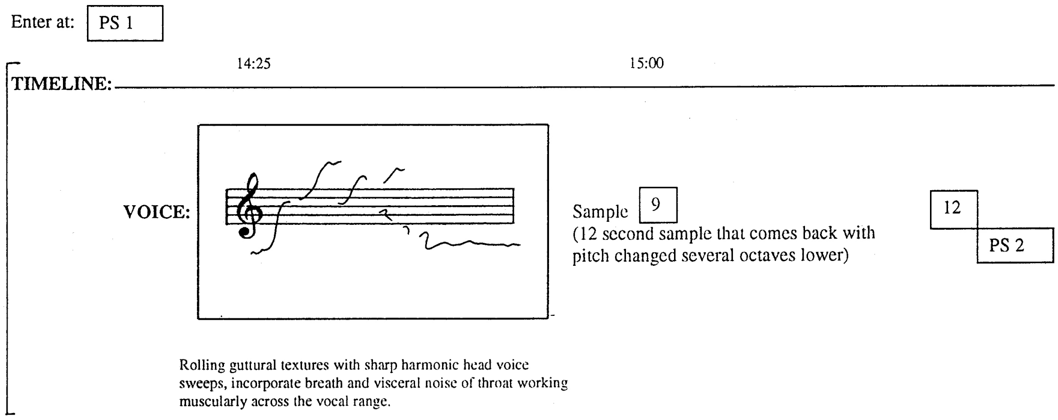


Figure 17. Detail from the vocal score: 3rd movement of *The Suicided Voice*

This technique of vocal 'characterisation' is used predominately in the third movement and again in the fourth movement in conjunction with, what can be recognised as, speech patterns in order to convey the sonic idea of a child speaking. Once again these vocal articulations are executed in conjunction with a variety of live gestural (kinaesonic) expression.[78]

Overtone singing is used to great effect in the second movement where it creates rich multiphonic textures in the live processing. The recall of Preset 3 introduces a positive pitch change that includes a randomisation variable - this randomly offsets the start point of the granular loop.[79] Starting as a seemingly conventional piece of singing, this movement builds into a complex choral sequence of phrases that are sampled, processed and discarded over a low pedal drone and a changing sequence of unvoiced[80] material. The processing parameters in Preset 5 amplify and help to separate sung harmonic overtones so that when the live sample is mapped to the right-

[78] This vocal and gestural expressivity is further explored in *Hand-to-Mouth* when, what might be recognised as both spoken and later classical Lieder phrasing gives an organic structure to purely phonic acoustic articulation that are subjected to one or two levels of live kinaesonic processing this time on the fingers of the hands. (see Appendix C, DVD recording: *Hand to Mouth*)
[79] See Appendix B, p. 17 for a description of the processing used.
[80] Such as a non-definable tone – this concept originates from Vocoder principles where noise based sounds cannot be analyzed in terms of detecting a fundamental frequency.

arm gesture Wilson-Bokowiec is able to isolate six discrete harmonics and play them selectively by moving the right arm.

> I like these moments in the work because it is here that the piece becomes a dialogue between what is generated in the mouth and what is articulated on the body: voice to body. It's a very intimate and intensive dialogue.[81]

The fast smooth blending of sung and re-articulated melodic motifs in this movement is partly achieved by allowing artefacts from the performer's close monitoring system to re-enter the live microphone.[82]

A similar technique of fast progressive sampling is used in *Etch* when two sample loops are used to add multiple single note phrases (sung Bell Canto) to form a choir of chanting over a bed of more ethnic electro-acoustic voices and glitch type fricatives. Wilson-Bokowiec states that,

> What I like about the *Vox Circuit Trilogy* is that it allows me to work across a huge vocal range that is technically very challenging – not so much in terms of the production of the voice but in the movement between different types of vocalisations. The pieces require a very muscular approach to vocalisation that for me is absolutely engaging. As a composer you (sic) are very interested in the evolution of rich organic soundscapes – my role as a singer within the collaborative process is to provide as broad a palette of vocal ideas as possible (if we're improvising with a new processing patch idea) or to try and respond to the vocal ideas you direct me toward (you usually describe in words the feel or textural sense of what you're after) in so doing I stretch my own vocal range and practice.
>
> The same is true of my own technical mastery of the Bodycoder interface: both its developing expressivity and its utility. Sometimes you're (sic) after a level of expressivity and control that I haven't tackled before. In your (sic) prep for the in-studio development process, you may have already notionally programmed the controller end of an MSP patch – simulating control on the PC1600. But for me it's a challenge – I'm not a mechanical control-surface – within the Bodycoder, utilities and expressivities are distributed across my body and it sometimes takes me a while to rationalise the physicality of what you're after. Of course, I'm doing this at the same time as vocalising, which is why the development phase of a new piece can sometimes look and sound incredibly rough. Of all the pieces I think that *Hand-to-*

[81] Interview with Julie Wilson-Bokowiec – Dartington College, 2010.
[82] This was an 'in situation' solution to the problem of sonically blending multiple fast, live sampling which was later solved in *Etch* when two sample loop buffers were used in conjunction with two granular buffers (see Appendix B, p. 50).

> *Mouth* is the most difficult in terms of the nature of its vocal and physical expressivity.[83]

In *Hand-to-Mouth* the live acoustic voice is completely absent from the electro-acoustic mix. There is no audible counterpoint between the acoustic voice and the electro-acoustic. The energy, the breath and raw textures and tonalities of the acoustic voice are used to activate and articulate a range of complex DSP processing. The use of a four-voice *scrub* abstraction working in conjunction with a six-voice *tapharm* abstraction (including pre-delays programmed into six *tap~* objects) means that (from a performance point of view) the processed voice is not immediately responsive. Gestural kinaesonic expressivity is, on the other hand, one-to-one.

> …this very distinct discrepancy between immediate kinaesonic expression and delayed live processing of the voice, couple with the fact that I can't hear my own acoustic voice in the performance mix, is what makes this piece difficult to negotiate. I find that the delays make me feel like the processing is always lagging behind what I'm vocalising which has the effect of making me work harder - almost as if to try and promote immediacy, which is of course an impossibility.[84]

Programmed expressivity not only affects the performer's physicality but also their performance modality: their emotional state as well as the quality of effort and focus they employ from moment to moment. For a performer, these effects are both profound and challenging since they are not solely generated by the performer, in response to the composition, but are largely symptomatic of the expressive and interactive relationships that are configured within the Max/MSP environment. This is another reason why it is essential for the performer to be present during the development process of a piece – in order to take part in the negotiation of those qualities of effort and focus. I am fortunate that I work with a performer who relishes challenges and views her interactive relationship – her emotional, physical and technical journey through a piece, as an essential part of the performance itself.

---

[83] Interview with Julie Wilson-Bokowiec – Dartington College, 2010.
[84] Ibid.

5.4 Gestural Expressivity

To speak purely about gesture is really only to speak about choreography: gesture for gesture sake.[85] Gestural expressivity in relation to the *Vox Circuit Trilogy* is always kinaesonic: gesture is always in interactive relationship with sound. Sonic articulation is the reason for gesture. The relationship between gesture and sound is programmed in the Max/MSP environment where gesture is mapped and scaled to sound processing whether that is filtering, modulating, pitch changing etc., or scrolling through a granular loop buffer. By changing scaling ranges for a particular gesture to sound processing event the physical control of a particular kinaesonic relationship is altered. Large gestural ranges can be scaled for a smaller arch of sonic effect and small gestural ranges can be scaled to affect a large range of sonic effect. A huge choice of kinaesonic physicalities are made available through the use of scaling permutations. Changes in mapping and scaling within individual message boxes produce different kinaesonic sensitivities from moment-to-moment within a piece.

Scaling and mapping is used throughout the *Vox Circuit Trilogy* as the basis for modelling kinaesonic expression. To illustrate how scaling relates to gestural expressivity the third movement of *The Suicided Voice* provides a good example. Here scaling is used to configure a range of kinaesonic physicalities within a single movement and across two limbs of the performers body. The performer moves through four presets that offer different scaling configurations for both right and left arm gestural control. These are annotated within the message boxes as s1slo and s1shi and s2slo and s2shi respectively (see Figure 18, p. 71).

---

[85] See arguments for moving away from the notion of dance and choreography in section 1, p. 4 of this commentary.

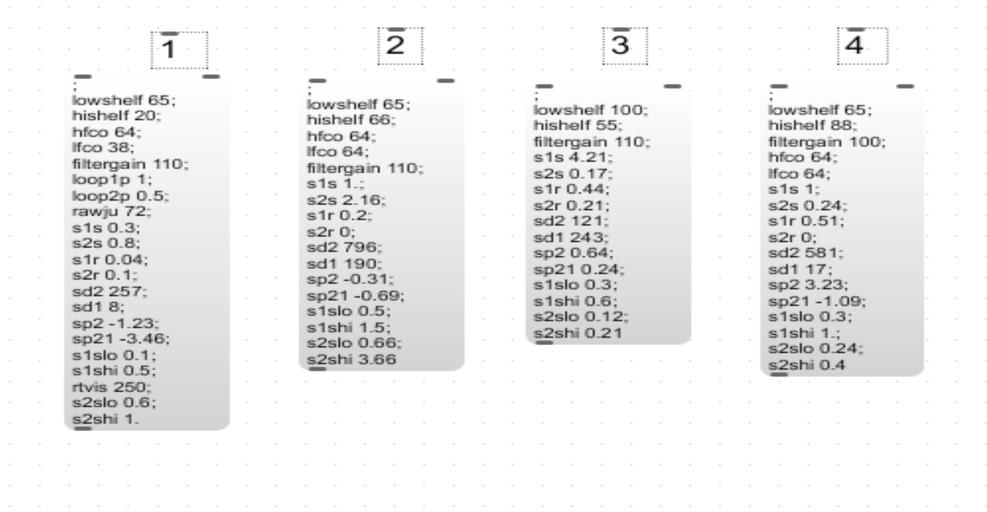


Figure 18. Preset messages boxes: 3rd movement of *The Suicided Voice*

Scaling across the right and the left arm in this movement is quite profound, with the right arm operating across the largest control ranges of between 3.0 to 0.09 and the left arm operating across a much smaller control range of between 1.0 to 0.3 (see Figure 19, below).

Left Arm	Left Arm	Left Arm	Left Arm	Right Arm	Right Arm	Right Arm	Right Arm
Preset 1	Preset 2	Preset 3	Preset 4	Preset 1	Preset 2	Preset 3	Preset 4
0.1 – 0.5	0.5 – 1.5	0.3 – 0.6	0.3 – 1.0	0.6 – 1.0	0.6 - 3.66	0.12 - 0.21	0.24 - 0.4
= 0.4	= 1.0	= 0.3	= 0.7	= 0.4	= 3.0	= 0.09	= 0.16

Figure 19. Right and left arm scaling: 3rd movement of *The Suicided Voice*

In terms of kinaesonic expressivity these calculations equate to the scale (size or range) of sound processing that can be controlled and affected across the 180 degree bend of the arm. A range of scaling across the four presets provides a blend of different types of kinaesonic expression (see Figure 20, below). Within each preset both the right and left arms are subject to different ratios of scaling and therefore offer different qualities of kinaesonic expression.

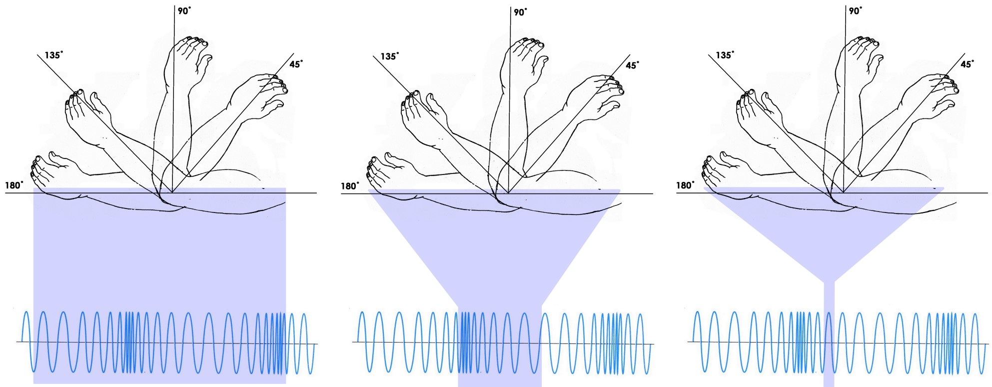


Figure 20. Notional graphic representation of the effects of scaling for gestural expressivity

A larger scaling range gives the performer a broader range of processing to control. This potentially requires more physical precision and/or offers the opportunity for the performer to selectively 'play' areas of processing/pitch. Choices are, of course, subject to compositional preferences, so scaling to gestural expressivity of live sound processing is always a negotiation between what the composition requires at that moment and the practicality of physical control from the point of view of the performer. This negotiation of gestural expressivity evolves throughout the development and rehearsal stages of a piece. Wilson-Bokowiec states that,

> …sometimes, even though the arm is scaled for a massive range of gestural control, I'm only going to a small portion of that range. This is something that evolves through the development of a piece – the initial intension might be to manipulate a sound across the full range, but when you (sic) hear it, you (sic) might only want me to articulate a portion of it. If we go on working on a section/expression like this, it very quickly gets into my body memory (my kinaesthetic memory) then, rather than re-scaling that event for a small range (which would change the quality of the gesture for me) its easier for me to keep the range wide – even though it's technically much harder to hit the specific portion or pitch within a wider range.[86]

[86] Interview with Julie Wilson-Bokowiec, Dartington College, 2010.

As a performer, Wilson-Bokowiec has also evolved a range of expressive preferences: quick and fine control is generally assigned to right arm manipulation (in *The Suicided Voice* and *Etch)* and it is not uncommon for processing to be moved from one limb to another during the course of the development of a new piece in accordance with expressive preferences. In the third movement of *The Suicided Voice* the general scaling ranges for processing across the four presets by the right arm is much greater than those assigned to the left arm: the right arm range is 3.0 to 0.09 as opposed to the left arm which has a general range of between 1.0 to 0.3. This gives some indication as to the difference in terms of gestural expressivity between the right and the left arm in this movement. Here the right and left arm work in counterpoint with each other. Both right and left arm are mapped to two *ss8pr* (*stutter-pshift* abstractions) but each arm has a different expressive relationship and interaction with each, identical, abstraction. In the piece Wilson-Bokowiec uses the left arm to locate a series of pitch/speed shifts. Because the scaling for the left arm is small these gestures look almost like gear changes, while the right arm is much more lyrical inside of very large scale ranges that require more finite expressive control.

The one-to-one kinaesonic gestural articulation of the *ss8pr* abstractions, like many of the processes within the *Vox Circuit Trilogy* is further influenced by the use of variables such as randomisation, in terms of the *ss8pr* abstraction this is manifest by the probability of repetition. Variables such as these exert an influence over vocal and gestural expressivity, and are components of another layer of expressivity that is modelled within the Max/MSP environment.

5.5 Programmed and Sonic Expressivity

Max/MSP enables a unique degree of expression to be modelled within the programming environment. Sonic expressivity starts with the design of the DSP processing with the acoustic voice providing the raw input material. The nature of the DSP processing can be of such complexity that even without the addition of gestural articulation the results can be sonically expressive in their own right. A good example of this is the opening sung phrase of *Etch*. This phrase is sampled into a granular buffer and subjected to processing which results in the randomisation of a broad range of multiple pitch changes. The additional quantization of these pitch values produces a rich multiphonic soundscape. The level of randomisation and quantization is chosen (composed) in order to create a self-evolving, extremely organic[87] choric identity.

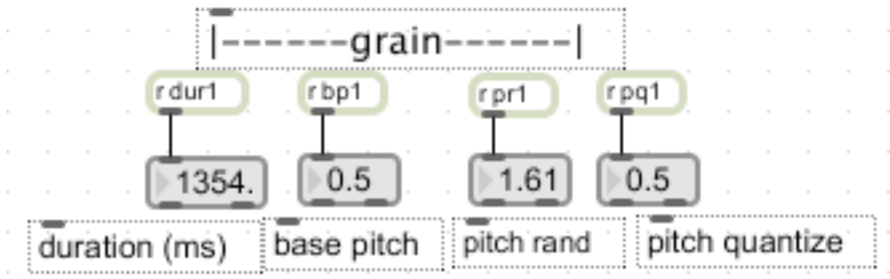


Figure 21. Preset grain values opening phrase *Etch*

Gestural articulation of this particular phrase is minimal and dedicated to granular scrolling across the axis of the right arm, this has the effect of setting the location of the start point of the granular loop, giving the sonic impression that pitch clusters are chasing the position of the arm. Randomisation creates a dithering latency that is

[87] Organic as in a living organism in which there is constant movement such as in an animal – manifest as blood flowing through veins and arteries etc. – a metabolism or flow of elements.

characteristically organic and appropriate for the complex nature of this particularly multiphonic layer which I have labelled here as ‘*Ethnic*’ (see Figure 22, below).

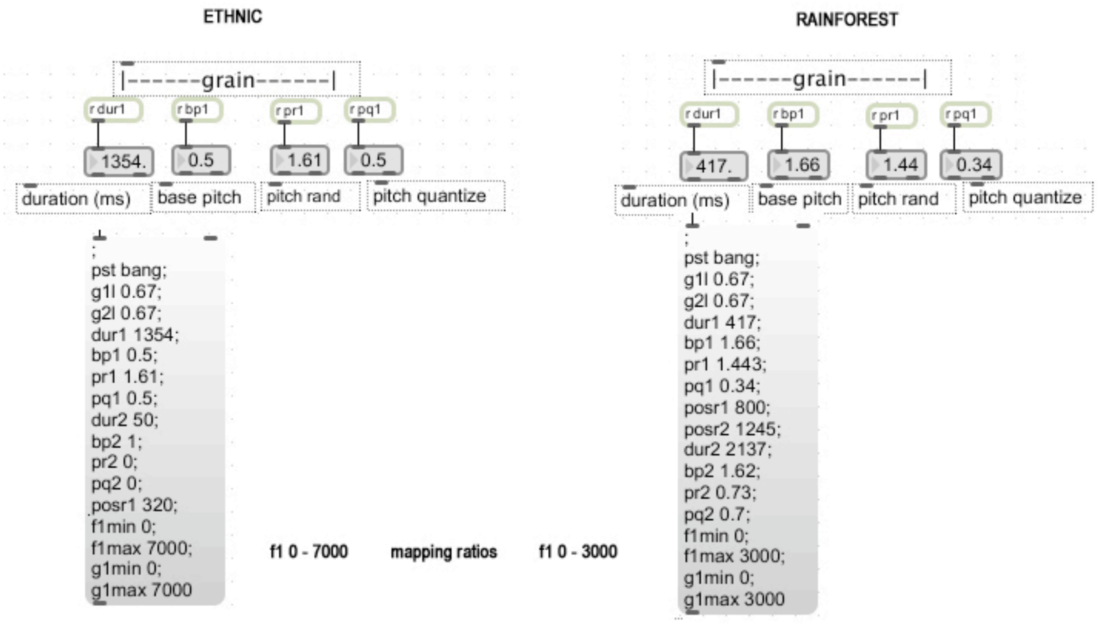


Figure 22. Preset message boxes for preset 1 and preset 5 - *Etch*

Later in the piece a second granular buffer that is subject to a greater degree of kinaesonic/gestural articulation is added to the mix (here notionally referred to as *Rainforest).* The grain duration (set at 417) is much smaller than in the *Ethnic* layer (set at 1354) as is the sensor scaling (0 – 3000) as opposed to (0 – 7000) and crucially the randomisation is less profound (1.443). This means that the performer is able to access small areas of sound with precision because of reduced randomisation. Gestural articulation within this preset state is therefore seen to be acute and precise and kinaesonically one-to-one. Although the basic architecture of the two granular abstractions are the same, small changes in programmed and sonic expressivity produces very different effects. The *Ethnic* preset has more innate sonic expressivity programmed into its variables, while the *Rainforest* Preset requires gestural/kinaesonic articulation in order that is sonic landscape is fully revealed/expressed. In this way, the sonic character of each of the two presets is made distinct. Navigating between the two preset states the performer is seen to move between different qualities of gestural expressivity. The 'tweaking' of aspects of a DSP patch to produce distinct expressivity is time consuming because it generally effects three levels of expressivity: programmed, sonic and gestural/kinaesonic. However, this painstaking work is a critical part of the interdisciplinary nature of the compositional process.

In *The Suicided Voice,* DSP processing includes graphic and parametric filtering and two types of granulation[88] (see Figure 23, below).

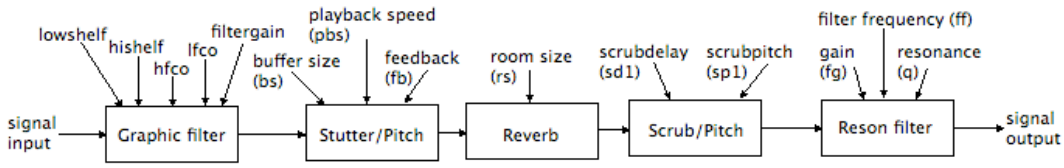


Figure 23. Signal path: 1st movement of *The Suicided Voice*

Electro-acoustic processes are coupled with live vocal expressivity[89] to produce a range of complex soundscapes that are further articulated by the real-time sensor control of various DSP parameters. In the case of movement one these parameters are resonant filter frequency (ff) controlled by the right arm sensor, scrub pitch (sp1) controlled by the left arm sensor and stutter playback speed (pbs) controlled by the wrist sensor.

---

[88] For an in-depth technical description of Max/MSP processes used here see appendix B, p. 9
[89] Discussed in Vocal Expressivity on p. 63 of this commentary.

In terms of pitch the vocal input is first processed by the stutter-pshift abstraction that is pre-set at a positive (>1) value of 1.28 (pbs) and a probability of repetition value of 0.6 (rp). A secondary, negative (<1) degree of pitch change (sp1) is affected by the scrub processor that produces a rich, varied and evolving sound which is sonically expressive even without additional gestural control.

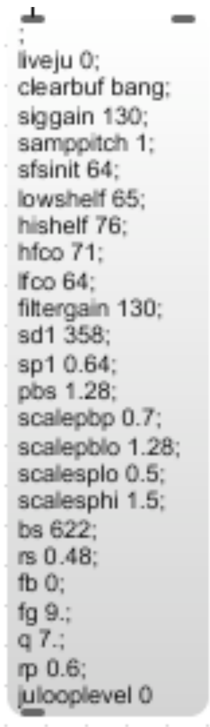


Figure 24. Message box: 1st movement of *The Suicided Voice*

Programmed expressivity is modelled in the scaling of sensor data to various aspects of DSP processing. At the start of the piece the left arm controls the pitch of the scrub processor, scaled between values of 0.5 (scalesplo) and 1.5 (scalesphi) where it is used to affect a rising glissando. The addition of a well-defined and sensitive rise in pitch, affected by the left arm, amplifies this form of expressivity. The gestural control of pitch contributes to the texture of the audio due to the fact that the two types of granular pitch abstractions generate artefacts that are introduced into the sonic landscape.[90] Further timbral modification of the voice is affected by the bend of the right arm controlling the filter frequency of the resonant filter. Pre-setting the resonance (q) of this filter to a value of 7 produces a narrow range of frequencies articulated by the right arm. At 1'27"[91] into the movement preset 2 is recalled that sets the resonance (q) of the filter to a value of 2. This has the affect of broadening the range of filter frequency that results in a more subtle degree of programmed and sonic expression. The pre-programmed changes in scaling between the two presets has a profound effect on the degree of sonic expressivity that is intimately linked to the gestural form.

- **Section summary**

It is evident that within the Bodycoder System and particularly in relation to the *Vox Circuit Trilogy* none of the four forms of expressivity work in isolation. Each form is intrinsically linked and interrelated. This intertwining of expressive forms and the compositional sensibilities that this requires is a unique aspect of the work. We have seen that the performer is affected by choices made in the programming and rehearsal/development stages of the composition that impact on their physicality, performance modality and vocal delivery. It is evident that the performer has to operate with multiple levels of awareness and is not simply a puppet with the composer 'pulling the strings'. The importance and, indeed, necessity of working inside a collaborative process with composer and performer working together to negotiate levels and qualities of expressive interaction cannot be overstated.

[90] See Appendix B, p. 12 for an explanation of generated audio artefacts.
[91] See Appendix C, DVD recording – *The Suicided Voice*

This process of intimately working together to develop new interactive works defines an authentic and distinctive form of collaboration that will be discussed in the following section.

6. Collaborative and Compositional Processes

Working collaboratively with a performer is not only a conscious artistic choice but one that is necessitated by the real-time and interactive nature of the work. It is difficult (although not entirely impossible[92]) to simulate the finite qualities and often multiple levels of gestural expressivity executed by the Bodycoder performer on less expressive studio based control surfaces. In terms of the *Vox Circuit Trilogy,* the acoustic vocalisations of the performer form the raw input material of the three pieces – this too is difficult to simulate without the presence of the performer.

Programmed expressivity such as sensor scaling, mapping and response composed within the Max/MSP software, also impacts upon the physicality (gestural expressivity) of the performer, it is therefore necessary that the performer participates in decisions that prescribe their physicality.

Because of the level of real-time control and responsibilities for both initiation and navigation of the Max/MSP environment as part of the realisation of the live performance, it is necessary that the performer is completely cogent with the larger hardware and software architecture of the piece. This knowledge is established through the compositional/development and rehearsal phases of a piece.

[92] I have used MIDI data, from a PC1600 controller, to simulate the performers real-time gestural control of certain live sound processes in order to formulate a range of program strategies in order to develop small MSP patches and compositional sketches as a precursor to the collaborative making process. However these experimentations in no way match up to the type of sensitive expression and control that a performer brings to the work.

The development and learning of the acoustic vocal score, the internalising of the gestural kinaesonic score, and an understanding of the larger architecture of a piece is established over periods of intensive rehearsal.

The performer's collaborative input and their intimate knowledge of the architecture of a work is a defining characteristic of the practice. This knowledge affords the performer both security within the live performance/composition and a level of autonomy that excludes the need for outside interventions from the mixing desk. This produces a truer level of virtuosity, not simply in terms of quality of gestural and vocal expressivity, but also in terms of self-determined control within the pre-composed structures.

Because composition in terms of the Bodycoder System and the *Vox Circuit Trilogy* means the articulation of types of interactive expressivity, the compositional/making process involves the slow movement-by-movement configuration and negotiation of all four elements. This is slow and painstaking work that in effect collapses aspects of technical development, sound composition and rehearsal into one.[93] The benefits to the performer of such a collaborative making process is that they are able to develop their performance skills along side the technological developments and my own compositional ambitions and influencing choices that impact upon their own performance expressivity. As the pianist and composer Bradford Gowen asserts:

> When a composer and performer are brought together by a work that is their joint concern, there is stimulation far above the level of practical, mutual need. The composer can express himself beyond the confines of notation (and may even learn

[93] Residencies at facilities such as the Banff Centre for the Arts (for the creation of *The Suicided Voice*) and The Confederation Centre for the Arts (for the creation of *Etch*) have provided the time and seclusion required for this kind of focused collaborative process.

> how his notation can be made more precise), and the performer is brought closer to the spirit and the letter of the music at the same time. In a piece that involves playing inside the instrument, the composer may learn from the player about variations in interior construction from one type or size of piano to another, and may revise his writing accordingly. Sometimes, even to play on the composer's piano gives the pianist a new concept of the intended sonority. If the composer has written with the pianist's individual style and capabilities in mind, he will be interested in the success of his attempt. Interpretations evolve and solidify as point after point is discussed. "What did you really mean here?" "I am surprised by the way you played it, but I like it." "That's just what I had in mind." "I like to use some rubato." "I had actually thought of it *this* way." "Is the tempo all right?" In such exchange lies the life-giving collaboration essential to music.[94]

In terms of my own work, conversations with the performer may centre on qualities of kinaesonic gestural/programmed expressivity "Can you map that to a shorter or larger physical range?" or "perhaps I can try that processing on the wrist rather than the elbow", "Can you try that vocal phrase against that looped sample and scroll with the right arm?" This type of collaborative dialogue moves the work beyond the boundaries of one person's imagination and experience. Of major importance to my work is the fact that my collaborator is also my spouse, this means that discussions about the work and creative processes continue outside the rehearsal studio. We also share and are knowledgeable about each other's personal creative processes and have, through our work with the Bodycoder System, strived to push creative boundaries and challenge each other's technical skills. Over the years the technology, together with our own skills, processes and ambitions for the work, have evolved side-by-side. What might be said to be unique about my work and creative processes has arisen out of this long-term collaboration whereby "transformative contributions are born from sharing risks and challenging, appropriating and deepening each partner's contribution"[95]

---

[94] In the liner notes for EXULTATION, New World Records 80304 An Artistic Collaboration by Bradford Gowen http://www.newworldrecords.org/liner_notes/80304.pdf. accessed 4/6/10

[95] John-Steiner, V. (2000). 'Joined Lives and Shared Work' in *Creative Collaboration*, Oxford University Press. p. 96.

As Vera John-Steiner points out:

> Individuals in successful partnerships reach beyond their habitual ways of learning, working, and creating. In transforming what they know, they create creative syntheses.[96]

[96] Ibid., p. 96.

7. Artistic Manifesto

In an unpublished article written for Mute magazine in 1997 I revisited a vision of a hypothetical interactive performance that had its origins in a short artist's statement I originally wrote for the alternative music magazine *Flowmotion* (now lost) in the early 1980s.

> Sitting in a theatre, a performance is about to begin, the audience goes quiet as the performance space fades to darkness. A low, almost subsonic drone is emitted from the loudspeakers, gradually a single spot of light beams down from above to reveal a lone; strangely clad performer crouched in a fetal posture.
>
> The performer slowly opens her arms, as she does so a flock of mutated birds seem to leap from the loudspeakers. She slowly stands upright and the drone's timbre is brightened, filtered into fragmenting elements of pulsating and rhythmic sound. Standing fully upright with arms now outstretched we see the performer, masked and clothed head-to foot in sculpted leather with anatomical details standing out in bold relief like a weird cross between a Dominatrix and a member of the Borg collective. The performer suddenly clasps her arms around her chest, the lighting immediately and dramatically changes state, a cluster of metallic sounds leap out of the loudspeakers to slowly die down, replaced by a steady metallic beat following perfectly the rhythmic patterns of her feet. The performer, keeping her arms around her chest, opens out her elbows, the low drone is immediately replaced with washes of electroacoustic noise, panning left and right and back again – synchronous, as she opens and closes her elbows. She leaps into the air, the beat stops, the wash of noise stops when she lands, to be replaced by silence. Now legs and arms are outstretched, this pose held for several seconds, until the performer starts to twist her torso slowly from side-to-side, as she raises her arms a strange vocoded sound is raised in volume which is timbrally mutated as she twists and turns, the sound in perfect symmetry with the dance. The artist moves her legs, each movement sculpting and morphing the vocoded elements to produce a rhythmic sequence of filtered sound. Behind the artist a large video screen flickers into life, on the screen we see the artist as an avatar, she continues to move, sounds and image flowing seamlessly. A rotating icon emerges from one corner of the projection, continuing her dance the performer reaches out to touch the image, as the avatar simultaneously makes contact a powerful percussive loop is triggered in perfect time with her movements, the vocoded elements weaving in and around the loop as she bends and opens her arms and legs. Several more rotating icons emerge on the screen, the performer moves her hands to touch these images which trigger sound samples of strange metallic origin producing cross rhythms to the main sequence. The music builds in intensity until the performer turns to face the audience and falls to her knees, plunging the stage into darkness and creating immediate and utter silence. Head now held down a ghostly whispering emanates from the loudspeakers, as the performer raises her head the lighting follows this movement by illuminating the face and we see that she is singing quietly into a head mounted microphone. The performer stretches out her arms and as she does so her voice is amplitude modulated by the movement of one arm and ring modulated with the other. Her arm movements create a subtle array of modulations as the beat frequencies lock and unlock with the source tones of her voice. As she stands the original bass drone is re-triggered to join the palette of sound – filters opening and closing with the movement of her arms.

This early vision formed a statement of intent that has largely been realized in my subsequent work with the Bodycoder System. It is a vision of the performer, situated – vitruvian-like (see Figure 25, below) - at the center of, and in total control of, a live interactive performance environment. Importantly this figure exists not as a puppet or a prisoner of the environment, nor are they seen as a dominating principle, but as a creative entity, whose physical presence is encoded in degrees and ratios for virtuosic interaction with the world in which they exist.

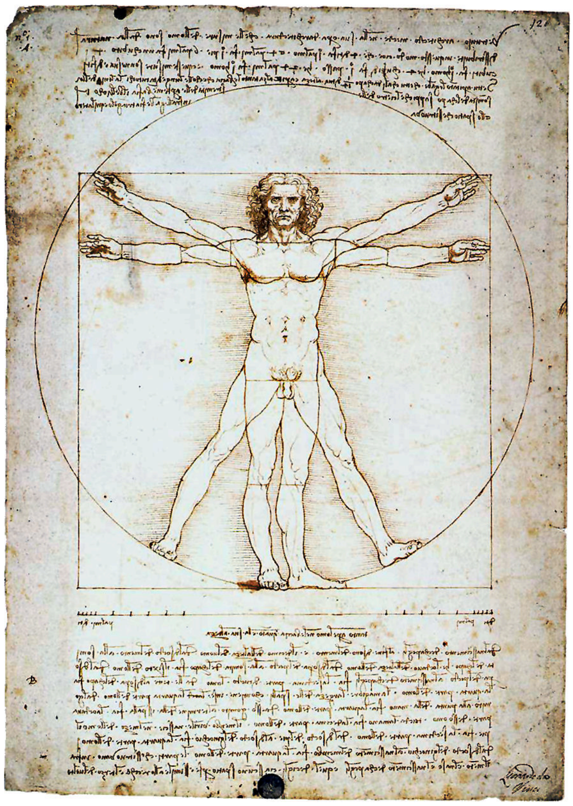


Figure 25. Vitruvian man

While the individual pieces of the *Vox Circuit Trilogy* have been performed both within concert hall and theatre settings, the trilogy is more ideally situated within a neutral 'black box' setting more readily available in theatre spaces. Here, video content is projected across the entire cyclorama (backdrop) of the stage that has the effect of placing the performing in the midst of the video images inside a visual landscape. Such an example occurs in *Etch* where the performer appears within kaleidoscopic terrains of bugs, pond life and vegetation. In this situation the scale of the video images diminishes the sense of the presence of a projection screen. The cyclorama itself can also be made to vanish into darkness. It is therefore possible for video images to appear out of the darkness - as in *Hand-to-Mouth* where 3D images create whirlpools and vortexes within the darkness. Furthermore, within the neutral and darkened space of a theatre it is easier to control and direct the audiences' experience of the work. Darkness within the auditorium also helps the speaker system to disappear from the audiences' view in order that the listener has a more immersive experience of the perception of sound and sonic entities moving in space rather than as emitted from identifiable speaker locations. The choice to costume the performer is also partly in order to hide and disguise the sensor technology. This is a conscious aesthetic decision to remove any questions arising from high visibility of technology on the performers body, about what that technology is and how it is working. Diminishing the visibility of sensor technology directs attention toward the physical language of interaction as it is expressed kinaesonically. Secondly, costuming the performer, both in theatre but particularly in concert hall settings, also signals the unusual nature of the performance modality that is about to be witnessed. The decision to remove much of the technology from the gaze of the audience particularly for *Vox Circuit Trilogy* is as a direct result of experiences and feedback from audiences of my work in the past. In my experience audience members tend to fall into one of two categories; the digital natives - those who have grown up with digital technology and who recognize, without any explanation or intellectual concern, the principles and language of physical interaction – and those generally older members of the audience who are not digital natives whose experience of the performance is often disrupted by questions and concerns for the nature of the technology. For this section of the audience, hiding the technology from view helps them to have a more sensual and immersive experience of sound, image and performance articulation. Although, in the early works such as *Bodycoder* and *Cyborg Dreaming* I did seek to actualize the notion of the cyborized body and create an image of the post-human by emphasizing and displaying the technology on the performers body, this was a brief flirtation with the idea of the technological enhanced body which quickly seemed at odds with the expressive principles that were beginning to emerge and inform the work. From 2000 onwards it was important for me to set my work apart from other prominent artists whose work was being strongly positioned within the realm of the post-human and whose use of technology was theorized as ‘prosthesis’ – such as Stelarc (see Figure 26, below).

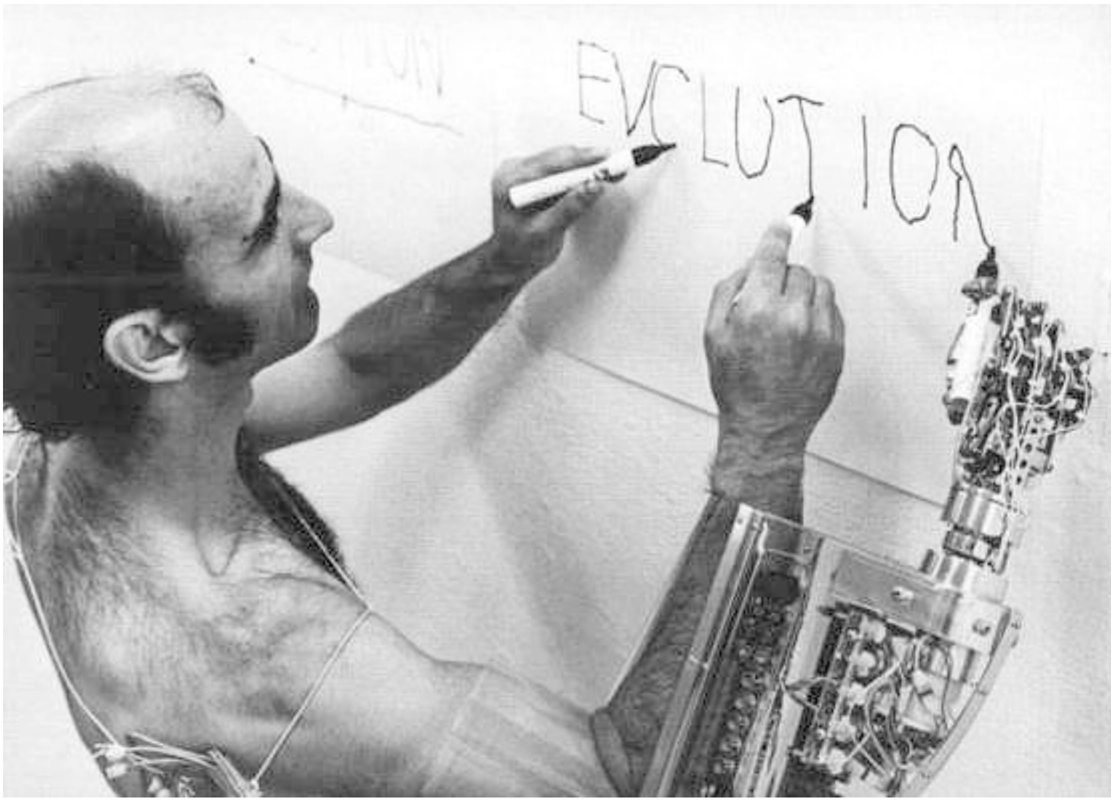


Figure 26. *Handwriting* (1982) Stelarc and his ‘third hand’.

Stelarcs' work is focused on the utilitarian relationship of body and technology and, although it is often theorized as more than this, his performative actions are, according to his own stated intentions, demonstrations of the functioning of a body with technology. In contrast, my interest lies more in the sensually expressive potential of both the performer and technology and the creation of composed pieces of work.

In 2002/3 when I began work on *The Suicided Voice* with the performer Julie Wilson-Bokowiec, the sensor array of the Bodycoder System had gone through a significant development that greatly expanded the number of input channels that would allow the performer to navigate more complex MAX/MSP patches and give access to more control parameters. We had also made the decision to abandon the physical language of dance that up until this point characterized gestural expressivity. It was a significant moment and we both approached the idea of making a new work with some trepidation.

The decision to use the voice as live input for control and transformation was, for me, a natural one and had its origins in both my early musical tastes and influences – particularly the vocalizations of Damo Suzuki of *CAN* whose use of voice could be described as instrument: singing that freely slides between tonality, screams, shouts and free extended vocalisations, often articulated through indecipherable utterances that had the shape of words but did not carry semantic meaning. I was also interested, from a compositional point of view, in timbrally rich breath-controlled instruments, the playing of which could include vocalisations such as the didgeridoo and trombone. In 1995, while in residency at STEIM, Amsterdam I purchased my first

Yidaki or Didgeridoo, with a view to teaching myself to play the instrument and in particular to master the art of circular breathing. I was aware of the potential of this instrument to generate unusual and rich timbral material - I later incorporated didgeridoo sounds as a vocoder carrier signal for my interactive trombone piece *Zero In the Bone*. The Didgeridoo featured prominently in my dance/music piece *Ghosts* (1997), providing most of the source material for the piece. The ability to use the vocal cavity and in particular the tongue to create overtones and to vocalize (sing or shout) over the root drone in Didgeridoo playing created complex multiphonic textures, this was of particular interest and directly led me to explore how multiphonics could be achieved my means of extended vocal techniques alone. This period of experimentation led to the exploration of Tuuvan Khomei and Sygyt vocal forms and, using my own voice, I experimented with how these sounds could be used as real time sonic sculpting elements: as modulators for vocoding pre-composed sound source material. I used this technique to impart real-time sonic expressivity in sequences of my tape work *Amera* (2009). It is important to state that the use of these aboriginal vocal forms have no cultural significance in any of my compositions post 1997, they are incorporated purely as a resource of unusual sonic signatures.

For Wilson-Bokowiec the movement from dance to the voice was more of a leap of faith. Although she had had a classical music training with voice as her main instrument, she had not worked with her voice for more than fifteen years, this she felt was advantageous, since she didn't feel encumbered by a deeply entrenched vocal technique that might otherwise restrict access to more experimental and extended forms of vocalization. Wilson-Bokowiec also brought to the project the title of the work *The Suicided Voice*, derived from an essay by the theatre artist Antoine Artaud concerning the painter Vincent Van Gogh whom Artaud viewed as a 'suicided' artist both in his attempts to redefine what painting was and in respect to his moving beyond the boundaries on what society defined as painting both in terms of practice and cultural artifact. The use of the term in relation to the phase of work we were about to embark upon seemed both bold and appropriate in terms of our intention to move into new unknown territories of practice, which ultimately led to the development of a new methodological approach to composition defined in the previous section of this commentary.

Approaching a new phase of work that resulted in the development of the *Vox Circuit Trilogy* using the voice was only really part of the story. It was a consequence of working with completely live vocal material that a) intensified the collaborative processes with a performer, b) altered the compositional process and c) led me to focus more particularly on qualities of expressivity and the language of interaction that is really at the core of these works.

In the programme note for the *Vox Circuit Trilogy* I state that the works are an 'exploration of the voice beyond the larynx'. What this actually means is quite complex. It concerns the interactive and compositional relationship of the acoustic voice and electronic voice, the physical/gestural re-articulation of voice by the body, extending into areas of automated and live articulation and distribution in relation to programmed expressivities, all of which are discussed in detail in section five of this commentary. Further, in approaching voice, I made the decision not to use words in order to convey meaning. In general lyrics in music hold little interest for me, explicit meaning carried by words is secondary to the significance of the voice as a sonic instrument. In listening to any type of music incorporating lyrics I have never assimilated the meaning or content of the words but have always heard/experienced the voice as sonority. The work of vocal artists such as Lisa Gerrard and Elizabeth Fraser who work with their own unique vocabularies that give precedence to the sonority of the voice and its ability to convey emotional meaning without using recognizable words is of far more interest to me. It seems to me that once the voice is released from the dominance of words, it can be heard for what it is: a powerfully human instrument of great expressive range and complexity. Devoid of word-based language the voice originates and sounds from a more immediate and visceral place, just as divorced from the technical language of contemporary dance the physicality of the body is derived from a more naturally responsive and intuitive place. It is not true to say that the *Vox Circuit Trilogy* does not contain any words, *The Suicided Voice* contains the only word-based phrases in the entire trilogy, these are:

> This bow, this sound…
>
> Deep in the throat…

These phrases, as well as the isolated words 'traveling' and 'process' appear in the second movement of the piece in which the 'O' of 'bow' is sampled and pitched changed one octave down. The pitch change allows the natural overtones and multi-phonics of the vocal sound 'O' to be heard phasing. This phasing or beating of the sound that coincidentally resembles the bowing of a stringed instrument like the double bass, abstracts the 'O' of 'bow' subverting the word meaning and shifting it into the expressive logic of the sonic landscape. Similarly the phrase 'deep in the throat' is sampled in a granular process that both randomizes and pitch changes the phrase upwards and the looped segment of 'D-ee' is selected for re-sampling. The meaning of the word 'Deep' is thus subverted through pitch change and compression into a glitch-like stuttering expression and is abstracted into a purely sonic register. In the same way gender specific vocal registers are wilfully subverted and fractured. Extended vocal techniques make available unusual acoustic resonances that generate rich processing textures and spiral into new acoustic and physical trajectories that largely traverse culturally specific boundaries - crossing from the human into the virtual, from the real into the mythical and the purely sonic. In the *Vox Circuit Trilogy* the voice, transformed and re-embodied within the interactive medium, becomes a fluid originality that is defined only by its own transmutations and its authentic sonorities.

8. The Vox Circuit Trilogy

In composing the *Vox Circuit Trilogy* I set out to explore the relationship between the live acoustic voice and the live electro-acoustic processing of the voice. I also wanted to investigate the way in which the voice can be used to produce unusual and authentic textures and in particular the use of extended vocal techniques.[97]

The Bodycoder performer operates on two expressive levels: gestural (kinaesonic) and vocal.

Why a Trilogy?

After the creation of *The Suicided Voice* it was decided that it would be useful to look at certain elements within that piece and to investigate both the vocal and Max/MSP processes that were used in the composition. The results of this investigation would entail the writing of two new pieces of work, forming a trilogy of pieces, with the *The Suicided Voice* being at the centre of the three works.

8.1 The Suicided Voice (2003/2007)

In the summer of 2003 we undertook a short self-directed residency at the Banff Centre, Canada in order to create a new piece for vocalist and Bodycoder System. A large studio with sound system and, importantly twenty-four hour access was made available for the duration of the visit.

[97] "The musical instrument with the greatest control intimacy is probably the human voice. A singer's vocalic control is largely innate and highly informed by speech as well as music. The range of musically desirable sounds produced by the human voice is enormous-far greater than that commonly used in traditional singing as amply demonstrated in the research work of the USCD Extended Vocal Techniques Ensemble". In Moore, F. Richard (1998). 'The Dysfunctions of MIDI'. *Computer Music Journal*, (12) 1, p. 22, (Control Intimacy is defined in the footnote on p. 108 of this commentary).

The approach taken to developing this work involved the construction of several processing patches in the UK. This would allow more time in residency to experiment and formulate the composition. In simulating performer control and manipulation of DSP processes a PC1600 MIDI controller proved to be an invaluable tool - enabling the control of variable parameters in the pre-designed Max/MSP patches, in effect simulating the sensor elements that would be later used in performance. The use of this type of control surface has already been documented in section 4 of this commentary proving essential in the early stages of the compositional process. The faders give tactile control over several parameters, which can be scaled to provide the kinaesonic expression foreseen in performance and without the necessity of the performer being present.

Pre-fabricated bend sensor elements and a pair of data gloves were made available for use in the new piece. Two bend sensor elements were fitted into small sleeves which could be fitted over each elbow, a third bend sensor was fitted into a sleeve sewn into one of the data gloves and a fourth sensor was fitted into a fabricated band designed to be worn around the neck.

- **The compositional process**

At the outset it was decided to incorporate various ways of singing by utilizing extended vocal techniques to create unusual timbral archetypes. This has led to some radical ways of using vocal sounds that have their origins in a workshop and performance given by composer Trevor Wishart and vocal ensemble Singcircle on the subject of extended vocal techniques in the 1980s. Subsequent to attending this event various Eastern European methods of ‘Throat singing’ – sometimes referred to as overtone singing were investigated. The most notable type of his type of singing can be found in the Mongolian region of Tuva and can produce some exceptional sounds, usually multiphonic in nature with a distinct use of strong overtones accompanying the fundamental or root tone. There are many artists working in the field of extended vocal techniques. One such contemporary artist, Joan La Barbara, has focused on using her voice as a multi-faceted instrument, exploring the use of multiphonics and extended vocal techniques with and without the use of electronics. Another notable performer and composer working in this field is Meredith Monk who, for the past forty years, has created and performed works using her voice as ‘instrument’ utilizing extended vocal techniques and multi-media presentation to produce pieces of historical importance both for live and recorded media.

Development of the piece took the form of long structured improvisations with the performer wearing the Bodycoder System, controlling the patch parameters identified as giving the most effective control and expressivity of the processed audio.

In realising the composition there were multiple factors that were influential in the compositional process both with further development of Max/MSP patches and the vocal material that was stimulating at the time. The fact of working in a fairly isolated environment meant that the sounds, visuals and cultures of the location and peoples were readily assimilated. An early visit into Banff town led to the meeting and subsequent lengthy discussion with an elderly First Nation resident who was exhibiting artefacts in a tepee situated in Banff public park. A visit, on the same day, to the railway station and goods yards led to obtaining numerous images in the form of digital photographs and movies - some of which were extremely iconic in nature. These images were to contribute to the visual elements of *The Suicided Voice*.

As three main processing patches[98] had already been designed it was necessary to restrict the time devoted to the investigation and experimentation of each of these patches before bringing them all together to structure the piece. Using ideas and material developed during the initial development of the patches enabled the performer to extemporize on this material, extending the tonal range into a higher register. Changes to the patches were needed to accommodate the higher tonal range and notes were taken to enable these changes to be programmed during breaks in the vocal sessions. These experiments were recorded on to a Mini Disc recorder and were listened to, usually on the same evening, which was essential to objectify the earlier material. Written notes were taken so that the most effective material could be re-visited the next day - re-recording the results for further analysis. In this way many small sections were identified within each processing patch, which worked well individually. These sections could be recalled by firstly storing the processing patch variables in patch presets to be recalled as dictated by the composition. As one finger switch had already been identified as a way to advance presets within each of the processing patches it was then a matter of placing the patches in an order that made compositional sense. Finally, notating this information, graphically, on a written score (see Appendix D, Scores). It is important to state that not all of the identifiable patches were used in the final composition and some still remain, unconnected – archeological 'ghosts' of the creative process. Structuring and refining the patches usually took place in the studio space, leaving time for the performer/visual artist to

[98] See Appendix B for an in-depth description of the processing patches used.

work on compiling and structuring the visual patches hosted by the Xpose software. As previously noted, the visual material, small movies and still images to accompany the piece, were collected in and around the town of Banff that gave the piece a sense of ‘place’ and continuity.

It was the intention at the outset to structure the composition in the form of several movements that could take advantage of the distinct types of processing employed in each patch: the technology, in effect, providing a manifold on which to build the composition. By allocating three finger switches to recall the three main processing patches the performer could recall each individual patch at any time.

- **Structuring the Piece**

The Suicided Voice starts with the performer singing a vocal phrase that is immediately processed by two different types of granular pitch processor (scrub and stutter_pshift)[99]. This heavily processed material is then filtered using the right arm sensor, affecting a filter frequency sweep of the processed voice. The processed output of the *scrub* processor is fed to a reverberation abstraction. The reverberation ‘tail’ of this abstraction is ‘frozen’ and released at various times by the performer activating a toggle function on a dedicated finger switch. Additional fricative, voiced and unvoiced articulations are expressed before affecting a rise in the pitch of the live and frozen material - performed by a sensitive bend of the left arm. The rising glissando is soon followed by a slow pitch decrease, again performed on the left arm. The movement ends with the performer holding the tone at a pre-defined pitch before advancing to the next movement by selecting processing patch three.

[99] The content and delivery of this phrase is documented in the section on Vocal Expressivity on p. 66 of this commentary.

The start of movement two begins with the performer speaking the phrase; "This bow, this sound". This phrase is sampled into a granular buffer (number one), the performer then scrolls through the sample using the right arm sensor. The granular preset is incremented and the performer then locates the word 'bow' on the right arm to smoothly loop the 'ow' portion of the word. Using a dedicated finger switch this loop is re-sampled into a looping recorder that is automatically faded up into the audio mix after four seconds, once this fade has been registered the pitch of the loop is performed as a glissando, transposed down by precisely one octave by a slow bend of the wrist sensor. The performer is required to locate this pitch transposition accurately and sensitively before releasing the control of the wrist sensor leaving a low bass drone that is continually looped for the rest of the movement. Movement two continues in this fashion with new material, ranging from sustained overtone, sirening and Bell Canto singing, sampled into granular buffer one, manipulated by manually and precisely scrolling through the buffer and then sampled twice at various times into the second of the two looping recorders.

The first version of the piece, performed during the Banff residency, only employed one looping recorder for the bass drone. A second looping recorder was added later in the UK when the piece was finally refined. This process of sampling and re-sampling/looping of granular material, whilst also advancing through five preset states, with corresponding preset changes in variables such as grain size, pitch and duration, results in an expressive and dynamic movement which evolves and builds in varying timbral complexity due to the use the of the rich harmonic phrasing required of the performer. The movement finishes by the performer clearing the second granular buffer, leaving only the original bass pedal that is finally faded out – initiated by the performer advancing to the next movement and processing patch two.

At the start of movement three the performer produces a low-pitched sustained vocalisation and immediately samples this into a looping recorder. This looped material is automatically faded up into the audio mix after two seconds but plays back an octave lower. This low 'drone' continues to be looped for the duration of the movement.[100] The performer advances to the next preset and samples a short rolling guttural phrase and explosive "Duuh!" into a sixteen second looping recorder that is automatically faded up to join the audio mix after two seconds. This additional sample loops at the original vocal pitch. The performer then adds additional live material to this mix, advancing and cycling through four patch presets - pre-programmed to recall different values of *scrub~* processor pitch and *stutter_pshift~* processor pitch. Each arm sensor, controlling the pitch of each of two *stutter*-pshift~ processors, is frequently used during the duration of the third movement to select and modulate extreme registers in the live vocal material with the performer vocalising a combination of speech patterns and sung phrases (see appendix D - vocal score, third movement). The sensitivity (scaling) of sensor data produces different levels of kinaesonic expressivity that changes between each preset within the processing patch. The expression and dynamism that these control elements give to this movement can readily be observed in the DVD recording of *The Suicided Voice* (see Appendix C). Additional variables recalled in each preset include the input filter values; lowshelf, highshelf, low frequency and high frequency cut-off and filter frequency gain values.

---

[100] This low drone was internalized by Wilson-Bokowiec as 'whale song' and is documented in the section on Vocal Expressivity on p. 67 of this commentary

In common with the first movement, the process of connecting the output of one type of pitch shifting abstraction into a different type of pitch shifting abstraction was found to give extremely interesting timbral results.[101] The movement continues by repeatedly cycling through the four sets of preset variables whilst the performer adds new vocalisations, predominately using extended vocal techniques, whilst continually modulating the pitch of the affected voicing using the left and right arm sensors. The movement concludes by the performer advancing to the next processing patch, this patch change initiates a programmed fade of the looping material.

The final movement of *The Suicided Voice* requires the performer to return to processing patch one, the performer recalling a dedicated patch preset and sampling a short, sung, vocal phrase into a looping recorder whilst actively modulating the cut-off frequency of a low pass filter by use of the right arm sensor. A final patch preset is then recalled, the performer accompanying the simple looped phrase with vocal phrases in different registers, imparting both a high childlike voice and a deep, adult sounding voice. These pitch changes are affected by the wrist sensor element whilst the sensor on the performer's neck controls the amount of reverberation mix of the processed vocals. The piece concludes with a distinct and controlled increase in reverberation whilst the right arm sensor modulates the filter frequency of the low pass filter.

[101] For an explanation of this process see Appendix B, p. 11.

8.2 Hand to Mouth

The second piece in the *Vox Circuit Trilogy*, entitled *Hand to Mouth* was a radical departure from any of the earlier pieces written for the Bodycoder System as it was decided to locate all sensor elements on the fingers of the hands of the performer, including the proportional bend sensors.

In composing *Hand to Mouth,* I designed the piece so that it should be impossible to hear the acoustic voice through the sound diffusion system – the extreme forms of sound processing used in this piece were informed by and extended the processing used in the third movement of *The Suicided Voice.* From the performer's' point of view *Hand to Mouth* is a duet between the acoustic voice and the performers live, interactive manipulation of the sound processing. However, the audience only hears the processing side of the duet. This presented an interesting, seemingly, disassociated, soundscape produced by the smallness of the gestures witnessed and the assumption, by the audience, of what the female larynx might produce.

- **The compositional process**

Several Max/MSP processing patches were designed capable of producing extreme and diverse sonic material, some which were variations and extensions of patches I had employed in designing *The Suicided Voice*. The idea was to be able to connect these processing patches in different combinations and be able to dynamically switch between 'preset' configurations during the performance, to enable this facility I used the *matrix~* object (see appendix B, p. 28)

Experimenting using my own voice and a PC1600 midi controller, to facilitate sensor emulation and control, led to the creation of numerous processing presets that included *matrix~* state i.e. stored interconnections between the various DSP processing patchers. Included in these presets were sensor scaling values which, by experimentation, gave the most expressive and dynamic control of the variables designated to be manipulated within each unique preset state.

- **Structuring the piece**

Experimenting with a variety of voiced and unvoiced articulations; processed with the various, interconnected processing patchers, produced a broad range of expressive sounding timbres. Improvising with these voicings and recalling different combinations of presets led to formulating a basic structure of the piece but it was only when the performer actually started rehearsing with these configurations that a distinctive identity began to emerge. The close collaborative process between composer and performer ensured that the piece could evolve with the enhancements that virtuoso physical and vocal expressivity can give to a piece of this nature. Although the physical levers used in the piece are naturally quite small, i.e. the finger bends, the focus of the performer and audience is entirely on the hands and fingers, similar to forms of Indian, Buddhist and Balinese dance practice. In the case of *Hand to Mouth* the hands and fingers are not meant to provide a decorative function or indeed provide any cultural reference or significance. As gestural expressivity is focussed entirely on the hands this sometimes results in extremely small lever movements of the fingers producing much larger electro-acoustic soundscapes. This idea of the small manipulating the large is further exploited through the use of large-

scale video projection. The same finger movements used to manipulate sound processing are mapped to and affect the video processing and projection.
This visual and gestural/kinaesonic control, together with the opportunity to extemporise pre-defined vocalisations means that new material gets incorporated into the basic structure of the piece. As a composer working in this medium this means that an intimate dialogue is achieved at an early stage of the rehearsal process, sometimes leading to unexpected areas of process control, effectively enhancing the dynamic of the composition. This 'evolution' in the compositional process continues well after the piece has formally been written, for example, slight variations in sung harmonics which are sampled and transformed mean that new material is produced. This dynamism in performance ensures that each piece is constantly evolving and that no two performances are ever exactly the same.

8.3 Etch

Etch (2007) is the final piece in the *Vox Circuit Trilogy* and was composed during a residency at the Confederation Centre for The Arts located on Prince Edward Island (PEI), Nova Scotia during two weeks in June 2007. During the residency we were given access to two rehearsal spaces at the MAC theatre in downtown Charlottetown where we were able to set up the Bodycoder System and have 24-hour access to the facilities.

- **The compositional process**

Before the visit various Max/MSP processing patches had been designed so that most effective use of the residency could be used to compose and rehearse the piece. Although my own voice was used in designing the Max/MSP patches I had not, at the stage of the residency, formulated any type of vocal forms or structures to be used in the piece. The idea was to return to the type of compositional process that resulted in *The Suicided Voice* and attempt to use the influence of being in a culturally and physical remote location to help form the piece.

Location

Prince Edward Island is situated to the east of Quebec and only recently joined to the mainland by the Confederation Bridge. A large island but with a population of only 138,000 means that the island has retained certain old world charms and values that are not usually present in the rest of North America. Large open spaces with an abundance of woodland areas means that there is a lot of native wildlife on the island and, as we were staying with an artist living within one of these woodland areas, this meant that we were exposed to sounds produced by the native wildlife which was going to become an important part in the composition. I was also heavily influenced by the creativity and art of our host, Hilda Woolnough,[102] an extraordinary fine artist whose sculptures, paintings and etchings were present over the whole house, hence the resultant title of the work: *Etch* and we dedicated the piece to our fine host and friend, sadly no longer now with us.

During the week previous to our residency we presented a performance of *The Suicided Voice*. This was part of the Intermedialities Conference, in Quebec City, where we were exposed to French-Canadian cultures, particularly Inuit sounds and images especially when visiting museums and exhibitions both in Quebec City and Montreal. Of particular interest were the soapstone sculptures filling the majority of

[102] Hilda Woolnough (1934 – 2007). http://en.wikipedia.org/wiki/Hilda_Woolnough, accessed 6/12/10

the gallery space in the Museum of Inuit Art in the old part of Quebec City. Many of these sculptures depicted the transformation of the human into animal, a principle common to many shamanic ideas. These multiple exposures to sounds, art and cultures ended up defining both the structure and content of the resultant composition.

- **Structuring the piece**

Working in conjunction with the performer several vocalisations had been identified that were interesting, both tonally and melodically, particularly a Yakut[103] form of open throat singing that utilizes a yodel/broken note effect. An interesting and musically stimulating processing effect was achieved by experimenting with granular pitch transpositions and randomizations. The resultant changes in these pitch values were stored in a Max/MSP patcher preset; Preset One. This processed chant was to form the opening phrase that was repeated and subsequently sampled into a granular buffer. The pitch randomisations and the dynamic and live scrolling through the granular buffer by the performer produced an exciting and rich bed of material that resembled a singing tribe of pygmies found in jungle areas of South America. This was obviously not North American Inuit singing, but, at this early stage, potential cultural influences had not been identified. The granular sample was repeatedly modified by scrolling through the sample buffer using the right arm bend sensor that was subsequently recorded into one of the looping buffers.

During the process of improvising with different types of vocal material a number of Bel Canto phrases were found to work well as added layer to the repeating chant. The reason that the Bel Canto voicing proved to work well with the tribal sounding

[103] Yakut is a remote region in Siberia inhabited by a nomadic race of people who use a particular form of throat singing only found in that region of Asia.

material was the fact that Yakut voicing utilizes open throat singing in which the sounds are produced low down in the chest and not filtered in the mouth cavity, thus producing a harmonically rich sounding voice. Bel Canto singing produces a very rounded type of voicing produced by filtering tones in the upper part of the vocal cavity. The resultant, smooth-sounding voice worked to complement the open throat voicing repeating in the looping buffer. A new Max/MSP preset was chosen by experimentation, enabling scrolling through of the sample buffer without any pitch transposition so that a number of Bel Canto phrases could be repeatedly sampled into the granular buffer One.

Etch was composed by a process of experimenting with vocalisations, treating them with various preset configurations and then by assigning and finally mapping real-time control of previously designated parameters, i.e. granular scrolling and random panning depth.

Sketches were recorded on to a flash recorder. These recordings were later analyzed outside of the rehearsal/compositional space. Some of these sketches, although interesting in themselves, were discarded, as they simply did not contribute meaningful material to the evolving composition. As mentioned earlier in this section that there were several influences that were to inform the composition of the piece, the initial Yakut chant motif being one that was later identified as related to being exposed to Inuit art, in particular the numerous soapstone sculptures in Quebec City. Another influence that was to inform the composition was the fact that we were staying in a remote woodland area that came acoustically ‘alive’ at night with the sound of birds and insects. Hearing these sounds on a daily basis together with memories of a visit to the Insectarium in Montreal, images of which were extensively used in the visual elements of the piece, resulted in the production of heavily processed vocalisations which resembled the sounds of birds, insects and frogs. Different types of animalistic vocalisations using various extended vocal techniques were heavily processed using large pitch and grain size variations that were further manipulated using the right arm bend sensor. *Etch* is constructed in a linear fashion repeatedly sampling new vocalisations into either one of the two granular buffers, manipulating the sample looping in that buffer, and recording this material into one of the two looping buffers. In this way complex and evolving material is produced to result in an engaging and visually stimulating piece that can vary subtly or otherwise from performance to performance.

Etch takes a number of elements from the first three movements of *The Suicided Voice.* These elements include the use of a powerful 'ethnic' voice in the opening Yakut chant that relates to movement one in *The Suicided Voice* that uses an original ethnic type phrase in the first moments that piece. The use of Bel Canto voicing that returns at various times during *Etch* sees a corresponding form in movement two of *The Suicided Voice.* Finally the use of non-sung extended vocal techniques sees an analogue in movement three of *The Suicided Voice,* producing 'insect-like' voices that are then accompanied by Bel Canto clusters of harmonies that conclude the piece.

The Suicided Voice, being the central piece in the trilogy, can be said to contexualize the two pieces that were created to complete the trilogy, in that the piece clearly comprises of processing elements and compositional sonic palettes that are included both in *Hand-to-Mouth* and *Etch.*

9. Conclusion:

The design of a single performer controlled interface realized in *The Navigator* (1995) was the beginning of a process of investigation that not only led to the development of a range of custom hardware interfaces, but also to the evolution of new and innovative approaches to composing for interactive electroacoustic music and ultimately the identification of four discreet types of expressivity associated with the Bodycoder System. Working across four levels of expression; vocal, sonic, programmed and gestural (kinaesonic) has necessarily led to the development of innovative new methodologies and approaches to composition exemplified in the *Vox Circuit Trilogy* and explored in this commentary. Composition for the Bodycoder System is not only concerned with what is heard (the sound composition itself), but also how expression is codified for execution by a performer interacting with a live Max/MSP environment. In terms of the *Vox Circuit Trilogy* composition is a vertical (as opposed to a horizontal) process of construction, necessitated by the need to attend to the interaction of four layers of expressivity. This is realised by manipulating the various degrees and ratios of interaction between expressive elements that gives rise to each fully formed piece. Because, my compositional practice is bound up in its live execution, the involvement of a performer in the development processes of new works is important since their physical expressivity is part of the composer's' remit. The intensive form of collaboration with a performer, described in this commentary, coupled with a particular compositional methodology that has developed as a result of striving to move beyond simple control to more acute, intimate,[104] complex and more

[104] F. Richard Moore uses the term 'Control Intimacy'; "determining the match between the variety of musically desirable sounds produced and the psycho-physiological capabilities of a practiced performer. It is based on the performer's subjective impression of the feedback control lag between the moment a sound is heard, a change is made by the performer, and the time when the effect of that

precise modes of live electroacoustic and kinaesonic expression, is peculiar to my work with the Bodycoder System.

Charting the evolution of my interactive practice has shown that several concerns were brought to light. From *The Navigator* where control meant the triggering of musical sequences and samples with few moments of gestural expression, to *Zero In The Bone* where more sophisticated levels of interaction facilitated an increased level of expressivity that was nevertheless restricted by the necessity of having to conform to a 'timeline'. Additional concerns were the limitations of interacting with fixed sensor mechanisms and DSP processes and sensor scalings that were fixed and immutable. These were limitations that informed the development and were, to a certain extent, overcome with the first generation of the Bodycoder System. Although hampered by both software and hardware restrictions, works created with the early incarnations of the Bodycoder System were, within the emerging field of interactive performance, groundbreaking (particularly with respect to the level of control assigned to the performer) and helped to polarize my thinking with regard to the particular qualities of expression possible and the potential of new compositional methods that were beginning to arise out of the work. My early identification of emergent kinaesonic expressivity further focused my practice on finding more flexible ways of accessing, manipulating and varying the qualities of live physical articulation of sonic material. I have discussed how moving away from a software/hardware architecture with fixed protocols to Max/MSP was a crucial moment in the development of a more flexible compositional medium. In

---

control change is heard". In Moore, F. Richard (1998). 'The Dysfunctions of MIDI'. *Computer Music Journal*, (12) 1, p. 21.

contextualizing the work I have evidenced how early dance and electro-acoustic music pieces gave way to more definitive kineasonic concerns. Placing the work within an emergent interactive performance context I have reflected upon a range of relevant systems and artists working with 'on-the-body' sensor mechanisms in order to demonstrate how the *Bodycoder System* and the *Vox Circuit Trilogy* in particular, occupies an original and authentic niche in this field of contemporary music performance.

I have demonstrated the uniqueness and innovative nature of The Bodycoder System in providing a highly flexible control mechanism through the use of the on-line/off-line protocol. Design and compositional strategies ensures that the performer has total structural, navigational and expressive control over each piece of work without third party intervention from the mixing desk or computer in order to facilitate a level of virtuosity on a par with established forms of acoustic music. This has only been achievable through a very long-term collaborative relationship with a single performer and through my own commitment both as a composer and technologist to the development of a single performance system. Within the field of interactive electroacoustic music such relationships and commitment to long term practice and development is rare and perhaps unique given the level of virtuosity and skill reached in the *Vox Circuit Trilogy.*[105]

Future artistic developments include the exploration of gestural spatialisation. *V'Oct (Ritual)* for vocalist and the Bodycoder System (first performances in 2011) broadens

[105] The need for long term collaboration, commitment to a single interactive system or instrument that enables skills development, has long been identified as lacking within the field and has been identified as being a major hurdle to the evolution of real virtuosity, see for example: Dobrian, C., and Koppelman, D. (2006) 'The 'E' in NIME: Musical Expression with New Computer Interfaces' in *NIME 2006 Proceedings,* p. 279.

the scope and range of expressive forms to include 8 channels of gestural spatialization as an extended form of kinaesonics. The gestural control of sound spatialisation was previously explored in *Etch* but was limited in its functionality and restricted to two channels. Gestural control of sonics over an eight channel system presents a number of practical and aesthetic challenges. Chiefly among these is how to integrate spatialisation into the compositional integrity of future works in terms of sonic and programmed expressivities. Also of concern is how gestural spatialisation is executed in such a way that it is not seen as merely demonstrative. Gestural spatilization also adds to the control responsibilities of the performer,[106] and it is expected that there will be a range of skills and particular perceptions that will need to be identified and refined. This may change established patterns of practice and will inevitably add another dimension to the collaborative process.

[106] Simon Emmerson sees this as a challenge for the future stating; "We might consider giving the performer some say over what happens in projecting field information. This would complete our idealized control revolution returning considerably more power to the performer than current systems allow". In Emmerson, S. (2007). *Living Electronic Music*. Ashgate Publishing Limited. Hampshire & Burlington VT. p. 96.

Bibliography

Arfib, D., Couturier, J., and Kessous, L. (2005). 'Expressiveness and Digital Musical Instrument Design' in *Journal of New Music Research* (34) 1.

Baalman, A., Moody-Grigsby, D., and Salter, C. (2008). 'Between Mapping, Sonification and Composition: Responsive Audio Environments in Live Performance' in *Computer Music Modelling and Retrieval Sense of Sounds* Volume 4969/2008.

Birringer, J. (2010). 'Moveable Worlds/Digital Scenographies' in *International Journal of Performance Arts and Digital Media.* Intellect (6) 1.

Bokowiec M. A., & Wilson-Bokowiec, J. (2003). 'Spiral Fiction' in *Organised Sound*. Cambridge University Press. (8) 8.

Bongers, B. (2000). 'Physical Interfaces In The Electronic Arts – Interaction Theory And Interfacing Techniques For Real-Time Performance' in *Trends in Gestural Control of Music,* CD-ROM, IRCAM, Paris.

Bongers, B., and Harris, Y. (2003). 'Approaches to Creating Interactive Spaces From Intimate to Inhabited Interfaces' In *Organised Sound* (7) 3.

Bosma, H. (2003). 'Bodies of Evidence, Singing Cyborgs and Other Gender Issues in Electrovocal Music' in *Organised Sound.* Cambridge University Press. (8) 1.

Bromwich, M. (1995). 'A Single Performer Controlled Interface For Electronic Dance/Music Theatre' in *The Proceedings of the International Computer Music Conference*. International Computer Music Association, San Francisco, CA.

Bromwich, M. (1997). 'The Metabone - An Interactive Sensory Control Mechanism For Virtuoso Trombone' in *The Proceedings of the International Computer Music Conference*. International Computer Music Association, San Francisco, CA

Bromwich M., & Wilson, J. (1998). 'Bodycoder: A Sensor Suit And Vocal Performance Mechanism For Real-Time Performance' in *Proceedings of* the *International Computer Music Conference.* International Computer Music Association, San Francisco, CA.

Cadoz, C. (2009). 'Supra-Instrumental Interactions and Gestures' in *Journal of New Music Research* (38) 3.

Collins, N. (2010). 'Musical Exoskeletons: Experiments with a Motion Capture Suit' in *The Proceedings of New Interfaces for Musical Expression Conference 2010*.

Danjoux, M. (2009). 'Wearable Performance' in *Digital Creativity.* Routledge (20) 1-2.

De Laubier, S. (1998). 'The Meta-Instrument' in *Computer Music Journal* (22) 1.

Derney, M., Leman, M., Lessafre, M., Maes, P-J., and Moelants, D. (2010). ‘From Expressive Gesture to Sound: The Development of an Emboddied Mapping Trajectory inside a Musical Interface’ in *Journal on Multimodal Interfaces.* Springer (3) 1-2.

Dixon, S. (2007). ‘The Rise Of The Cyborg’ in *Digital Performance A History of New Media In Theatre, Dance, Performance Art, And Installation.* MIT Press, Cambridge, MA.

Dobrian, C., and Koppelman, D. (2006) ‘The ‘E’ in NIME: Musical Expression with New Computer Interfaces’ in *The Proceedings of New Interfaces for Musical Expression Conference 2006.*

Emmerson, S. (2007). *Living Electronic Music*. Ashgate Publishing Limited. Hampshire & Burlington VT.

Gurevich, M., and Trevino, J. (2009) ‘Expression and its Discontents: Toward an Ecology of Musical Creation’ in *The Proceedings of New Interfaces for Musical Expression Conference 2009.*

Hemment, D. (1998). ‘Bodycoder And The Music Of Movement’ in *Mute* magazine. Issue 10.

Hunt, A., and Kirk, R. (2000). ‘Mapping Strategies For Musical Performance’ in *Trends in gestural Control of Music,* CD-ROM, IRCAM, Paris.

Hunt, A., and Wanderley, M. (2002). ‘Mapping Performer Parameters to Synthesis Engines’ in *Organised Sound.* Cambridge University Press. (7) 2.

Hunt, A., Wanderley, M., and Paradis, M. (2003). ‘The Importance of Parameter mapping in Electronic Instrument Design’ in *Journal of New Music Research* (32) 4.

Impett, J. (1994). ‘A Meta-Trumpet(-er)’ in *Proceedings of the International Computer Music Conference 1994*, San Francisco, CA.

Jessop, E. (2009). ‘The Vocal Augmentation Manipulation Prothesis (VAMP): A Conducting Based Gestural Controller For Vocal Performance’ in *The Proceedings of New Interfaces for Musical Expression Conference 2009.*

John-Steiner, V. (2000). ‘Joined Lives And Shared Work’ in *Creative Collaboration* Oxford University Press.

Kampmann, W., and Schmidt, H. (1998). *Can Box: Book,* Medium Music Books, Munster, Germany.

Miranda, E., and Wanderley, M. (2006). *New Digital Musical Instruments: Control and Interaction Beyond the Keyboard.* A-R Editions, Inc.

Moore, F. Richard (1998). ‘The Dysfunctions of MIDI’ in *Computer Music Journal*, (12) 1.

Nort, D. (2009) 'Instrumental Listening: Sonic Gesture as Design Principle' in *Organised Sound*. Cambridge University Press. (14) 2.

Ng, K. (2002). 'Sensing and Mapping for Interactive Performance' in *Organised Sound.* Cambridge University Press. (7) 2.

Tam, E. (1995). *Brian Eno, His Music And The Vertical Colour Of Sound*, Da Capo Press, Inc.

Wilson-Bokowiec, J., and Bromwich, M. (1999). 'The Bodycoder System: Intensifying The Collaborative Process Through The Use Of New Technology', in: Enders, B. & Stande-Elbe, J. (eds.) *Global Village – Global Brain – Global Music*, Osnabruck, Germany: Electronic Publishing.

Wilson, J., and Bromwich, M. (2000). 'Lifting Bodies: Interactive Dance – Finding New Methodologies In The Motifs Prompted By New Technology – A Critique and Progress Report With Particular Reference To The Bodycoder System' in *Organised Sound.* (5) 1.

Wilson-Bokowiec, J., and Bokowiec, M. (2006). 'Kinaesonics: The Intertwining Relationship Of Body And Sound' in *Contemporary Music Review. Special Issue: Bodily Instruments and Instrumental Bodies.* London, Routledge Taylor & Francis Group. (25) 1+2.

Wilson-Bokowiec, J., and Bokowiec, M. (2010). 'Sense & Sensation: The Act Of Mediation And Its Effects' in *Intermedialities*. CRI Universite du Montreal. 12.

Siegel, W., and Jacobsen, J. (1998). 'The Challenges Of Interactive Dance: An Overview And Case Study' in *Computer Music Journal.* (22) 4.

Siegel, W. (2009). 'Dancing The Music: Interactive Dance And Music' in *The Oxford Handbook of Computer Music*, Oxford University Press, England.

Webb, B. (2007).'Partners in Creation' in *Contemporary Music Review*, Routledge. (26) 2.

Winkler, T. (1995). 'Making Motion Musical: Gesture Mapping Strategies For Interactive Computer Music' in *Proceedings of the International Computer Music Conference.* The International Computer Music Association, San Francisco, CA.

Winkler, T. (1998). 'Motion Sensing Music: Artistic And Technical Challenges In Two Works For Dance' in *Proceedings of the International Computer Music Conference.* The International Computer Music Association, San Francisco, CA.

Winkler, T. (1998). '*Composing Interactive Music – Techniques and Ideas using MAX*'. MIT Press, Cambridge, Massachusetts.

Internet links:

An Artistic Collaboration by Bradford Gowen
http://www.newworldrecords.org/liner_notes/80304.pdf accessed 4/6/10

Counterdance:
www.myspace.com/counterdance - accessed 17/12/10

Dance and Technology Zone:
http://art.net/~dtz/ - accessed 18/11/10

Michel Waisvisz:
http://www.crackle.org/TheHands.htm - accessed 05/02/10

Miburi user manual:
http://www2.yamaha.co.jp/manual/pdf/emi/japan/port/MiburiR3J.pdf - accessed 17/11/10

Miburi – Yamaha advertising:
http://web.media.mit.edu/~joep/MPEGs/Miburi.mpg - accessed 18/11/10

Miburi – demonstration and performance excerpt:
http://www.youtube.com/watch?v=77bQnSdotDo

Pamela Z – *Nihongo:*
http://www.pamelaz.com/NihongoMov.html - accessed 02/04/10

Pamela Z – *Voci:*
http://www.pamelaz.com/VociMov.html - accessed 02/04/10

Troika Ranch – FleshMotor:
http://www.troikaranch.org/pubs/FleshMotor_MIT_Press.pdf - accessed 05/02/10

Discography:

Adamson, Barry (1988). *Moss Side Story,* CD, Mute Records STUMM 53

Can (1972). *Edge Bamyasi,* LP, United Artists UAS 29414

Can (1971). *Tago Mago,* LP, United Artists UAD 60009/10

Cluster (1980). *Cluster '71,* LP, Sky Records sky 047

Czukay, Holgar (1979). *Movies*, LP, EMI 3319

Eno, Moebius & Roedelius (1978). *After The Heat,* LP, Sky Records sky 021

Faust (1971). *Faust,* LP, Polydor 2310142

Gilbert, B.C. & Lewis, G (1980). *3R4*, LP, 4AD Records CAD16

Harvey, Jonathan (1999). *Mortuos Plango, Vivos Voco*, CD, Sargasso SCD 28029

Hawkwind (1970). *Hawkwind*, LP, Liberty Records LBS 83348

Neu (1972). *Neu*, LP, United Artists UAS 29396

Schulze, Klaus (1974). *Black Dance,* LP, Caroline Records CA 2003

Smalley, Denis (2004). *Impacts Interieurs: Valley Flow (1991-92), Piano Nets (1990-91), Wind Chimes (1987), Clarinet Threads (1985), Darkness after Time's Colours (1976),* CD, Empreintes Digitales IMED 0409

Smalley, Denis (2000). *Sources/Scenes: Base Metals (2000), Empty Vessels (1997), Tides (1984), Pentes (1974),* CD, Empreintes Digitales IMED 0054

Tangerine Dream (1974). *Phaedra,* LP, Virgin Records V 2010

This Heat (1979). *This Heat*, LP, Piano Records THIS-1

This Heat (1981). Deceit, LP, Rough Trade ROUGH 26

Throbbing Gristle (1978). *D.o.A.*, LP, Industrial Records IR0004

Various Artists (2000). *Sonic Art from Aberdeen, Glasgow, Huddersfield and Newcastle* CD, MPS Music & Video, MPSCD013

Wishart, Trevor (2000). *Red Bird; Anticredos*, CD, EMF 022

Appendix A

The Evolution of the Bodycoder System

A1.1 The First Evolution

The transition from a wired, sensitized performance environment, as was manifest in *The Navigator* (1995*)*, to a wireless on-the-body system required the development of sensor elements that could be worn on various parts of the body.

Several original sensor elements had been designed and constructed for *The Navigator*, based on conductive foam and conductive rubber. It was found that the carbon impregnated foam packaging, widely used to hold electro-sensitive electronic components, exhibited an electrical resistance. By sandwiching two pieces of carbon foam together and connecting wires to the top and bottom layer, a variable resistor could be realized – a drop in this resistance being measured with a physical increase in pressure being applied to the two layers. This decrease in resistance could be converted into a voltage by connecting the plates as a voltage divider network (see Figure 1, below).

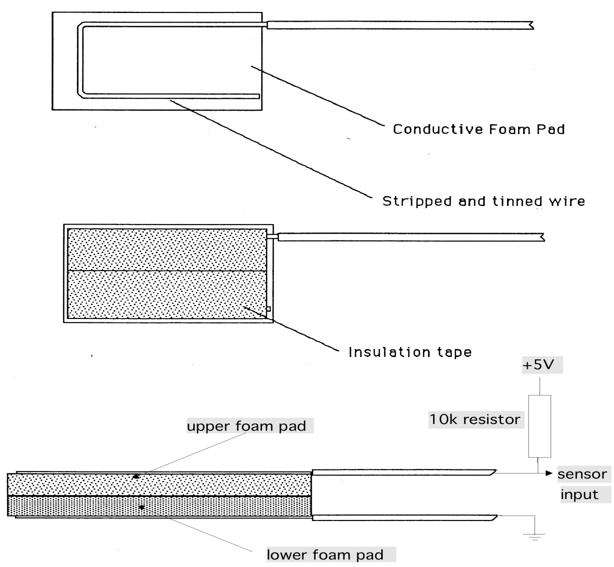


Figure 1. Conductive foam sensor construction

This technique was employed to construct several pressure sensors in the production of an interactive installation, *A Passage to India* (1995), commissioned by Wakefield City Art gallery. The reliability of these sensors was proven when the exhibition period was extended in duration by several months and the installation became one of the most popular pieces in the gallery's collection.

Further exploration and experimentations at this time revealed that conductive rubber strips used to form electromagnetic sealing gaskets in electronic enclosures exhibited an increase in electrical resistance when stretched. A potential divider could be constructed resulting in a variable control voltage that could be used as proportional control sources for sensor interfaces such as the MidiCreator[1]. To enable creative exploration of sensor control a method to simulate the MIDI Creator was required. Investigation showed that it was possible to perform a hardware modification to a commercial MIDI controller, in this case a PC1600 made by Peavey in the USA.

The PC1600 controller consisted of 16 faders and 16 push buttons each of which could be programmed to generate many types of MIDI data including note on/off data and MIDI control messages. Importantly, any MIDI message in the form of a hexadecimal data string including System Exclusive data could be generated. As each PC1600 fader generated a variable voltage, in the range of 0 to 5 Volts, it was found possible to break circuit tracks and insert a switch that would enable an external voltage to be routed to the sampling circuitry. In one switch position an existing

[1] MidiCreator Project - a sensor interface developed by The University of York and promoted within the music education sector by Dawsons Music. The MidiCreator was a small programmable MIDI interface which had fourteen sensor inputs which allowed the connection of switched or proportional sensors working in the range of 0 – 3.2 volts.

control fader would operate as normal and in the other position an external control voltage could be input. In a similar way the PC1600 switches could be bypassed and an external switch input could be used in the same was as explained above. The PC1600 was modified to accept four proportional inputs and four switched inputs, the external inputs connecting via a 15 way D-Sub connector on the rear of the unit (see Figure 2, below).

Figure 2. Customized PC1600

This switching arrangement enabled local triggering and control from the PC1600 itself, without external voltage control. This meant that new works could be rehearsed in the confines of the studio i.e. a performer did not have to be 'wired' or present during the development process. This was an extremely important fact in the development of the system, and the compositional processes that followed, that has continued to the present time. The ability to be able to compose and develop a piece of work and subsequently rehearse the piece, replacing sensor elements with tactile fader control via a MIDI control surface, cannot be overestimated.

In 1997 an invitation to participate in a three weeks self-directed residency at STEIM in Amsterdam was accepted. The residency enabled time to explore sensor and sensor interface technologies that could possibly be integrated into the development of an on-the-body sensor system. Since the production of *The Navigator* (1995) research had started on the development of a ‘body suit’ that enabled various types of sensor elements to be connected and subsequently evaluated. The four main types of elements to be investigated were:

1. glove mounted tactile switches.
2. stretch devices based on conductive rubber cord.
3. stretch devices based on linear slide potentiometers.
4. pressure sensors constructed from conductive foam.

Any combination of these elements could be connected to a suit-mounted breakout box that was in turn connected to the PC1600 controller via a 15 way ‘umbilical’ lead. In this fashion it was possible to evaluate the functionality of the various sensor elements both in terms of accuracy and physical robustness.

The sound sources used for these experiments were held in a large capacity Emu4x hardware sampler. MIDI control data and note on/off messages were received by Opcode’s StudioVision Pro software sequencer prior to being output to the sampler.

Prior to the STEIM residency several banks of timbrally rich samples were designed together with routing control data via the Emu4x’s comprehensive digital modulation matrix (see Figure 3, p. 5). Any combination of modulation source signal, including external MIDI controller data, could be connected to any Emu4x modulation control input. This enabled sampler voices that could be comprehensively modulated and filtered by an external control source. The aim was to create a new piece of interactive work with the prototype 'body suit' and to bench test a range of sensors for their reliability, durability and also to evaluate suitable on-the-body sensor positioning in collaboration with performer/dancer Julie Wilson.

Modulation Sources

Off
Crossfade Random
Key (+, ~), Velocity (+, ~, <)
Release Velocity, Gate
Pitch Wheel, Mod Wheel
Pressure, Pedal
MIDI A-H, Foot Switch 1 & 2
Flip-Flop Foot Switch 1 & 2
MIDI Volume (Contr. 7)
MIDI Pan (Contr. 10)
Key Glide
Volume Envelope (+, ~, <)
Filter Envelope (+, ~, <)
Aux. Envelope (+, ~, <)
LFO 1 & 2 (+, ~)
White Noise, Pink Noise
kRandom 1 & 2,
Lag 0 in (summing amp out)
Lag 1 in (summing amp out)
Lag Processor 0 & 1
DC Offset, Summing Amp
Switch, Absolute Value
Diode, Flip-Flop, Quantizer
Gain 4x

Modulation Destinations

Off
Key Sustain, Fine Pitch, Pitch
Glide, Chorus Amt
`Chorus Position ITD
`Sample Start, Sample Loop
Sample Retrigger
Filter Freq., `Filter Resonance
Amplifier Volume, Amp Pan
Amplifier Crossfade
Volume Envelope Rates (all)
Vol. Env. Atk, Dcy, Release
Filter Envelope Rates (all)
Filt. Env. Atk, Dcy, Release
Aux. Envelope Rates (all)
Aux. Env. Atk, Dcy, Release
LFO 1 & 2 Rates
Lag Processor In 0 & 1
Summing Amp, Switch
Absolute Value
Diode, Flip-Flop, Quantizer
Gain 4x
Cord 0-15 Amount

Figure 3. Emu4x Modulation matrix

A1.2 Custom sensor evaluation

1. The glove mounted switches were essentially miniature computer keyboard switches with four small holes drilled in the four corners of the switch housing to facilitate attaching the units to the finger tips of a leather glove. It was essential that the performer could reliably detect when a switch had been activated so switch elements that had a definable 'click' were used in the prototype. These elements worked well in practice, however, it was later found that a head-mounted radio microphone readily picked up these audible clicks. This could pose a problem if these sounds were then sampled along with the vocal source.

2. Thin conductive rubber cords were sewn into tubular pockets along the length of 'Tubi-Grip' type bandages that could be positioned against the elbow and knee joints. Electrical connections to each end of the conductive cord were made by simply wrapping several turns of tinned copper wire around the cord, leaving short length of wire protruding from each end to which wires could be soldered. It quickly became clear that these sensor elements were not reliable enough to withstand frequent use. The cords had to be tensioned in their non-bend state so that when the joints were bent a repeatable resistance change could be measured, this tensioning weakened the material and with repeated use the cords would simply break.
3. Small pressure sensors constructed out of pieces of carbon impregnated conductive foam were placed in pockets sewn into 'Tubi-Grip' bandage sleeves, these were positioned on the inside of the elbow and knee joints such that bending caused a compression on the sensor elements resulting in a decrease in electrical resistance. Although quite uncomfortable to wear these sensors did not easily break with repeated use however, they exhibited a large hysteresis[2] that subsequently got worse with extended use.
4. Small linear fader potentiometers, modified so that the fader wiper would return to a default position when not activated, were positioned on the upper arms and thighs. A short length of nylon cord was attached to the fader actuator, the other end being attached to mountings sewn into the suit material. The nylon cord was routed down thin channels sewn down the length of 'Tubi-Grip' sleeves positioned over the elbow and knee joints. Small tension springs were attached to the fader actuator and to one end of the fader housing

[2] Hysteresis: defined as the lagging of an effect behind its cause, as when the change in magnetism of a body lags behind changes in the magnetic field.

so that when the arms and legs were in their extended position the fader wipers would return to their default positions. These sensors gave the most accurate results in terms of resistive linearity but were difficult to position on the body and to achieve repeatable results. The main problem being that with repeated use the anchors on the suit fabric would deform the suit fabric, hence shortening the range of the sensors. A solution was to anchor the suit material to the arm and leg extremities with loops of material routed under the feet and palms of the hands but this was both uncomfortable and deemed to be unpractical for use in dance performance.

Figure 4. Prototype Bodycoder Suit at STEIM (1997)

After a demonstration of the prototype system (see Figure 4, above) to the staff at STEIM, one of the hardware research and development staff: Jorgen Brinkman, suggested that It might be useful to look at bend sensors that the studio director, Michel Waisvisz, was using for his *Hands*' project.[3] The bend sensors, supplied by the Images Scientific Instrument Company, Staten Island, New York, were small resistive thin film devices (see Figure 5) that exhibited a change in electrical resistance when flexed.

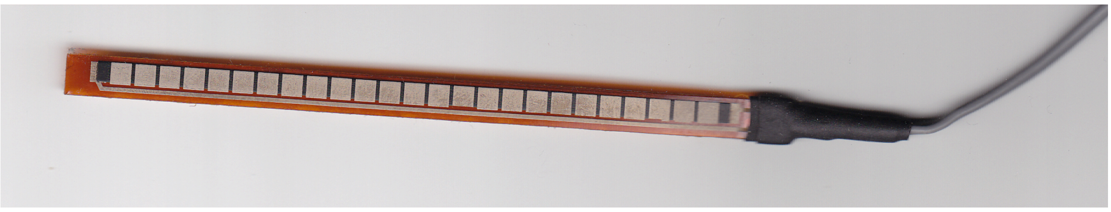


Figure 5. Images Scientific Instrument Company - bend sensor

Brinkman's offer to evaluate this device was accepted for possible incorporation into the body suit. It was found that the sensors exhibited no hysteresis, were linear in their output range, and providing that secure termination was achieved, proved to be durable and importantly gave repeatable results. This 'chance' discovery of a reliable and durable sensor mechanism proved to be a turning point in the development of the Bodycoder System and meant that it was now possible to refine the interface and investigate radio technologies to enable wireless operation.

A modification to the sensor elements was required that would further increase durability and operational stability. This refinement entailed attaching a thin piece of spring steel down the entire length of the sensor element, encasing the soldered termination wire with heat shrink sleeving and securing this to the end of the spring steel with cyanoacrylic adhesive. Finally the whole length of the element, including termination, was sheathed in two lengths of heat shrink sleeving, ensuring that the sensor was totally secure with little possibility of a malfunction occurring due to cable/termination failure (see Figure 6, p. 9).

[3] Michel Waisvisz's *Hands* project is investigated in the main body of the commentary p. 19.

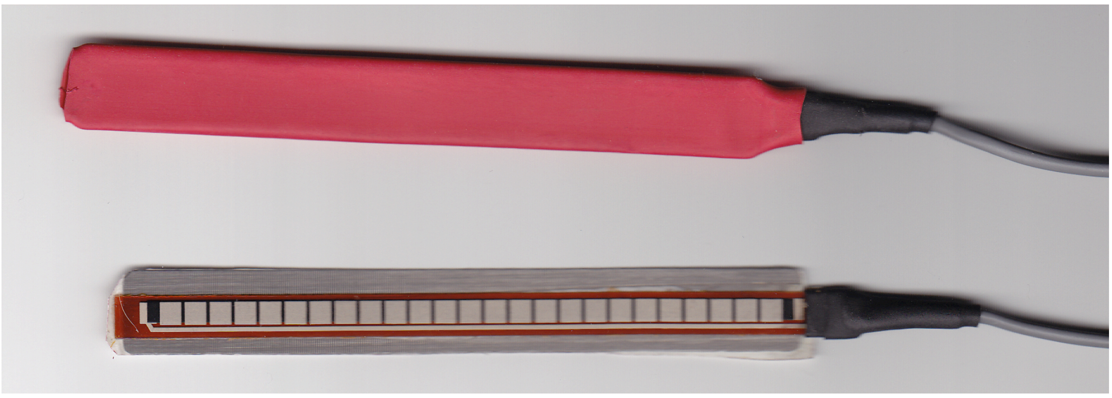


Figure 6. Bend sensor attached to spring steel (lower image)
bend sensor sheathed and ready for use (top image)

This refinement was important if the sensors were to be able to withstand the rigors of contemporary dance performance and importantly, give confidence to the performer and composer that sensors would continue to function with rigorous physical use.

Whilst working at STEIM an invitation was offered to evaluate the institute's own sensor interface – Sensor Lab[4] with a view to obtaining a unit for incorporation into the Body-Suit project. However, it was felt that there were limitations with using the Sensor Lab for the interactive dance works that were being explored at the time. On a physical level it was thought that the interface was too bulky and the circuitry too fragile to be able to withstand the rigors of contemporary dance performance. The Sensor Lab was a 'wired' interface and it would be necessary to design and construct a separate radio transmitter/receiver system which would further increase the physical 'footprint' of the worn system. The final decision to reject the Sensor lab was its reliance on a complicated and non-intuitive programming language: SPIDER. This would necessitate learning a new programming language, and was seen as a potential barrier to the creative process, after all the idea was to create pieces of music and not

[4] Sensor Lab – a wired analog sensor to MIDI interface developed at STEIM in 1981 using 'SPIDER' - a custom designed programming language running on a Macintosh computer.

be encumbered by a lengthy process of learning a new software language and operational protocols.

During the STEIM residency there was the opportunity to look at other sensor-based systems such as BigEye[5] written by Tom Demeyer. Although BigEye was certainly a most impressive piece of software, its reliance on using video cameras to sense movement and position of a performer relied on having the artist fixed to a particular 'frame', this was seen as too limiting for prospective projects. Being a strictly 'non-tactile' sensor mechanism BigEye did not provide the accuracy or the degree of interactive intimacy that was required to actively sense and respond to contemporary dance movements. Current personal research had moved away from the fixed sensor environments explored in *The Navigator* (1995) and *Zero in the* Bone (1997). Using a system such as BigEye would be a step backward, not forward. It was also apparent that realizing a vision of creating powerful and expressive new pieces of work required collaboration with an individual who had the physical expressivity and aural sensitivity to achieve these artistic goals. This collaborator /performer would have to have good physical ability, have undertaken extensive dance training and importantly have acute kinaesthetic[6] sensitivity and musicianship.

Subsequent to the STEIM residency, contact was made with Micron R/C Systems – a small company specializing in radio control systems for use in model aircraft projects. Micron could supply kits of electronic parts to construct transmitter and receiver circuits working in the 35Mhz or 40Mhz band of radio frequencies. These designs

---

[5] BigEye is a software program that samples a live or recorded video signal and converts this data to MIDI code in real-time, this was only developed for the Macintosh OS9 system and was discontinued in 2001.
[6] Kinaesthetics: meaning the movement principles of the body.

used N.B.F.M. (narrow band frequency modulation) circuitry to provide up to 7 servo outputs from the receiver circuit. The transmitter section used a single integrated circuit (IC) coder that could accept any combination of switched or proportional inputs. The coder circuit was housed on one of two small circuit boards, the other board containing the transmitter circuitry (see Figure 7, below). On further investigation it was discovered that the coder section could, in fact, accommodate an extra input channel that would make possible an eight-channel transmission system. As the receiver circuitry utilized a nine-channel counter CMOS IC (type 4017) to provide pulse width modulation (PWM) output decoding, this would enable a full eight-channel system to be constructed.

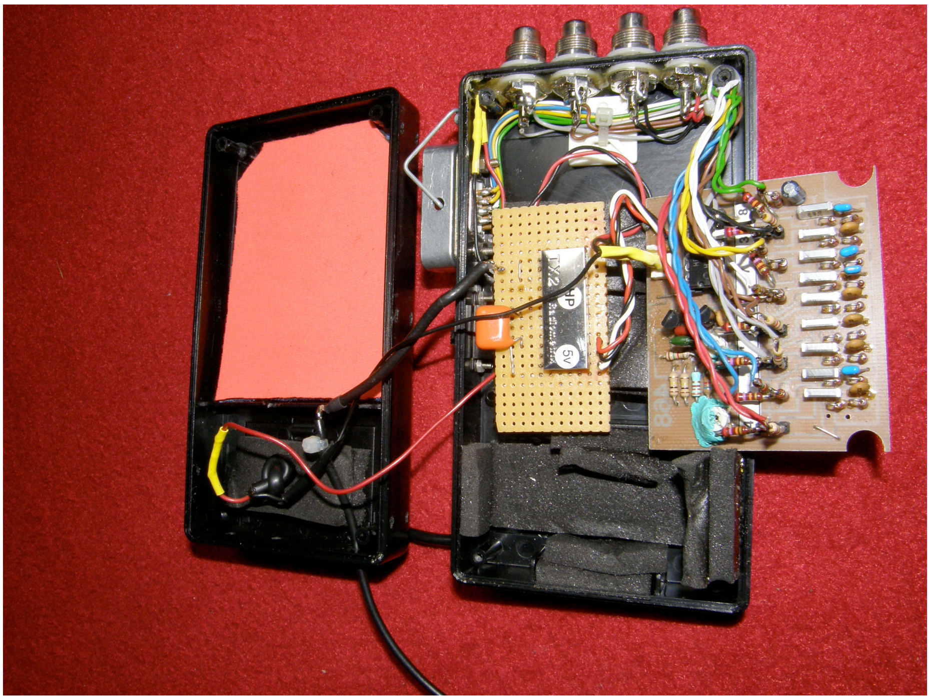


Figure 7. Bodycoder Mk.2 transmitter construction

A1.3 Transmitter design and construction

The transmitter circuit boards were fitted into a project case, small enough to be worn by a dancer but large enough to accommodate a battery and connectors for the switched and proportional (bend) sensors (see Figure 8, below). Resulting from the wired experiments with the body suit it became clear that the ideal situation would be to use a combination of switched sensors and proportional sensors – the switched sensors enabling navigation and initiation of specific MIDI 'events' and bend sensors enabling modulation and timbral control of triggered events and music sequences. Giving the performer the ability to navigate through a software environment was essential if the system was not just a method of triggering sounds and sequences. The idea of giving a performer total control of the audio-visual environment, first realized in the production of *The Navigator*, was achievable if this combination of utilitarian and expressive control was successfully integrated into the design of the system.

It was important that connections to the transmitter pack were secure and robust but also relatively quick to replace in case of failure/damage. Four pairs of switch connections were made via a 9 way D-Sub connector that could be locked into

Figure 8. Bodycoder mk.2 Transmitter Case

position with a spring clip. Each of four bend sensors were connected to the case using lockable, screwed, phono connectors, resulting in an extremely reliable and secure mode of connection (see Figure 8, p. 12).

The transmitter coder was originally designed to accept 1000 ohm potentiometers resulting in a modulation output signal consisting of a train of variable width pulses, the pulse width varying with increase and decrease in potentiometer resistance. Experimentation with the Images Scientific Instrument Company bend sensors showed that these exhibited a flat resistance value of 15,000 ohms and a ninety-degree (full) bend value of approximately 45,000 ohms. Using the bend sensor as one half of a potential divider, the other half created with a series connected 18,000 ohm resistor, resulted in a range of sensor values which were compatible with the coder circuit, providing variable pulse widths between 0.65ms and 1.27ms with the pulses spaced by 13ms.

Switch inputs to the coder were simply achieved by switching a fixed resistor value to a potential divider, to be compatible with the pulse width range achieved with the bend sensor elements i.e. un-switched coder input = 0.65ms and switched coder input = 1.27ms.

Bench experiments with the completed transmitter unit showed that, although the outputs from the coder circuit were consistently accurate over time, this was not the case when used with a 9v battery supply. It was obvious that a drop in the DC supply voltage was causing changes in the PWM output. The small PP3 type battery did not have sufficient capacity to supply the circuitry for more than thirty minutes so it was decided to use an external battery pack using a series of large capacity Nickel

Cadmium batteries. This situation, although not ideal, meant that the transmitter could reliably operate for up to three hours on a fresh set of batteries. The battery pack was housed in a leather waist-mounted pouch that also held the transmitter case.

A1.4 Receiver design and construction

The radio receiver was constructed on two small circuit boards, the receiver circuit employing a monolithic low-power FM signal processing system housed in a 16-pin dual in-line integrated circuit. The MC3361 narrow band receiver IC and associated discrete components were connected to the decoder circuit comprising a HEF 4017 decoder IC that reconstituted the eight channels of data.

A way of accurately converting the PWM data into control voltages was required to enable connection to the customized PC1600 MIDI controller. The first version was designed around a propriety voltage-to-frequency (V/F) and frequency-to-voltage (F/V) converter integrated circuit. The TC9402 16-pin integrated circuit could be configured to operate in either a V/F mode or F/V mode. When used as a F/V converter the circuit would generate a DC output voltage linearly proportional to the input frequency waveform. Initial experimentation showed that the small range of PWM variation from the radio receiver decoder circuit resulted in an extremely small variation in DC output voltage from the TC9400. The use of several stages of DC amplification and offset scaling circuitry resulted in an output voltage in the required range of 0 – 5V. The large amount of gain required from this circuitry and the necessity to perform physical nulling and calibration meant that access was needed to several small potentiometers housed on the circuit board. To facilitate the DC offset adjustments, four small holes were drilled in the receiver/decoder case, directly above the calibration presets so that these adjustments could be made before each rehearsal and performance.

The process of calibrating the output voltage to zero (0 V) with no sensor bend and to maximum voltage (5 V) with full sensor bend meant that the full range of MIDI output (0 – 127) was available. It was also deemed useful to be able to monitor these control voltages without recourse to connecting a voltmeter to the system outputs. To achieve this monitoring a system of eight Light Emitting Diode (LED) bar-graphs was incorporated into the receiver case. The system was calibrated to indicate a fully illuminated ladder of LEDs on full sensor bend and switch activation (see Figure 9, below). This system of visually monitoring all eight sensor channels proved to be invaluable both during performance and rehearsals.

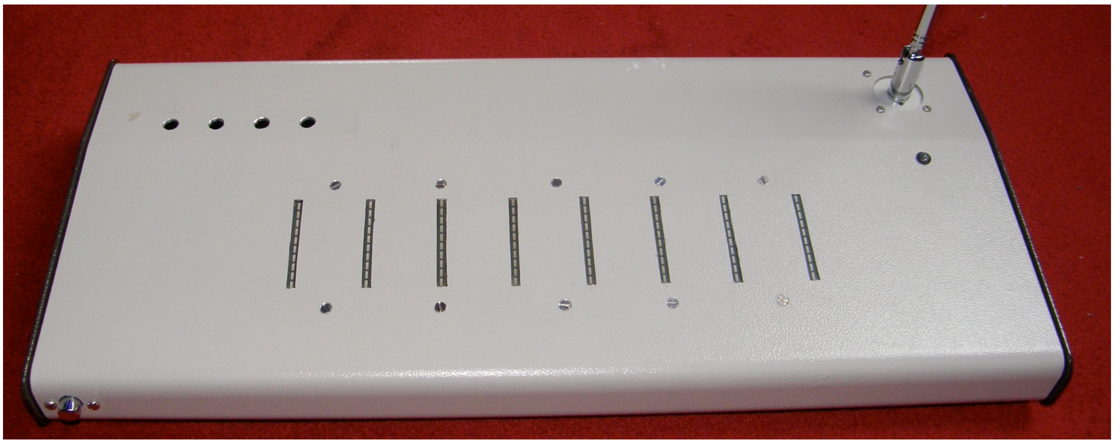


Figure 9. Bodycoder Mk.1 + 2 receiver case

Although the F/V circuitry, once calibrated, worked reliably well it was always necessary to finely tune the proportional channel gain preset potentiometers on the receiver circuit board. This tuning entailed removing the top panel of the case so that screwdriver adjustments could be made. The 9402 integrated circuit was originally designed to work with continuous variable frequency waveforms and was not particularly efficient at converting a variable pulse width modulation signal, hence the requirement to add the high gain amplifier stages to the convertor outputs.

A decision was made to affect a complete re-design of the F/V circuit resulting in a higher range of output voltage at the conversion stage. The eventual design used a combination of exclusive OR gates and quad bi-lateral switches to form an integrator function that accurately converted the PWM signal and importantly gave a higher voltage at the output of the integrator. The addition of one stage of analogue amplification, connected to a higher voltage supply enabled gain and offset adjustment to be made with only two preset potentiometers per channel. A simple diode clamp circuit connected to the proportional output channels ensured that the output voltage was restricted to a maximum of 5V. Employing driver transistors connected to small dual-in-line relays delivered the required four switch outputs. The re-designed circuitry included the replacement of the original transmitter and receiver circuits with Radiometrix TX2 and RX2, 2nd generation, FM data link modules. These modules, working at the higher frequency of 433.92Mhz, offered a broader reception range and would also work on a wider range of supply voltages. The newly designed receiver circuitry was fitted into the same case as the original Mk.1 design that enabled the visual monitoring of the sensor data (see Figure 10, p. 17).

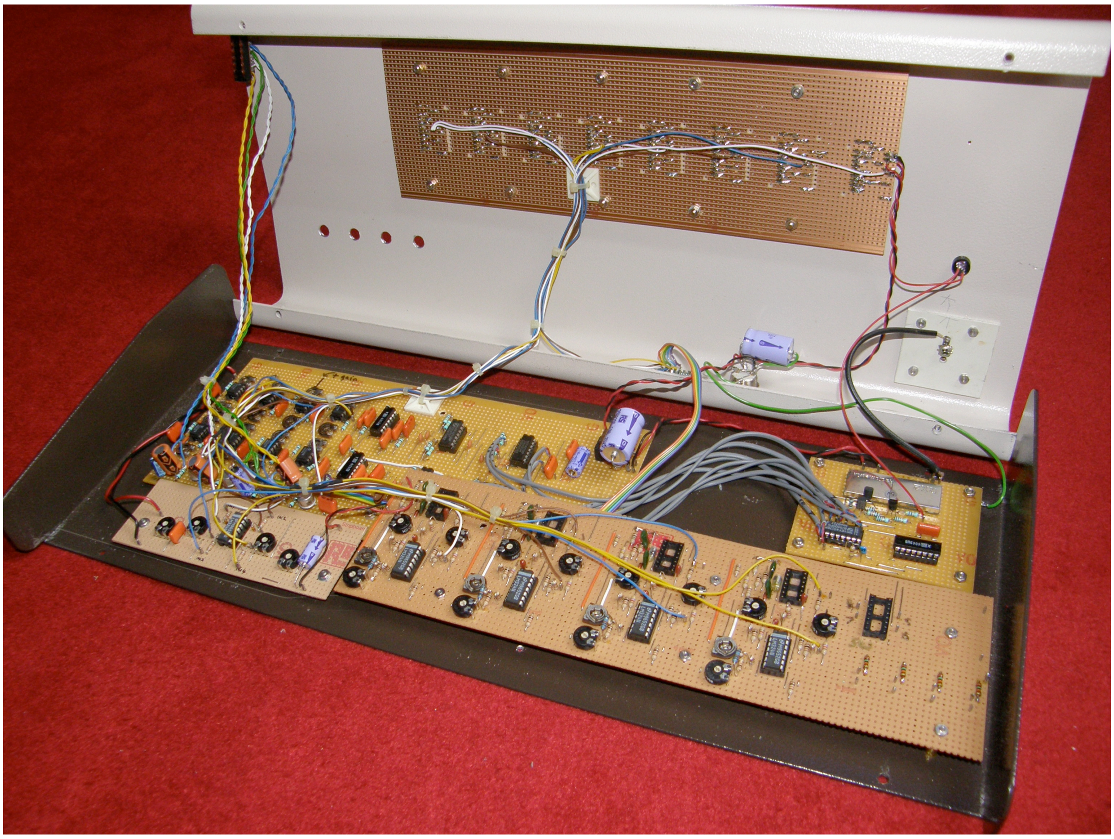


Figure 10. Bodycoder Mk.2 Receiver circuitry

A1.5 *Bodycoder* - A first outing

The first work composed for the fledgling Bodycoder System, was *Bodycoder* (1997). The piece was performed at the Lawrence Batley Theatre, Huddersfield on 17th September 1997 as part of *The Anatomy Class* – promoted as 'a programme of four exhilarating works blending live electronics, video projection, computer animation and dance to create a powerful and sensual theatrical experience'.

The *Bodycoder* piece was created using Opcode's Studio Vision Pro sequencer as the host program that held pre-composed MIDI sequence tracks. The sequence tracks were held in a number of sub-sequences that could be triggered by the performer and variously modified by routing MIDI controlled data to an Emu4x digital sampler. The

bend sensor outputs from the on-the-body sensor array were routed 'thru' the StudioVision sequencer programme using Opcode's system of 'MidiKeys.[7]
Live manipulation was achieved through the use of bend sensors worn on four axis of the performer's body – one sensor on each elbow, one on the torso and one worn on the left knee. Extensive use was made of the morphing processes implemented in the system of 'Z-Plane' filters employed in the Emu sampler. Being able to 'morph' from one set of filter parameters, in real time, directly and intimately controlled by the performer added a great deal of kinaesonic expressivity both sonically in terms of the filtering, and gesturally, in terms of the dancer's performance. This intimate mode of 'textural' control had become a defining and requisite element in my compositions that had started over a decade previously with the design and construction of analogue synthesizers and effect processors. Using the Bodycoder technology I had successfully transferred this control to a live performer who could now perform new works in real-time.

Although this first public outing for the Bodycoder System achieved critical acclaim there was a fundamental problem in the way the system was implemented. This problem was manifested in the fact that the MIDI controller data was always being transmitted 'live' to the digital sampler with no facility for switching this information on or off. A solution would be to use finger switches to enable/disable this controller information but as the finger data was being used to trigger sounds and sequences this was not an option that could be employed. This system of sensors always being 'live' imposed a restriction on the performer/choreographer and indeed the composer as constant consideration had to be given to the active sensor data. This limitation, due

[7] For a full description see: Bromwich M., and Wilson J. (1998), 'Bodycoder: a Sensor Suit and Vocal Performance Mechanism for Real-time Performance' in *Proceedings of* the *International Computer Music Conference.* International Computer Music Association, San Francisco, CA. pp. 292-295.

to the fact that there was a limited number of sensor channels available plus the fact that the software employed did not facilitate the dynamic routing of sensor designation, was to result in the decision to use the Max/MSP environment as a software host.

A1.6 The Second Evolution

The limitations of using a software program with limited protocols was rapidly becoming apparent and although Studio Vision Pro had enabled the integration of external controllers to facilitate real-time control of MIDI devices, the program was not able to re-map sensor control parameters such as scaling and sensitivity values. The continually 'live' sensor data also needed to be addressed if the system was to evolve alongside future compositional ideas.

A useful feature of the Peavey PC1600 MIDI controller was the ability to map any of the sixteen switches to enable its associated fader message i.e. the MIDI data from a fader would only be output whilst its associated switch was being depressed. This mode of operation could be pre-programmed and stored in the preset memories of the device. By dedicating finger switches to duplicate this function it was possible to enable which sensor was 'live' at any time. This process of on-line, off-line working was to become a major and defining element in the development of the Bodycoder System and has been implemented in all works composed for the system up to the present time. The importance of enabling the performer to be able to take control of audio processes cannot be overestimated. This is a unique feature of the Bodycoder System and allowed the creation of pieces of work that would otherwise have not been possible.

A major departure in creating the next piece of work for the evolving Bodycoder System was the decision to compose an interactive dance piece without the use of a host computer. Familiarization with the Emu4x digital sampler and its extensive system of modulation routings led to the belief that it was possible to write a kinaesonically expressive piece of music using pre-composed / designed samples held in the large and expanded memory of the sampler. As experience was gained in programming the PC1600x i.e. to send 'raw' midi data in the form of data strings (see Figure 11, below), it was possible to send note on/off information combined with controller messages to trigger and control samples in real time.

1	**PC 1600 patch:28**	**Midi Data**	**Function**
2	Finger 1	Press: 86 48 7F	Swich off 'Barbican Tribal' ch.7
3	Finger 1	Rls: ---------------	-----------------
4	Finger 2	Press: 98 41 7F	Trigger 'Weirding' ch.9
5	Finger 2	Rls: 88 41 7F	Release 'Weirding' ch.9
6	Finger 3	Press: 97 41 7F	Trigger 'Space' ch.8
7	Finger 3	Rls. 87 41 7F	Release 'Space' ch.8
8	Finger 4	Press: Program 28 ch.16	Patch change PC1600
9	Finger 4	Rls: -----------------	-----------------
10			
11	Left arm	-----------------	-----------------
12	Right arm	Channel 9 Controller 1	Filter Frequency 'Weirding'
13	Leg	Channel 8 Controller 4	Quantised Pitch of 'Space'
14	Torso	-----------------	-----------------
15			
16	**PC 1600 patch:29**		**Function**
17	Finger 1	99 35 7F 9E 11 7F (Toggle on)	Trigger 'New Loops' ch.10
18	Finger 1	89 35 7F 8E 11 7F (Toggle off)	Stop 'New Loops' ch.10
19	Finger 2	9D 30 7F 9E 12 7F	Trigger 'Clusters' ch.14
20	Finger 2	8D 30 7F 8E 12 7F	Release 'Clusters' ch.14
21	Finger 3	Send Leg position	Sample leg position to trig.'Birds'
22	Finger 3	-----------------	-----------------
23	Finger 4	Send Torso position	Torso position Filter fx. 'New Loops'.
24	Finger 4	-----------------	-----------------
25			
26	Left arm	Channel 15 Controller 1	Pitch of 'Birds Notes'
27	Right arm	BE 04 pr BD 01 pr	Filter Frequency of 'Clusters'
28	Leg	9E pr 7F 8E pr 7F	Notes to send to 'Birds Notes'
29	Torso	Channel 10 Controller 1	Filter Frequency of 'New Loops'

Figure 11. An example of *Zeitgeist* (1999) MIDI coding

By dedicating one finger switch to output a program change on a discrete MIDI channel this message could be then be returned from the Emu4x MIDI output, to advance through numerous pre-programmed presets stored in the PC1600x. Using this method it was possible to construct a complex piece of music without the aid of a controlling computer program (Figure 12, below).

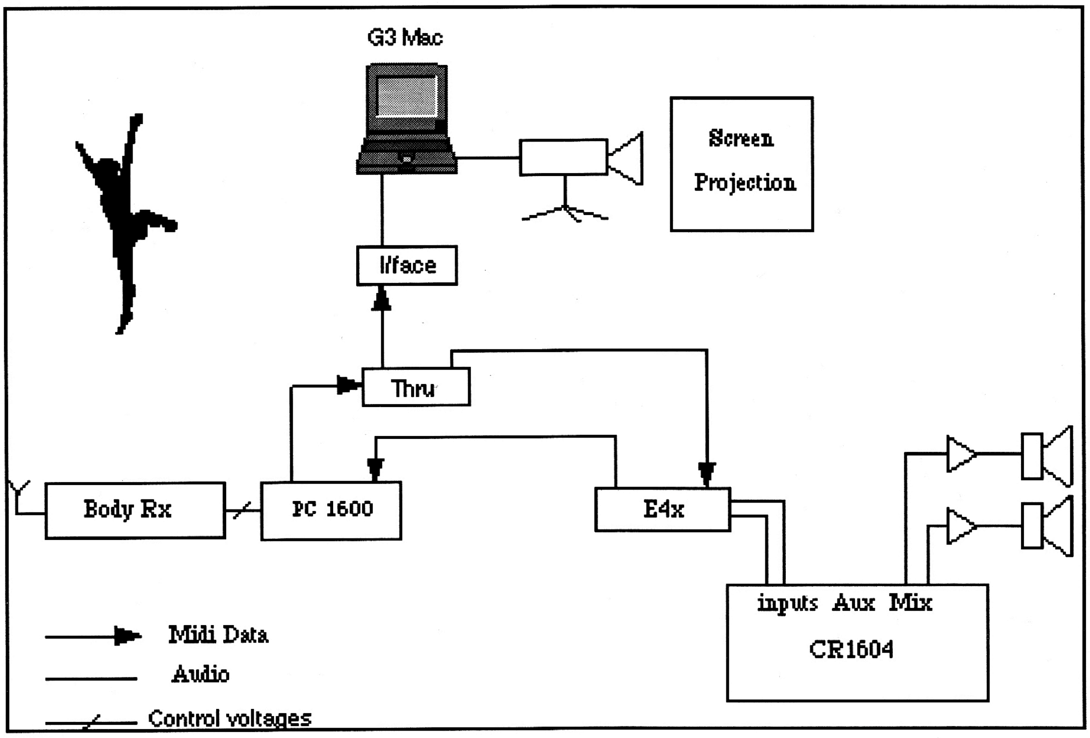


Figure 12. *Zeitgeist* performance set up

The computer used for the piece; *Zeitgeist* was only employed to host the video display program - Xpose.

Zeitgeist was premiered at the Klangart Congress held in Osnabruek in 1999. Although *Zeitgeist* received an excellent reception at Klangart it was always going to be a risky undertaking to present a work of this kind. This was due to the fact that it was possible for MIDI note data to get 'stuck on' and this data could only get cleared at the next preset transition. The PC1600x had been programmed to send note off information in case this situation occurred, but this was not an ideal situation and it certainly did not inspire total confidence in the performer who was acutely aware of this possibility. Although the creation of this piece had satisfied the technical goal to produce a 'stand-alone' system it had not satisfied the aesthetic goal to create totally original and authentic timbres. Even though considerable time and effort was spent facilitating a comprehensive system of external control functions this did not satisfy the creative desire to control the interiority of a sonic palette that also included the generation of sound itself. Advancing research into creating and controlling completely original sounds and textures required the need to look at other methods of producing and controlling this material.

During a visit to the 1995 International Computer Music Conference a paper entitled "*Making Motion Musical: Gesture Mapping Strategies for Interactive Computer Music*" [8] was presented by Todd Winkler from Brown University. Winkler mentioned several interactive systems including Mark Conglio's MIDI Dancer system[9] that enabled a dancer to control video playback, a lighting system and the position of a video camera mounted on a robotic platform. Winkler actively promoted the use of Max as an open-ended software program for the creation and manipulation of MIDI data. Winkler was to go on to write a defining book on the creative and practical use of Max in composing for interactive music.[10]

A1.7 The next Generation of Bodycoder System

Although the first generation Bodycoder System had proved to be robust enough to withstand the rigors of dance performance it was clear that having only eight sensor

---

[8] Winkler, T. (1995). 'Making Motion Musical: Gesture Mapping Strategies for Interactive Computer Music' in *Proceedings of the International Computer Music Conference*. The International Computer Music Association, San Francisco, CA. pp. 261-264.
[9] Conglio's MIDI Dancer system is documented in the main body of the commentary p. 16.
[10] Winkler, T, (1998). *Composing Interactive Music – Techniques and Ideas using MAX*, MIT Press, Cambridge, Massachusetts.

channels was limiting the sophistication of projects that could be designed for such a system. Another deciding factor in designing a new system was the fact that the 40Mhz radio frequency used in the first generation of the Bodycoder System was found to be susceptible to external radio interference. This particularly became noticeable whilst working in Budapest with the students at the Liszt Ferenc Academy of Music.[11] Subsequent to the Budapest visit contact was made with The University of Huddersfield's Department of Computing and Engineering with a proposal to design and develop a second-generation interface. The Department of Computing and Engineering had the resources to design and fabricate circuitry at the LSI (Large Scale Integration) level that would be required to meet the criteria needed for the proposed project. The maxim was to enable a minimum of sixteen sensor channels, have low power consumption, extend the performing range and be small enough to be worn on the body of a performer without constraints on physicality/movement. CAD (Computer Aided Design) systems were in place in the Department that could have been used to aid the design and manufacture of the LSI circuitry, but unfortunately there was no member of staff willing or available to spend valuable research time on the proposal. Initially disheartened by this negative response, contact was made with a small, fledgling French company, LA Kitchen who had recently brought to market a sixteen-channel radio sensor interface. Correspondence with LA Kitchen designer Thierry Corduys led to obtaining a 'bare-board' system, enabling the design and fabrication of several 'link' modules that could interface with the new system. LA Kitchen's transmitter circuitry relied on sensors being connected to one or two multi-way connectors, enabling eight or sixteen channel operation. This was unsuitable, as

[11] In October 1999 we were invited by The British Council to be guest artists at the Making New Waves festival organized by The Hungarian Computer Music Association. Presenting an evening's concert of works and taking part in a day-long workshop working with students at the Liszt Ferenc Academy in Budapest.

a fundamental requirement was the ability to connect securely a number of different sensor elements and switches, in any potential combination. The LA Kitchen protocol meant being literally tied-down to multiple sets of multi-core cabling resulting in physical restrictions on movement. The receiver circuitry was fitted into a custom enclosure (see Figures 13 and 14, pp. 24- 25). The design and construction of two interface modules gave the ability to rapidly connect two basic combinations of sensors and switches as follows:

Module 1: up to eight proportional sensors and eight switched elements, see Figure 15, p. 26.

Module 2: up to four proportional sensors and twelve switched elements, see Figure 16, p. 27.

Figure 13. Bodycoder II receiver (front)

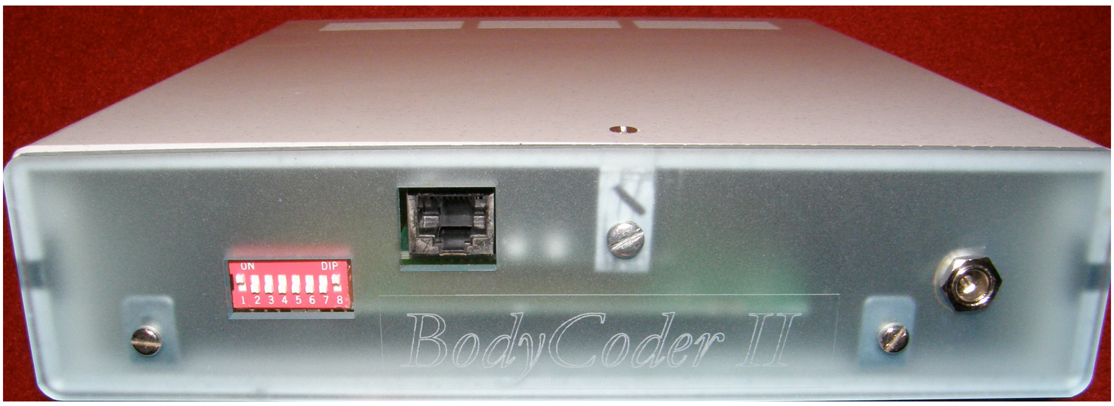


Figure 14. Bodycoder II receiver (rear)

Either of the two interface modules could be attached to the transmitter with short lengths of ribbon cables and their associated connectors. Miniature SMC screw connectors were employed to allow easy and secure connection for the bend sensors that could be individually connected to each of the dedicated sensor channel inputs. It was vitally important that sensor connections were totally secure and could not be inadvertently pulled out during a performance, hence the use of the screw type connector that locked each sensor cable in position. These connectors were designed to be used with miniature co-axial cable but this type of cable was not flexible enough for rigorous physical use. Sub-miniature two core screened cable that could be carefully attached to the connectors and held in position with layers of heat shrink sleeving were employed (see Figure 17, p. 27).

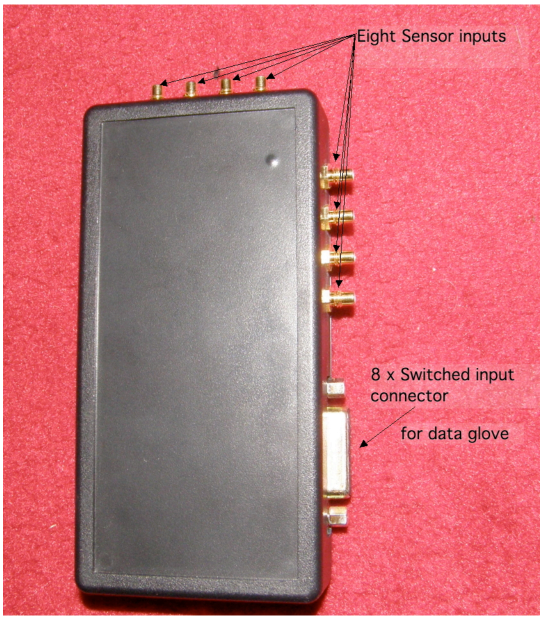


Figure 15. Interface module 1

Interface module 1 employed a single 15 way D-Sub connector enabling the attachment of a single data glove, incorporating eight finger mounted switch elements.

Interface module 2 employed two D-Sub connectors that were routed to the switched sensor channels, enabling two sets of switches that could be mounted on either hand i.e. a right hand data glove with four finger mounted switches and a left hand glove, with eight finger mounted switches (see Figure 18, p. 28).

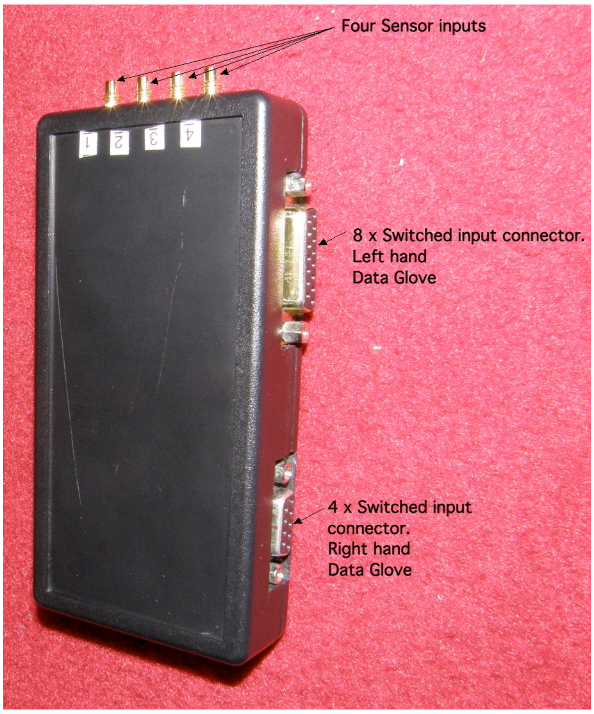


Figure 16. Interface module 2

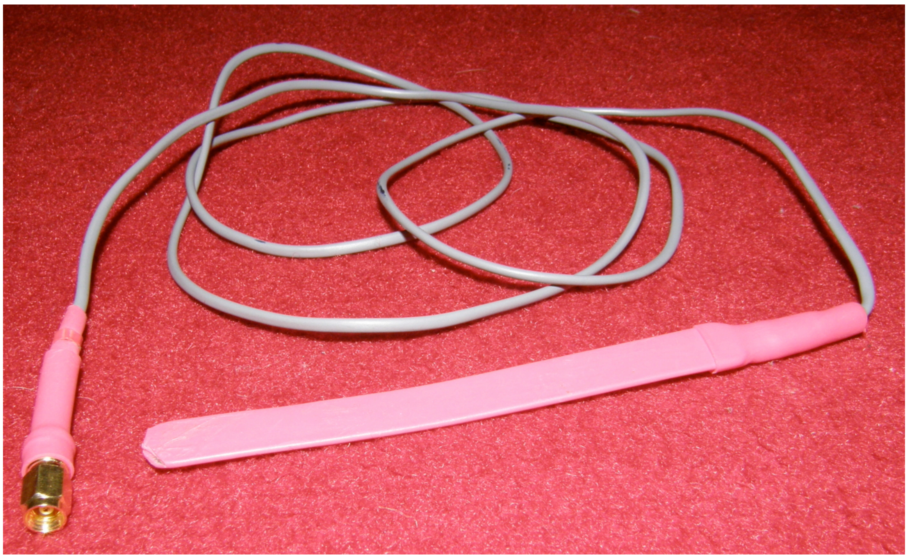


Figure 17. Subminiature connector and bend sensor

As the radio frequency (RF) module operated at the license exempt frequency of 433Mhz this was seen as a further improvement over the original Mk.1 Bodycoder System. This meant that the system was less prone to be affected by external radio frequency interference and also enabled a larger range of transmission/reception. The ability of the new sensor module to transmit data using the OpenSoundControl (OSC)[12] protocol meant that sensor resolution was increased from the 7 bits of the previous (MIDI) system to 10 bits. A sensor range of between 0 – 1096 could now be achieved instead of the old sensor range of 0 – 127. This increase in sensor resolution had great implications in designing future Max/MSP patches as much smoother and finer ranges could be employed in the control of DSP objects i.e. fine pitch control was now possible without resorting to interpolation methods to try and alleviate the restrictions of using a 7 bit system.

[12] Open Sound Control (OSC) is a transport-independent networking protocol for real-time musical control information. It was introduced in 1997 by the Center for New Music and Audio Technologies (CNMAT) in Berkeley, California.

Figure 18. Data gloves and connectors

Appendix B

The *Vox Circuit Trilogy* -Technical description

B1.1 *The Suicided Voice* (2003/2007)

- **Max/MSP design and implementation**

The Suicided Voice is in four movements following the processing patch structure: Patch1, Patch3, Patch2, finally returning to Patch1. The three processing patchers can be seen by referring to the lower part of Figure 1, page 3 (designated as *patcher sfs*, *patcher ss8pr* and *patcher granular*). Each processing patcher has a unique sensor patcher, only active when the relevant processing patcher has been enabled. This activation is achieved by using three *pcontrol* objects, selected by the *enable* command. This ensures that MIDI data is only passed whilst an active patch is in operation. In addition to the isolation of MIDI data it is important that received sensor data is only connected to the active processing patcher. This is achieved by using simple, three output *gate* objects, sending the respective sensor channel uniquely to one of the three sensor patchers.

- **Sensor translation and scaling**

Data from the bend and switch sensors is received via the *otudp receive* object and formatted to the OSC protocol via the *OpenSoundControl* object developed by Adrian Freed at CNMAT at Berkeley. The OSC messages are first unpacked, the bend sensor data then connected to a simple calibration system that ensures that the full range of the sensors is available. This calibration is performed at the start of each piece end requires the performer to locate each sensor at their minimum positions, i.e. straight positions, these values being stored in integer number boxes and then locate all sensors at their maximum positions, i.e. fully bent positions and again store these values in integer number boxes. This arrangement can readily be seen, highlighted, towards the top of Figure 1, p. 3.

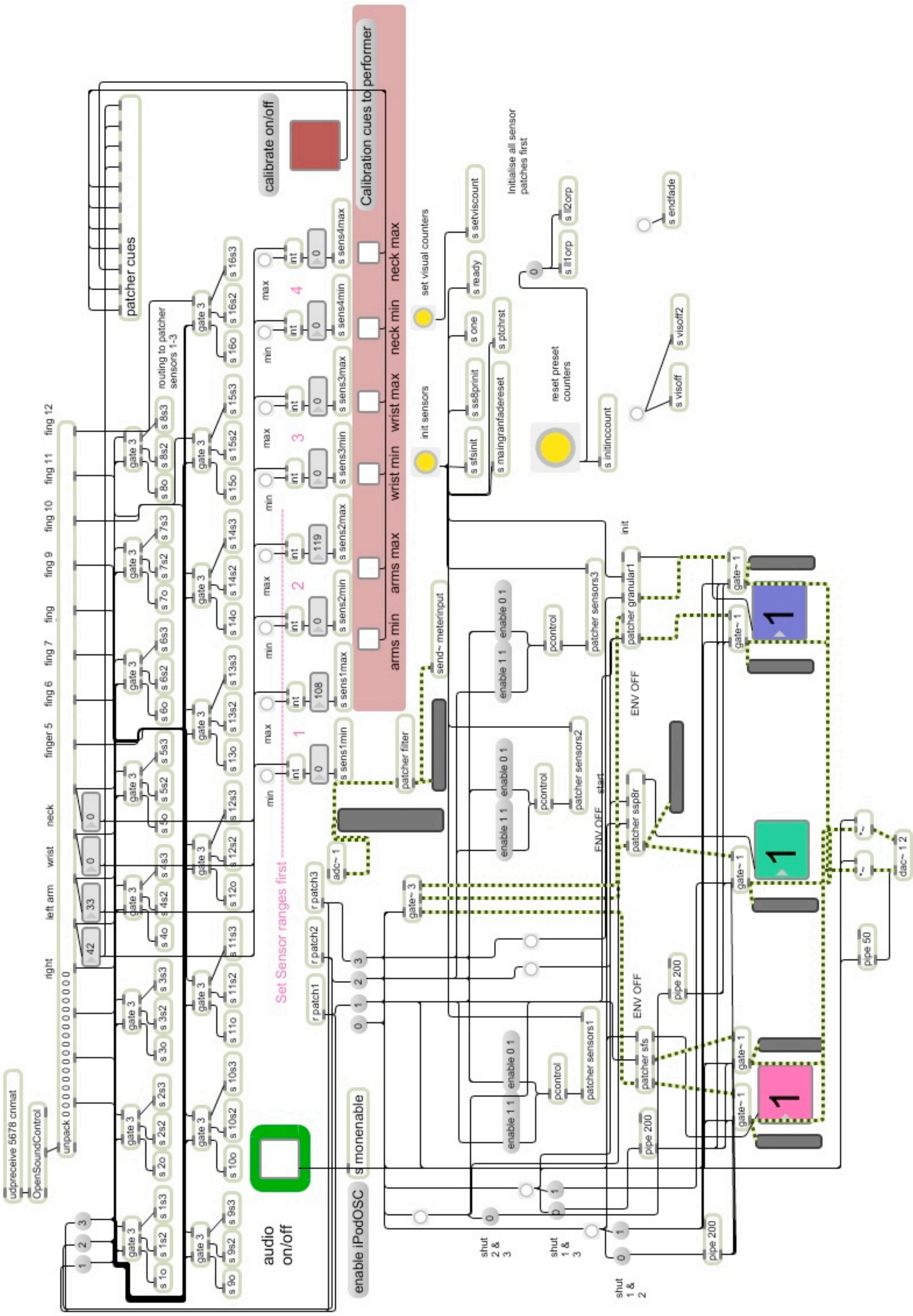


Figure 1. *The Suicided Voice* main patcher

The four sets of sensor minimum and sensor maximum values are connected to *map* objects, located in each sensor patcher, so that the full range of bend sensor values are accurately scaled and mapped to their respective control function in each processing patcher. Originally the calibration process either required the performer to be present at the computer location or to respond to visual signals from the person monitoring the computer program, either way the process was not satisfying on a professional level.

Recent developments in WiFi technology have meant that the calibration process can be done remotely by providing the performer with a system of visual cues on a small monitor screen i.e. an iPodTouch running the TouchOSC[1] application. This system of cues is activated via the main patcher (see Figure 1, p. 3). A calibrate button sends a *page* command to an iPodTouch which opens a second display page on the iPodTouch (see Figure 2, below).

Figure 2. iPod calibrator display

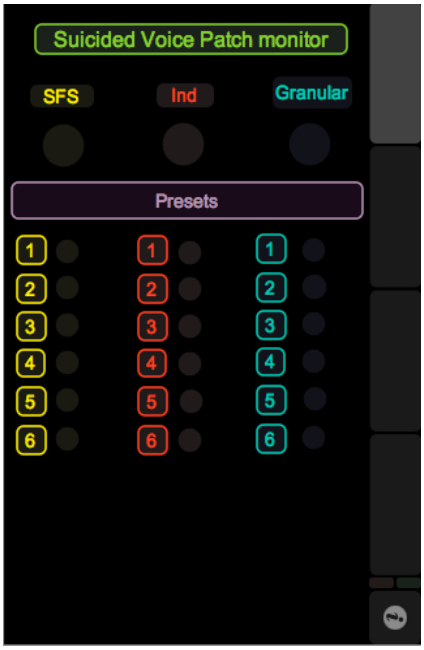


Figure 3. iPod patch monitor

Calibration cues are then sent to the performer to request the positioning of each sensor element in a straight or fully bent position whilst these values are stored in

[1] TouchOSC designed and developed by Hexler.net using the OSC protocol to send and receive data to and from an iPhone/iPodTouch to a host computer using WiFi.

their respective *int* objects. Once calibration has been successfully completed a *Page1* command is transmitted to the iPod to display *Page One* - a patch monitor screen containing preset and patch information that enables the performer to see which processing patch is active and the active preset within each patch (see Figure 3, p. 4). The cue management system is resident in a subpatcher; *patcher cues* (see Figure 4*,* p. 6).

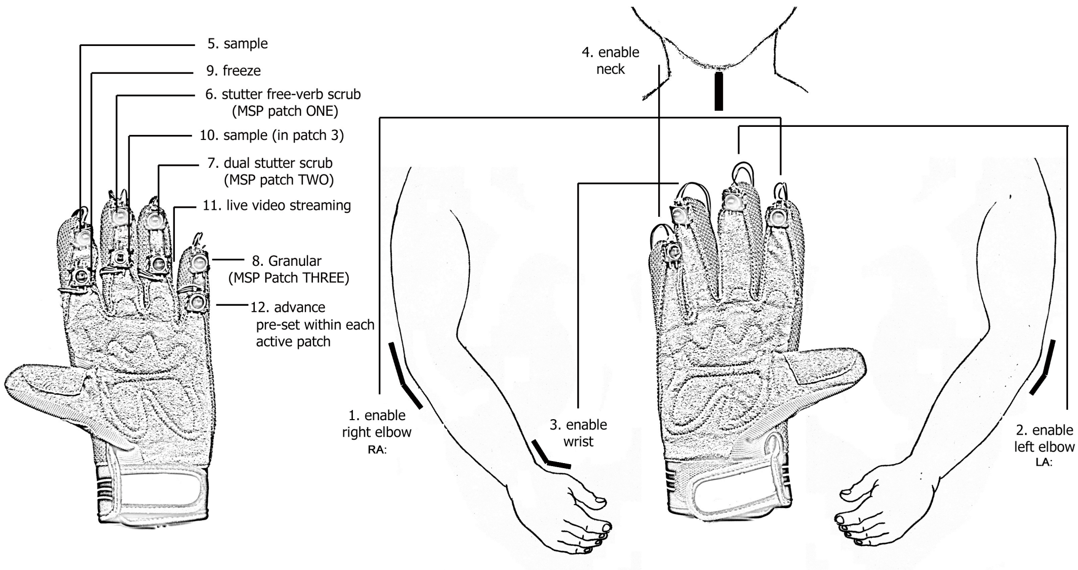


Figure 3b. Finger switch designations

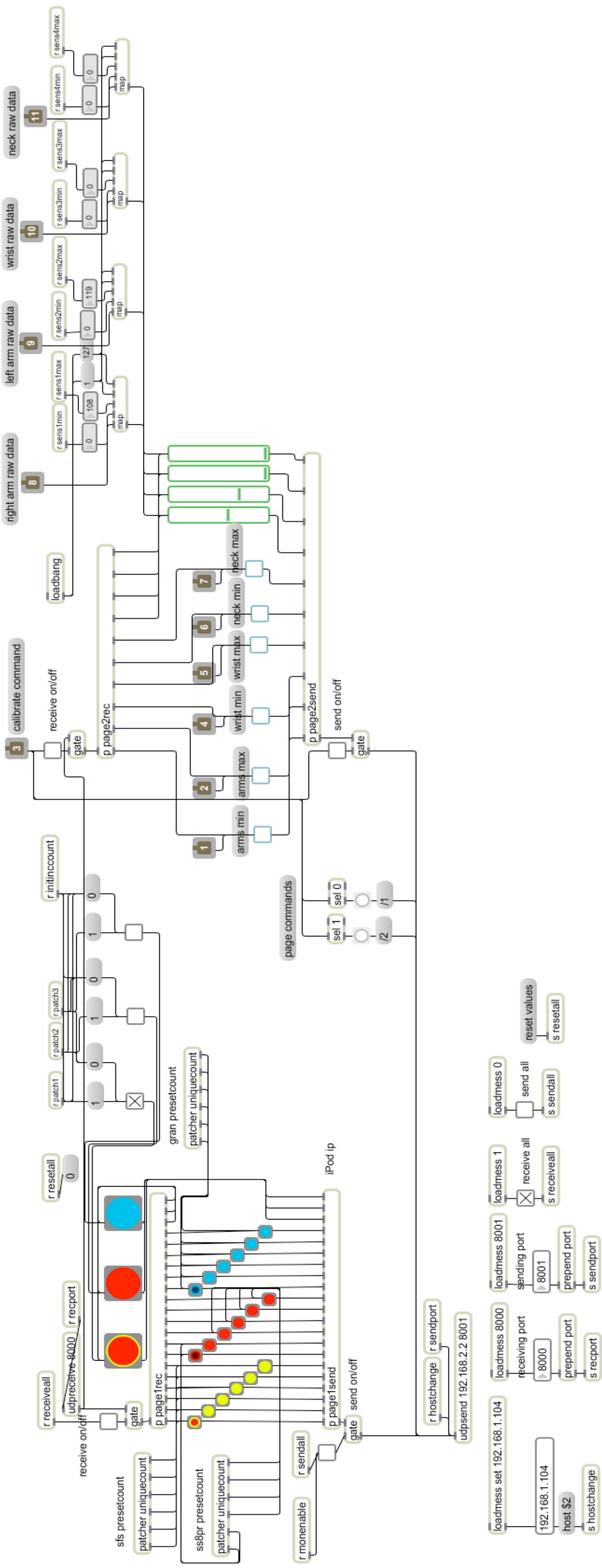


Figure 4. *The Suicided Voice* Cue Management patcher

It is useful, at this stage to look at the three main processing patchers in detail and in the order that they are recalled in the piece.

- **Processing patcher 1: *sfs***

The dedicated sensor patcher receives the sixteen channels of sensor data from the main patcher via the *gate 3* objects (see Figure 1, p. 3). Data from finger switches 1 to 4 are used to enable each of the four bend sensors to facilitate on-line/off-line working[2] (see Figure 5, p. 8). The bend sensor data is connected to four *map* objects before being output to their designated processing functions, these are: right arm to filter cutoff frequency, left arm to scrub pitch1, wrist to stutter pitch and neck to reverb balance. The left arm and wrist sensors are dynamically mapped from patch preset to preset, receiving scaling values held in preset message boxes. Switch data is connected to patcher detectors that ensure that only one 'bang' is sent on depression of a finger switch (this function can be see by referring to Figure 23, p. 38). *Patcher sensors1* also incorporates a preset increment counter; *patcher preset inc,* this patcher receives its counter increment signal directly from dedicated finger switch 12 (see Figure 3b, p. 5). The other finger switch functions enabled in this patcher are: finger 5: sample into loop, finger switches 6, 7 and 8 are dedicated to recalling one of the three main processing patchers, this is a common function to every sensor patch used in the piece, and finger switch 9: reverb freeze. Finger switch ten is dedicated to a visual function i.e. sampling the live head mounted camera input, see visuals section, p. 26, for a full explanation of the visualizations and control functions used in

[2] See Appendix A, p. 19 for a description of this protocol.

the piece. *patcher sensors1* also incorporates a visuals patcher: *patcher xpose1* (see Figure 17, p. 28).

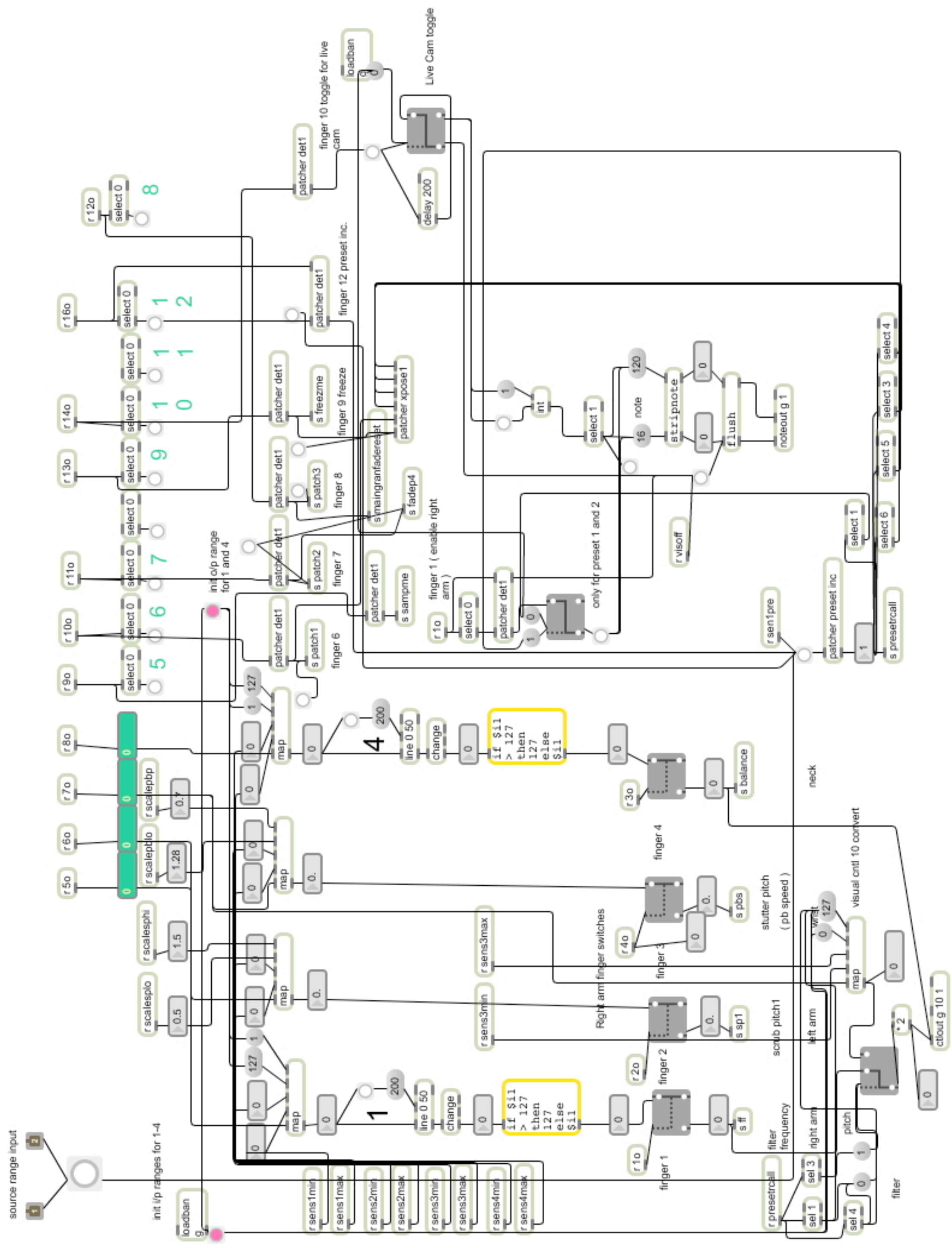


Figure 5. *The Suicided Voice* Sensor patcher

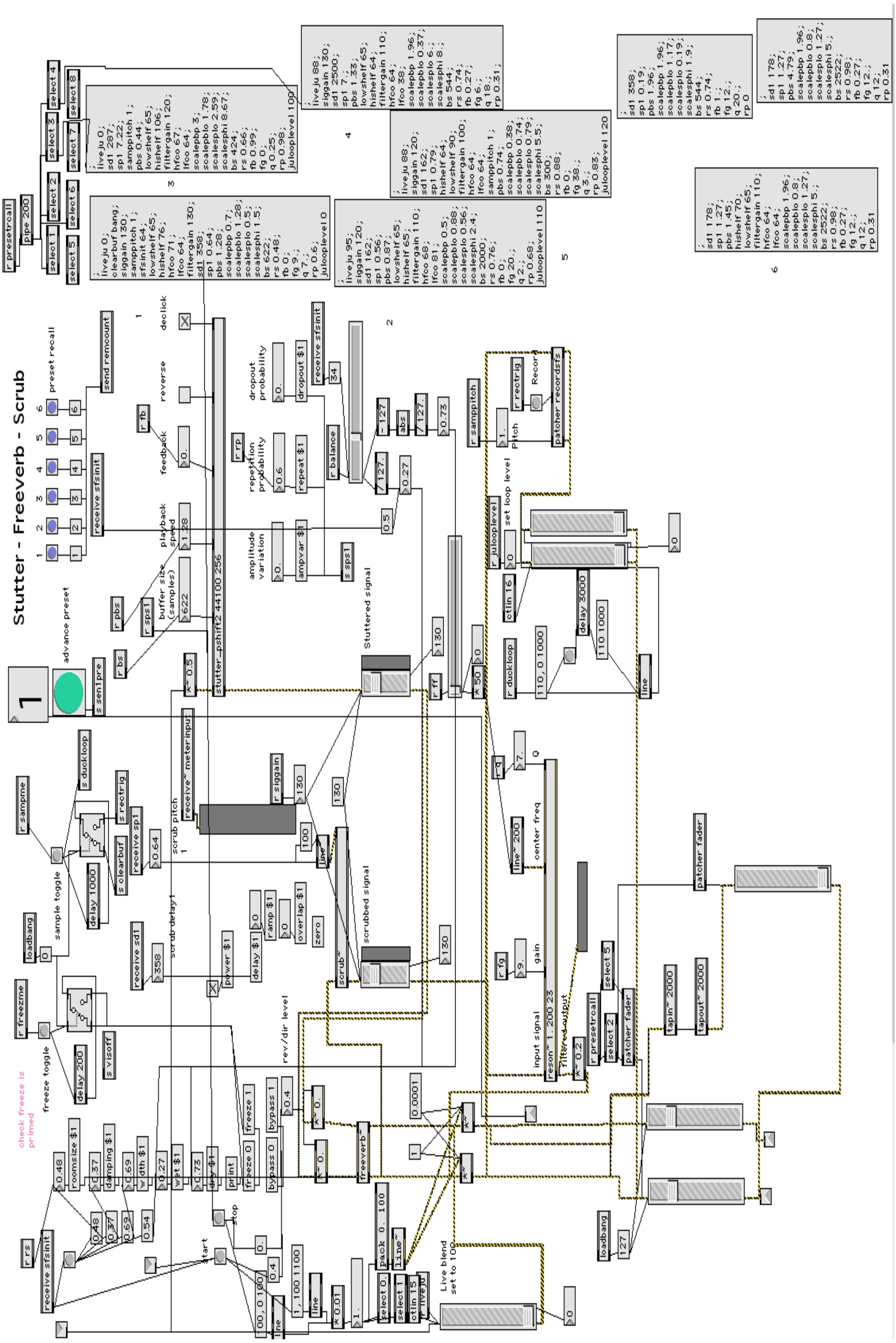


Figure 6. *SFS* - main DSP patcher

The audio input of the main patcher (see Figure 1, p. 3) is fed in series to three individual processing patchers via a graphic filter (see Figure 7, below).

Due to the large variations in audio processing in the three, quite different, processing patchers, plus the wide range of vocal techniques used in each section of the piece, it is useful to modify the frequency range of the vocal input. This pre-processing of the live vocal signal is particularly important in the second and third movements of the piece where low pitched drones are continuously looped. Filtering out the high frequencies from the live vocal input ensures a much smoother and cleaner 'pedal'.

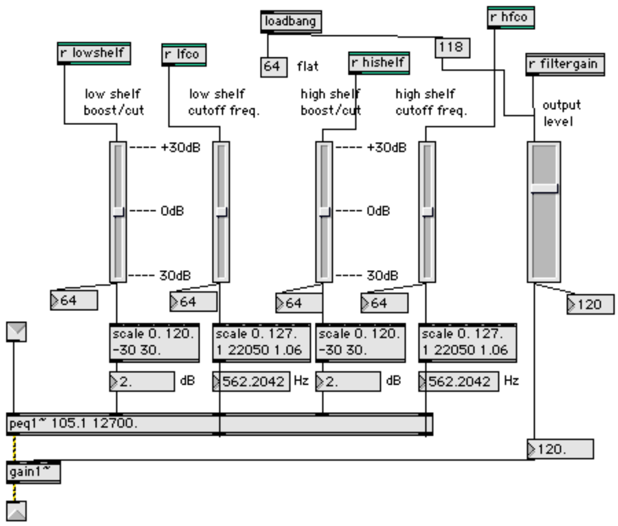


Figure 7. *The Suicided Voice* graphic filter

Cutoff frequency and gain values are stored in the preset message boxes to be recalled on the selection of each preset.

- **Digital Signal Processing [1]**

The *stutter_pshift2* patcher is based on an abstraction designed by Joshua Kit-Clayton in which two *stutter~* objects are connected in such a way that granular processing can be achieved including extreme pitch changes on the signal without clicks being introduced to the signal, as can frequently occur when using a single *stutter~* object (see Figure 8, below).

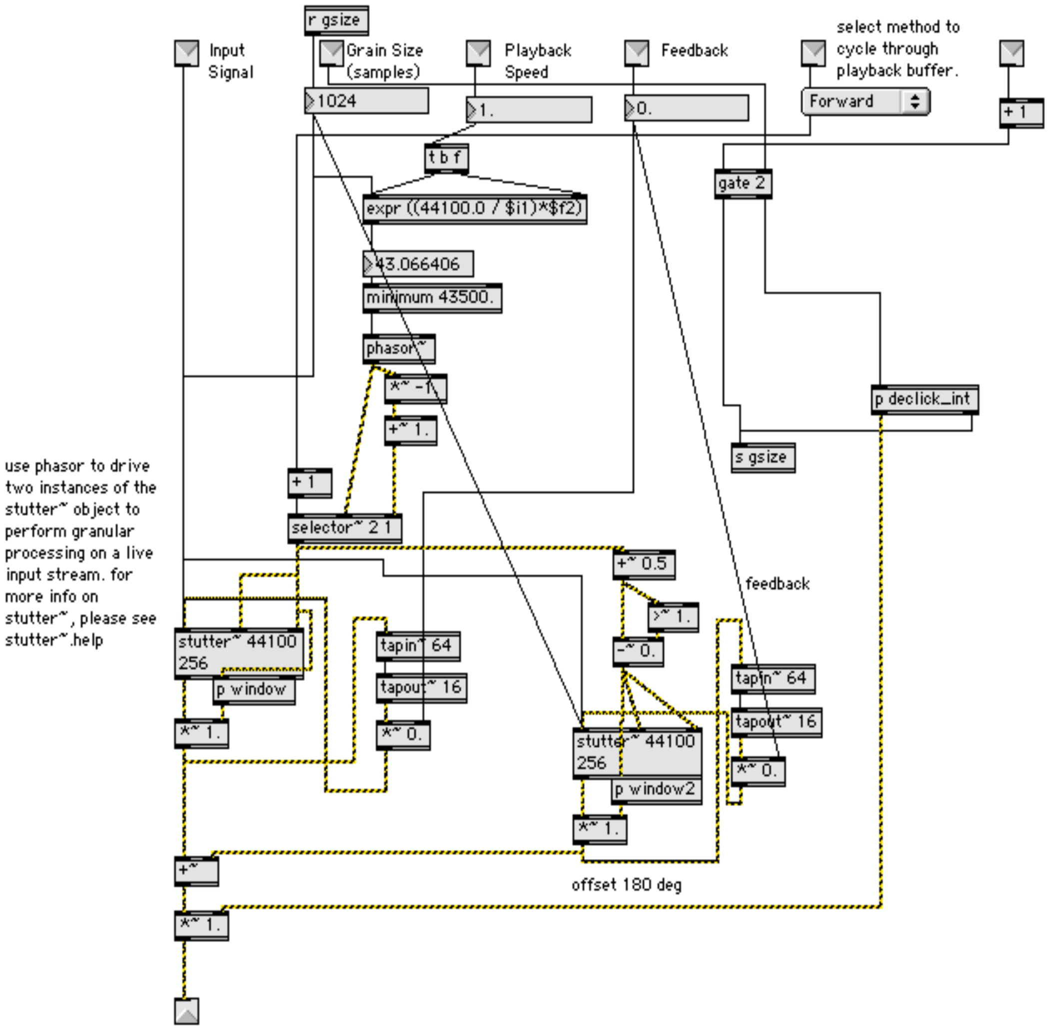


Figure 8. *Stutter-pitchshift2* abstraction

Here two grains are being played at a time, each one offset by the window size divided by playback speed. The periodic artifacts produced by this windowing process are similar in nature to amplitude modulation and it is this effect that results in interesting timbres when used to process the vocal sounds used at the start of the piece. Preset variables used in this abstraction were stored in message boxes to be recalled by the performer during the piece, these were; buffer size, playback speed feedback and probability of repetition.

The output of *stutter_pshift2* is connected to *freeverb~*, a reverberation processor, based on a Shroeder/Moorer reverberation model designed by Olaf Matthes (see Figure 6, p. 9). This processor is quite efficient in its CPU overhead and has several functions that lend themselves to external control. The 'room size' variable parameter is stored in the preset message boxes, this variable is optimized for each of the stored patches/processes. It is possible to freeze the reverberation 'tail' within the reverberation process and this is affected by devoting one finger switch to toggle this function on and off. This freezing of the reverberation tail occurs several times during the first movement of the piece as indicated in the score (see Appendix D). The output of the reverberation processor is connected to a second pitch change abstraction; *scrub~* which is part of the Percolate suite of DSP abstractions developed by Dan Truman at the Music Centre at Columbia University. *Scrub~* was developed to allow real-time delays to be varied without the introduction of discontinuities into the signal. *The scrub~* abstraction actually consists of three internal buffers, connected and addressed so as to alleviate the normal problems using a single delay buffer. As it happens there is no necessity to use the varying delay time facility in the piece, more interesting are the generated sonic artifacts as alluded to above. By employing two different pitch change processes connected in series, each with different characteristics and each introducing different artifacts, extremely interesting timbres can be produced. For example, in Preset 1 the pitch of the *scrub~* abstraction is set to a value of 0.64 whilst the preceding value of pitch (from the *stutter~* abstraction) is set to 1.28. This process of affecting a high, positive value of pitch change, followed by a low, negative value of pitch change, brings the processed vocal signal back into the normal pitch range of the vocalist. Any artifacts, such as amplitude modulation, are also brought into this pitch range. This produces extremely rich timbres, particularly when the performer is producing extended vocal techniques that include quite complex harmonic material.

Again preset variables used in this abstraction are stored in message boxes to be recalled by the performer during the piece, these are; scrub delay time; *sd1* and scrub pitch; s*p1*. The output of the *scrub~* abstraction is finally connected to a simple low pass filter, i.e. a *reson~* object with the centre frequency being controlled by a sensor worn on the left arm. The preset variables controlling this object are; filter gain; *fg*, and filter bandwidth; *q*. The output of the filter is connected to the main stereo output *dac~* object via two *gate~* objects. These are employed so that only the output of that processing chain is connected to the *dac~* object when selected for that movement, the other two processing chains being gated off until required.

A live, unaltered, vocal signal is introduced into the processing patcher in varying amounts, dependant on the preset selected, this variable; *liveju*, is stored in the preset message boxes together with the other preset variables including the scaling values for the bend sensor inputs.

Included in the main body of the patch are various fader subpatchers, these are employed to ensure smooth crossfades between DSP processes when presets are incremented. There is also a looping recorder patcher (*recordsfs*), this is only used in the final movement of the piece during operation of patch Preset 5.

A simple counter receives the output from a dedicated finger switch to recall a bank of preset variables required for that section of the piece, these message boxes can be seen on the far right of the patch (see Figure 6, p. 9). Only four presets are used in the piece; presets 1, 2, 5, 6, the remaining presets remain in the patch as 'ghosts' of previous incarnations of *The Suicided Voice*. These presets were developed during the intense rehearsal process (during the Banff residency) and it was only on the return to the UK that final refinements were made regarding the optimal compositional structure.

A 'work in process' performance of the piece was presented to an audience of staff and fellow residents at the Banff centre during the last few days of the residency. This performance contained a fifth movement using Preset 4 of the *sfs* patcher, but on analysis of the recorded presentation its inclusion was deemed unnecessary and this movement was subsequently removed from the final version of the piece. This deleted movement utilized extreme variations in pitch shifts which resulted in quite electronic sounding tonalities, which although related to the live vocal input were deemed to be working against the musical structure of the composition.

Unconnected message boxes still remain in the final patch as they still contain an interesting combination of variables that could, one day, be used in a new piece of work.

- **Processing patcher 3: *granular* patcher**

The sixteen channels of sensor data used for this processing patcher are received by patcher*; patcher sensors3*, via the *gate* objects (see Figure 1, p. 3). Bend sensor information is connected to four *map* objects before being output to their designated processing functions, these are: right arm sensor to granular scrolling, wrist sensor to loop1 pitch and neck sensor to loop 2 pitch.
Patcher sensors3 also incorporates a preset increment counter; *patcher preset inc,* this patcher receives its counter increment signal directly from dedicated finger switch 12 (see Figure 3b, p. 5).

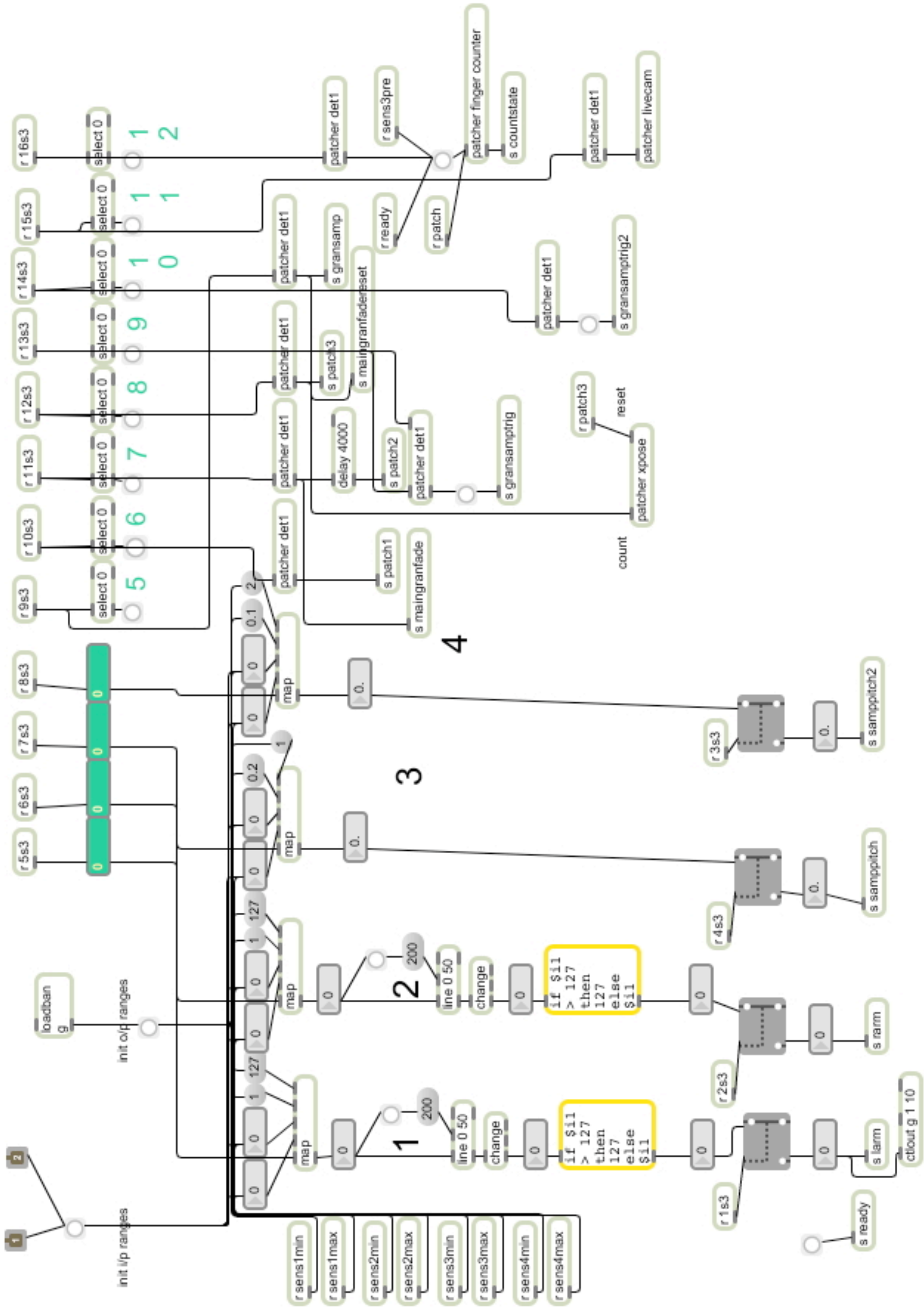


Figure 9. *Granular* sensor patcher

The other finger switch functions enabled in this patcher are: finger 5: sample into granular buffer, finger switches 6, 7 and 8 are dedicated to recalling one of the three main processing patchers, this protocol being common to all sensor patchers used in the piece. Switches 9 and 10 are used to sample the contents of the granular buffer into looping buffers 1 and 2 respectively. Finger switch 11 is dedicated to a visual function i.e. sampling the live head mounted camera input. Finally, finger switch 12 is used to advance the preset counter, again a function common to all three sensor patchers. *patcher sensors1* also incorporates a visuals patcher: *patcher xpose.* This is documented in the visuals section of this appendix (see p. 26).

- **Digital Signal Processing [2]**

The *granular* processing patcher is used in movement two and is recalled by using a dedicated finger switch; finger 8 (see Figure 3b, p. 5). The processing patcher utilizes four instances of the *grain~* abstraction, which was developed as a first generation granular playback mechanism written by Nakomotu Sakonda (see Figure 10, below). Each instance samples an input signal, setting four grain phases; 0, 0.25, 0.5 and 0.75. It was a simple process to modify the *grain~* abstraction to record a live signal, this was achieved by first recording the live signal into a buffer that was then referenced in each *grain~* abstraction (see Figure 10, below and Figure 13, p. 20).

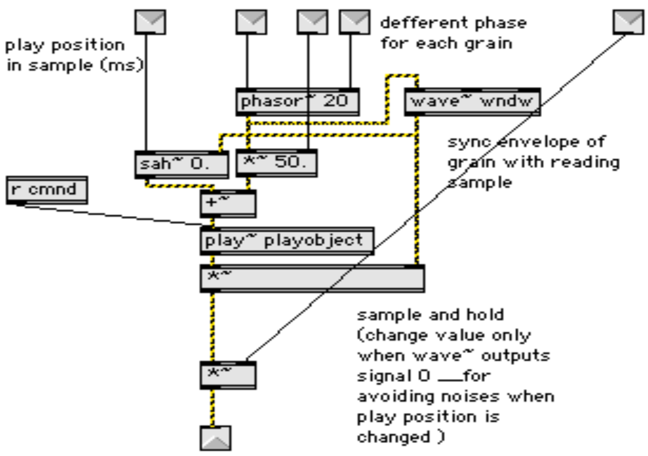


Figure 10. *Grain~* abstraction

Two variable elements were identified as having the most useful and potentially expressive control functions, these were; sample scrolling and sample pitch. As in the previous processing patch, message boxes hold variables to be recalled by the same, dedicated finger switch. The preset variables, attributable to the main granular processor, are granular loop length, granular pitch, scaling for the scrolling sensor and a randomization position. The randomization variable is an important element in this processing section as it imparts a certain 'organicity' to the samples recorded into the granular buffer. This type of randomization is also used to good effect in *Lifting Bodies* (1999) providing an essential variation to the looped, pre-composed soundfiles used in that piece.

The *granular* patcher includes two, 12 second, recording/looping buffers (*patcher loop* and *patcher loop2*), into which the output of the granular buffer can be recorded, the recording initiated by a dedicated finger switch (see Figure 3b, p. 5). The two loop recorders use the *wavefade~* abstraction that is included in the examples folder of the Max/MSP software installation (see figs.11 and 12, p. 19). *Wavefade~* uses two *wave~* objects, driven by a variable rate *phasor~* object, to control the speed/pitch of a recorded buffer. A *trapezoid~* object is used to fade in and out the playback loop to avoid any clicks that would normally occur without the use of a cross-fading process. This avoidance of clicks is essential when using a live sample looper and the addition of a variable, controlling the length of cross-fade, allows a totally seamless loop to be achieved.

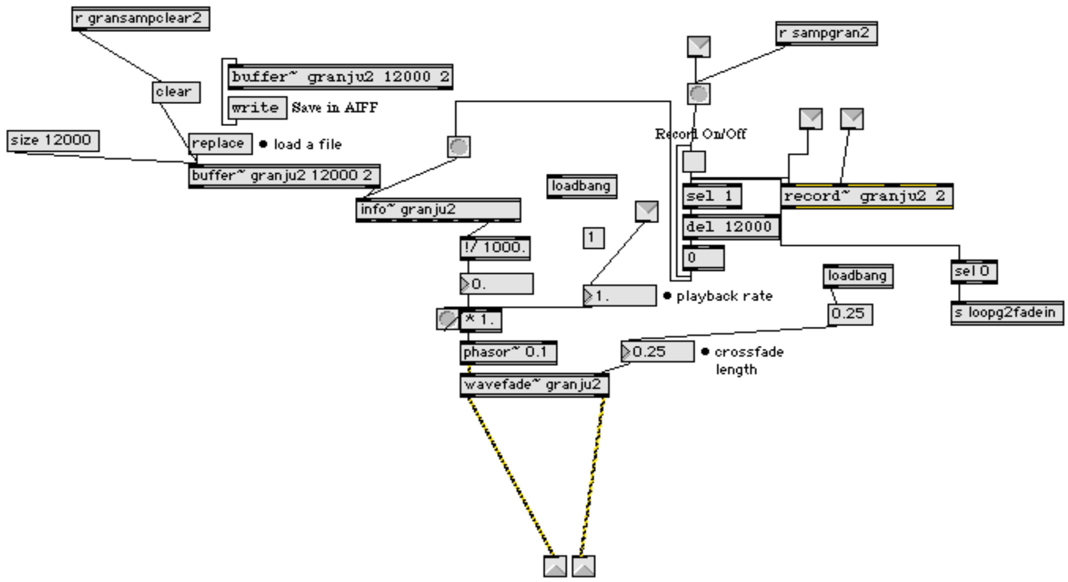


Figure 11. Looper patcher

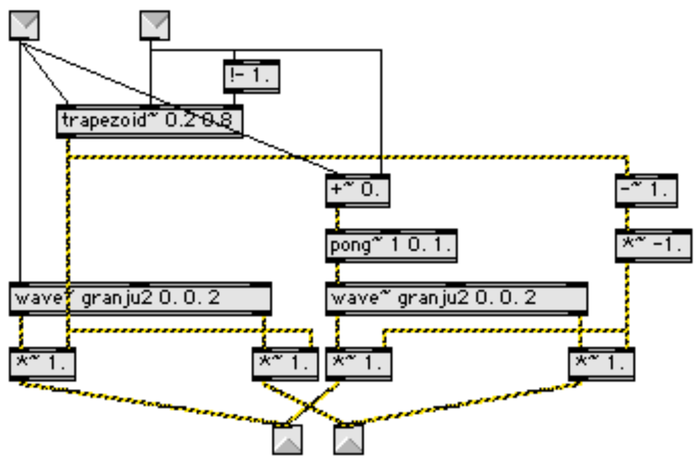


Figure 12. *Wavefade~* abstraction

The playback rate, and hence pitch, of *looping recorder 1* is controlled by the wrist bend sensor.

The patch contains several *fade* patchers that ensure that granular and loop buffer material is faded in and out at various preset rates, ensuring no abrupt transitions occur.

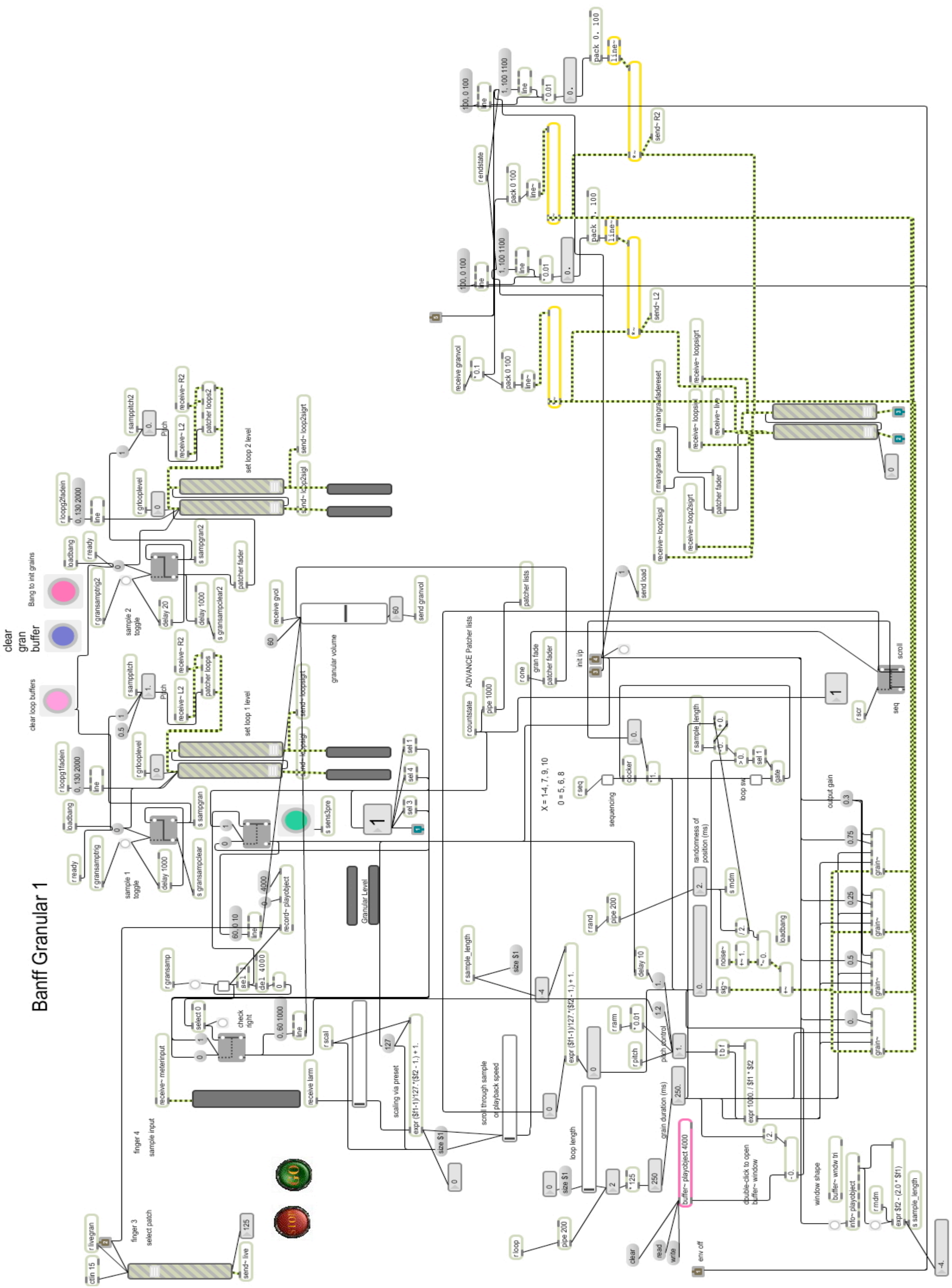


Figure 13. *Granular* - main DSP patcher

As can be seen at the bottom of the main *granular* patcher (see Figure 13, above), *line* objects have been employed to ensure smooth transitions between preset states, this is extremely important in this processing patch, giving a sense of the soundscape ‘breathing’ in and out as a virtual ‘analogue’ of the physical voice of the performer.

- **Processing patcher 2: *ssp8r***

The sixteen channels of sensor data used for this processing patcher are received by *patcher sensors2* via the 16 *gate* objects resident in the main patcher (see Figure 1, p. 3).

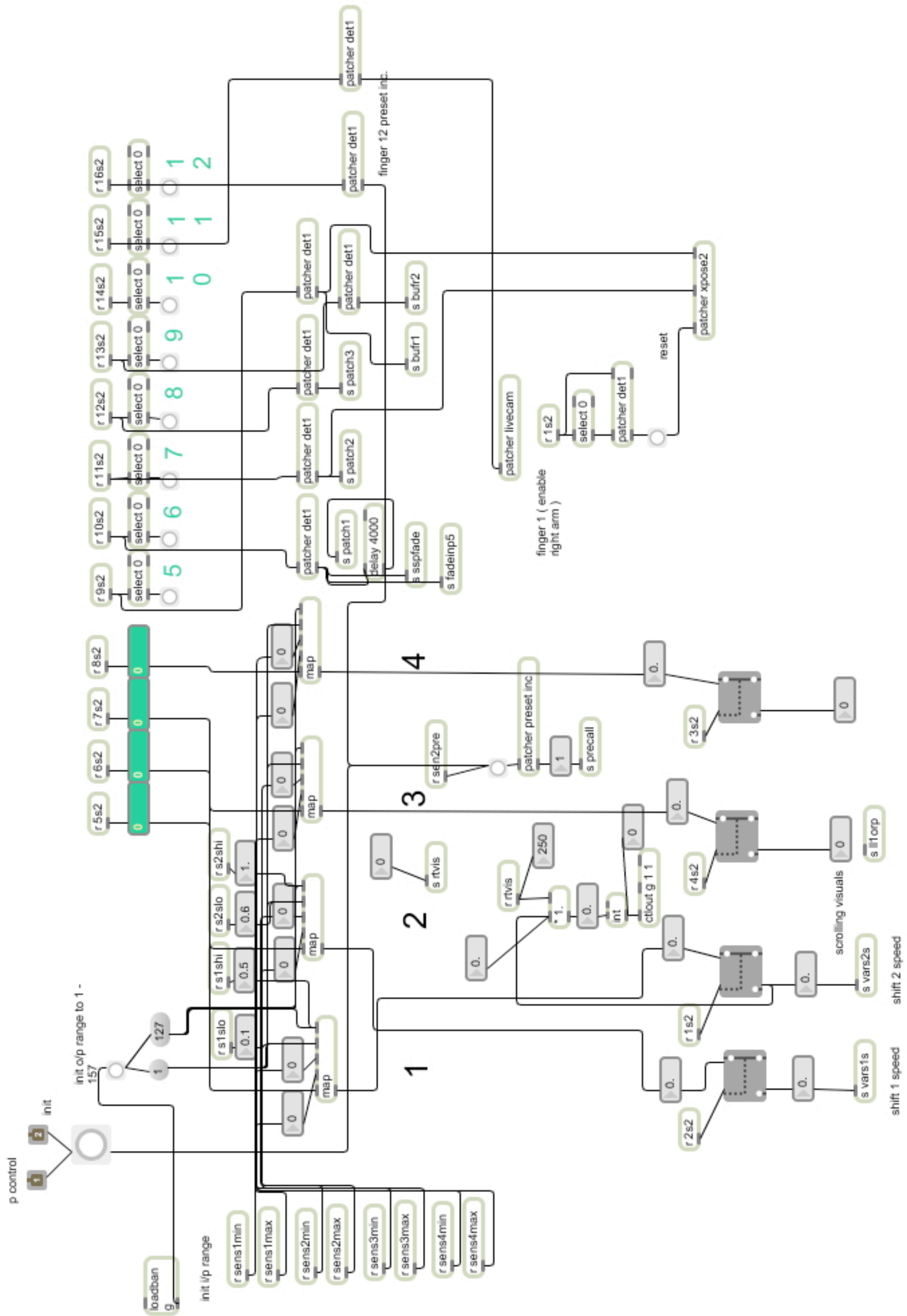


Figure 14. *Ssp8r* sensor patcher

The two active bend sensor inputs are connected to *map* objects before being output to their designated processing functions, these are: right arm to pitch shift 1, left arm to pitch shift 2. (see Figure 14, p. 22). Sensitivity and range values for each individual preset are stored in the preset message boxes. Finger switch 5 initiates sampling into a sixteen second looping buffer; 1, and finger switch 9 initiates sampling into a twelve second looping buffer; 2.

In common with the two previous sensor patchers: *patcher sensors2* also incorporates a preset increment counter; *patcher preset inc*, this patcher receives its counter increment signal directly from dedicated finger switch 12 (see Figure 3b, p. 5).

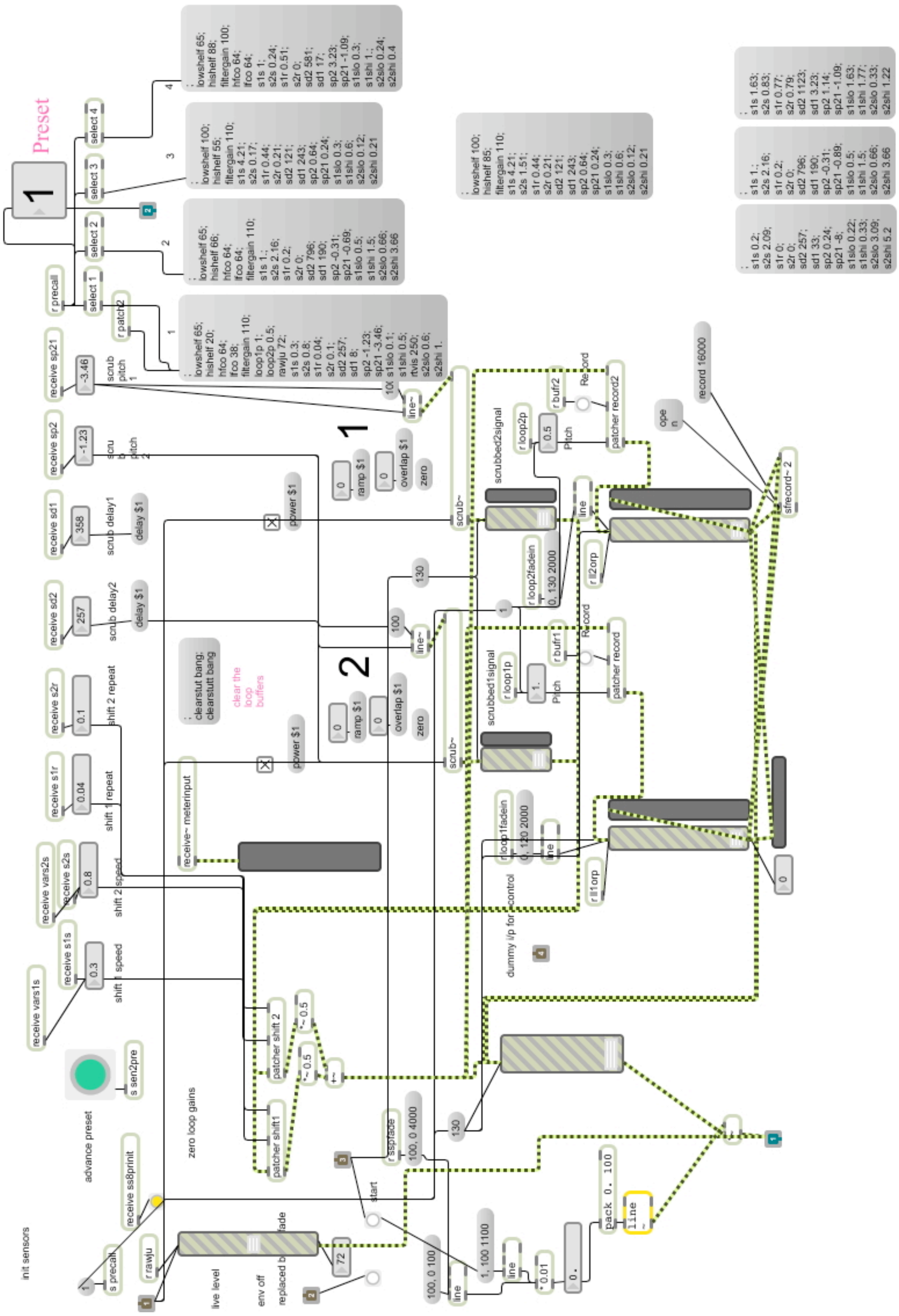


Figure 15. *Ss8pr*: main DSP patcher

- **Digital Signal Processing [3]**

Processing patcher: *ss8pr* (see Figure 15, p. 24) is recalled for use in movement three and uses the most extreme form of processing in the whole piece.

The live vocal sound is firstly connected to two *scrub~* abstractions with values for variables *sp2* and *sp2.1* being held in message boxes recalled by the usual preset recall, this function is initiated by activating the patch using finger switch 7 (see Figure 3b, p. 5). The outputs of the *scrub~* abstractions are connected to two pitch shift patchers, *Pshift1* and *Pshift2*, each employing the *stutter-pitchshift2* abstraction (see Figure 7, p. 10), this process is referred to on p. 11 in the description of processing patch1. Pitch control in these two processing patchers is via the two arm sensors (see Figure 3b, p. 5), different scaling values for these sensor elements are held in each preset message box - giving different ranges and sensitivity values for each active preset within the processing patch. The outputs of each pitch shift abstraction are mixed and fed to two record patchers that use *Wavefade~* to ensure glitch-free sampling into a sixteen second and a twelve second looping buffer (see Figure 16, below).

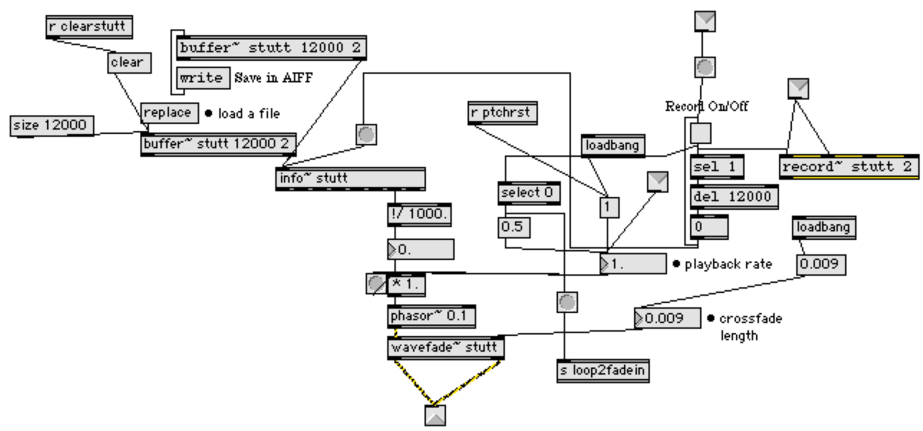


Figure 16. Looper patch

- **Visual Elements**

In *The Suicided Voice* the performer is framed by a large projection screen. This is an extremely important factor in the piece providing a dramatic backdrop to the physical expressivity of the live performance. A separate visuals patcher is incorporated into each of the three sensor patchers, the use of *pcontrol* objects ensuring that MIDI data is only received for the active processing patch (see Figure 1, p. 3).

As each visuals patcher works in essentially the same way I will only look at the first of these patches that is active in movements one and four. Referring to Figure 17, p. 28, an audio freeze command increments a counter value. This counter value is used to trigger various images held in an XPose patch on a second Macintosh computer. The link between the MSP patcher and the XPose program is achieved via a MIDI link comprising two, single-port MIDI interfaces. These MIDI interfaces are used to send and receive MIDI data - from the Max/MSP patch to the XPose patch. The Xpose patch responds to both MIDI note on/off data and controller data, the note on data triggering the image files. This can clearly be seen in Figure 17, p. 28, whereby on receipt of a counter value of 1, a note value of 17 with a velocity value of 120 is sent to a *noteout* object. This note trigger, and its associated visualization, stays on until patch change 3 is received whereby the note, and hence the visualisation is turned off. Combinations of freeze command triggering and preset detection triggering enables different images to be triggered at different times and for different functions. An additional function enables the performer to sample a live video signal fed from a head mounted radio camera focussed on the mouth (see Figure 18, p. 29).

This live video sampling is enabled by detecting finger switch 10 that operates a toggle function i.e. switching between live streaming and locking a frozen snapshot of the sampled video image. The bend sensor located on the performer's neck is used to control a video effect process within Xpose to modulate the live video image to produce an effective and dynamic visualisation to accompany the audio transformations.

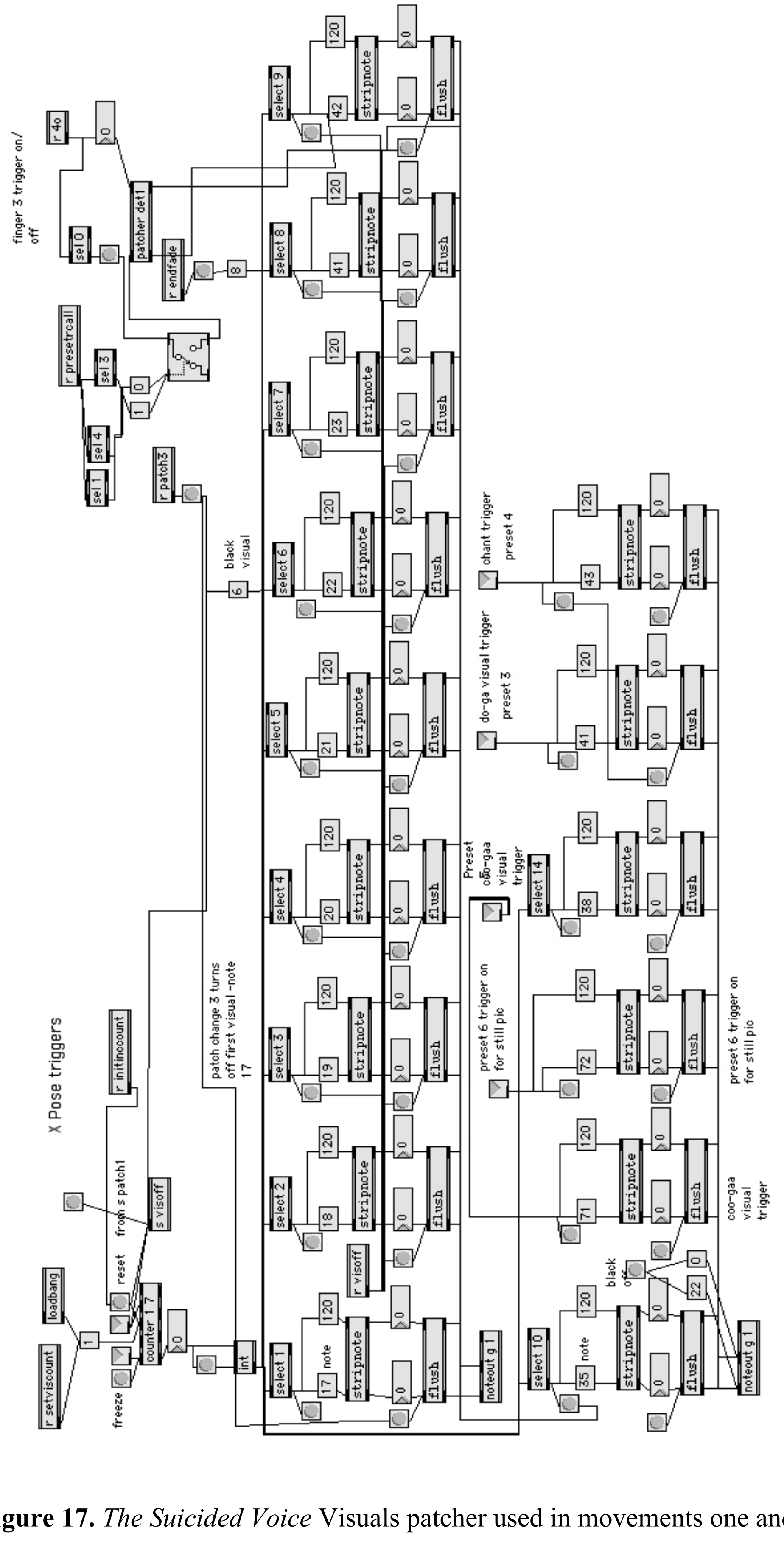


Figure 17. *The Suicided Voice* Visuals patcher used in movements one and four

Figure 18. Head Camera and radio microphone (Banff 2003)

B1.2 *Hand to Mouth* (2007)

- **Max/MSP design and implementation**

Hand to Mouth employs ten preset configurations controlling several instances of two main processing patchers, a reverberation processor and two live looping recorders. It is useful, at this stage to look at the two main processing patches in detail.

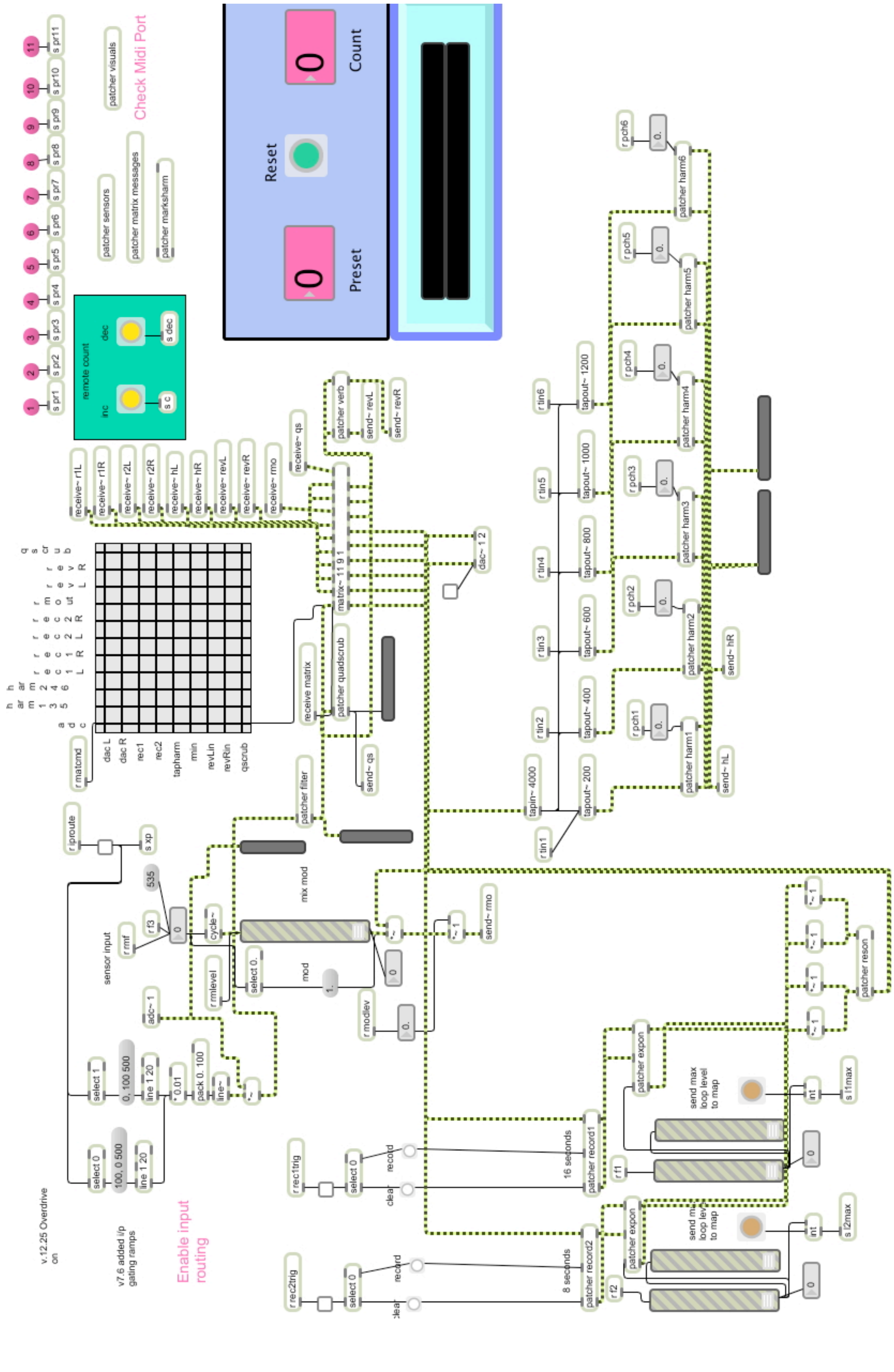


Figure 19. *Hand to Mouth* main patch

- **Processing patcher: Quadscrub**

This patcher uses four instances of the *scrub~* abstraction, described on page 12 of this appendix, and uses the *poly~* object to address each instance as required by each preset. The main controllable variable *f4* is connected to all four instances via + objects (see Figure 20, p. 32). The *f4* variable is added to four discrete pitch variables, *p1* to *p4*, these pitch variables are stored in the preset message boxes; *Patcher messages1* to *Patcher messages11* (see Figure 20, p. 32). As each preset also contains the scaling for the sensors, including the sensor controlling the *f4* variable, the *quadscrub* patcher can be configured to give a wide range of 4 voice pitch harmonisations.

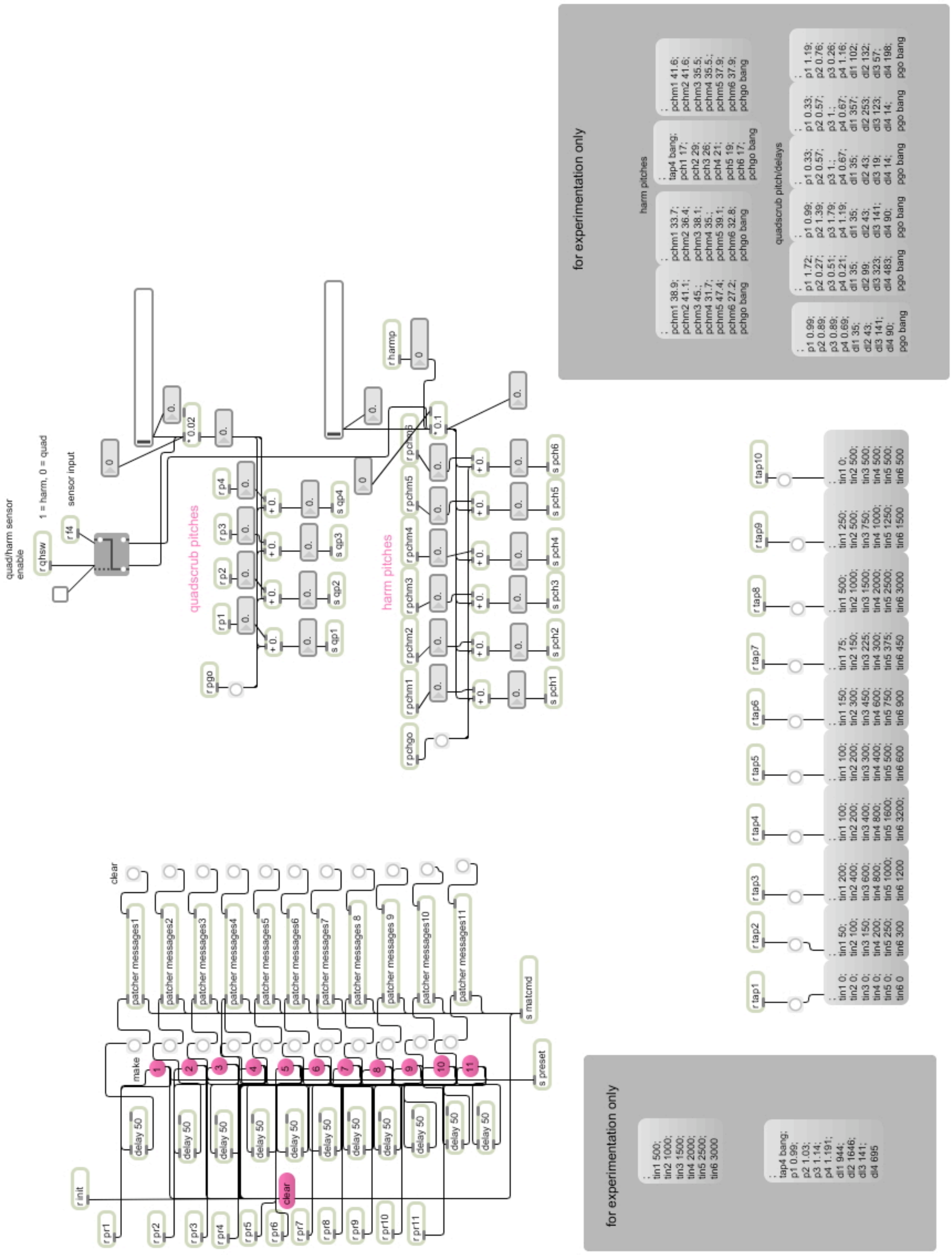


Figure 20. Message patcher/*Scrub* & *Harm* scaling

The controllable variable *f4* is operated by the finger 4 sensor that can also be configured to control the pitch of the six *Harm* patchers, this sensor routing is enabled by sending a 1 or 0 to *qhsw*, this can be seen at the top of Figure 20, above, and is set and recalled for each active preset. The other set of *Quadscrub* variables stored in each message box set the delay time (*dl1* to *dl4*) of each instance of *scrub~*. Each preset message box holds values that were defined in the experimentation process to produce a wide range of timbres that could be effectively controlled in real time. It is interesting to look at the unconnected message boxes, visible at the lower right hand side of Figure 20, p. 32, that show sets of pitch and delay variables that were used during the experimentation process, some of which ended up being used in the final piece.

The monophonic inputs and outputs of the *Quadscrub* patcher are connected to the *matrix~* object together with the inputs and outputs of the second main processing patcher; *Harm*.

- **Processing patcher: Tapharm**

Six instances of the *Harm* patcher (*harm1* to *harm6*) are connected via simple *tapin~* and *tapout~* objects, each of which can be pre-set with different delay tap time messages (*tin1* to *tin6*). The controllable pitch variable, *harmp*, is operated by the bend of finger 3 that can also be configured to control the frequency; *rmf* of a simple amplitude modulator. The *rmsw* value, 1 or 0, held in the preset message boxes, controls finger 3 sensor routing. For example in Presets 1 and 2, finger 3 controls the harmonisation pitch and in Preset 3, finger 3 controls the amplitude modulator frequency.

In a similar fashion to the *Quadscrub* patcher the controllable variable *harmp* is connected to all six instances via + objects (see Figure 20, p. 32). The *harmp* variable is added to six discrete pitch variables (*pchm1* to *pchm6*), these pitch variables are stored in the preset message boxes (*messages1* to *messages11*). As each preset message box also contains the scaling for the sensors, including the sensor controlling the *harmp* variable, the *harm* patchers can be configured to give a wide range of six-voice, pitch harmonisations. The pitch ratios for *pchm1* to *pchm6* were obtained during the experimentation process and result in a wide range of timbral signatures that gives the performer a wide expressive range from a small physical lever.

- **Additional Patch design**

Due to the large dynamic range required from the performer it was essential to incorporate some form of limiting at the start of the processing chain. To facilitate this an *OMX* limiter is used with preset values for threshold, input level and output levels being stored in the preset message boxes. These values were set in the rehearsal process to be optimal for each processing preset (see Figure 21, below).

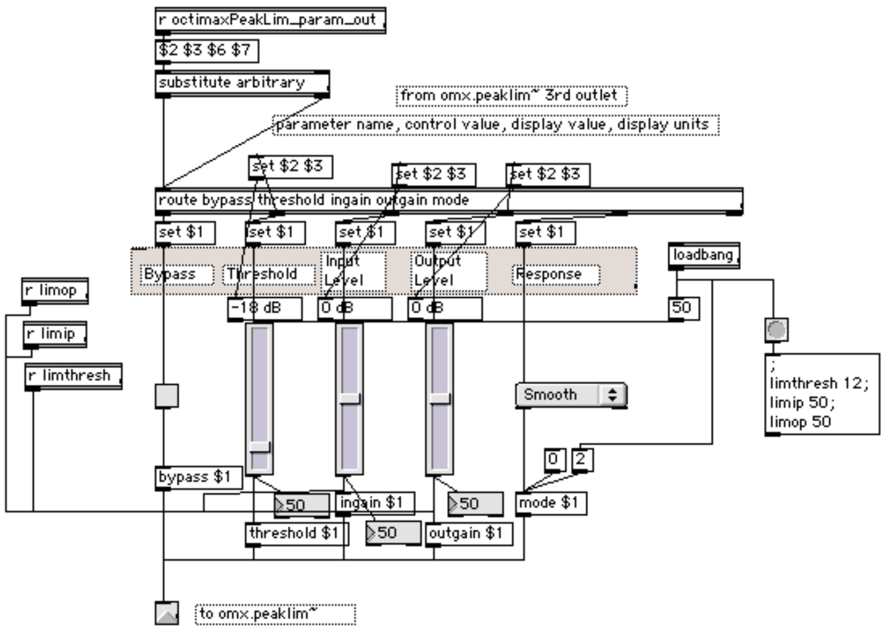


Figure 21. OMX peak limiter

An 8 second and a 16 second looping recorder patcher is incorporated into the main control patcher. The signal inputs and outputs, connected to the looping recorders, are also connected to the *matrix~* object. In this way outputs from any of the processing patchers can be recorded into the recording buffers at any stage in the signal chain, enabling material to be recorded separate from the live and processed vocals.

Two dedicated finger switches are allocated to record or clear the recording buffers by simply employing a *toggle* function to switch these functions; *rec1trig* and *rec2trig* (see Figure 19, p. 30). In this way the performer can record material into a buffer with the activation of a single finger switch, clear the buffer on the second activation of the same switch and record new material into the buffer on the third switch depression. The performer can also control the level of the two looping recorders, enabled by the activation and operation of two dedicated bend sensors on fingers 3 and 4. The recorded material held in each looping buffer is an essential and important element in defining the composition. Complex and timbrally interesting material can be built up and sensitively incorporated into the audio mix by the operation of the two finger sensors. The outputs of the looping recorders are connected to a *reson~* filter, the centre frequency of which is controllable via finger sensors 3 and 4. This filter was bypassed in the final version of the patch as it was deemed unnecessary to include this extra level of processing to achieve the required results. This patcher was subsequently retained in the final version, enabling its use in the possible development of a new piece at a later date.

- **Sensor translation and scaling**

Data from the bend and switch sensors are received via the *otudp* receive object and formatted to the OSC protocol. The OSC messages are first unpacked, the bend sensor data then connected to a simple calibration system that ensures that the full range of the proportional sensors are available. As with *The Suicided Voice* this calibration is performed at the start of the piece end requires the performer to locate both arm sensors at their minimum positions, i.e. straight arm positions, these values being stored in integer number boxes and then locate both sensors at their maximum positions, i.e. fully bent positions and again store these values in integer number boxes (see Figure 22, p. 37).

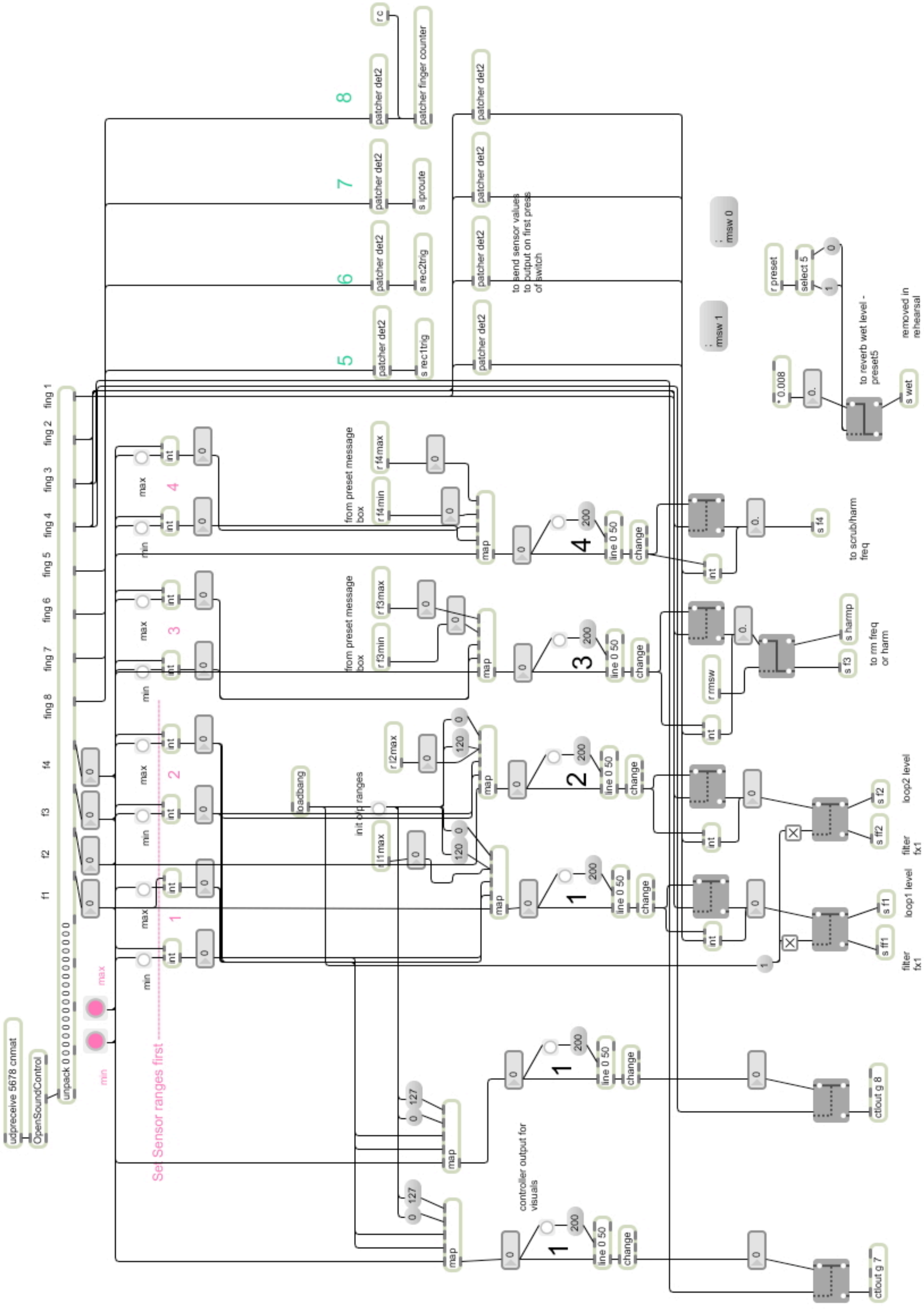


Figure 22. *Hand To Mouth* sensor patch

Referring to Figure 22, above, it can be seen that detector patchers have been employed to receive the data from finger switches 5 to 8. In the early stage of development of the second generation of the Bodycoder System it was found that it was not feasible to use the raw data from switch elements to enable patch navigation and routing as the output from the unpacked sensor data would repeat every four milliseconds, i.e. at the coder sample rate. This meant that even though a held switch would output a value of 1023, this value would result in repeated bangs from a *select* object. This was practically useless, for example, when only one bang was required to increment a patch change. It is interesting to note that the original method, employed to circumvent this problem was different from the one used in subsequent pieces developed for the system. As can be seen by referring to Figure 23, below, the techniques used to facilitate the switch detection are markedly different and arise simply by not having encountered the *onebang* object during previous development work. As usual, in MSP design, there are different ways of achieving the same goal and it was decided, at an early stage of MSP programming, that it is not always necessary to search for the most efficient design, as this can hinder and slow the creative process. Composing whilst developing Max/MSP patches usually occurs within a limited time frame, sometimes whilst attending a fixed period residency, so it is vital to be able to achieve results within this period and not be overly concerned with optimizing patch design. Optimizing patch designs can be done at a later stage and outside the respective residency or set compositional periods.

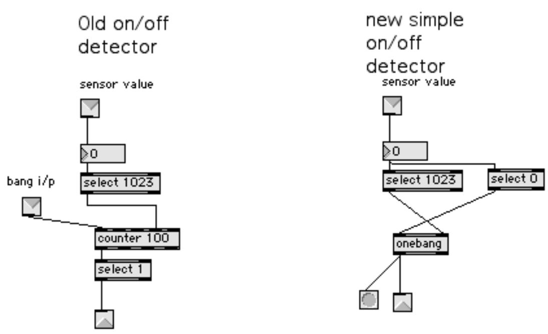


Figure 23. Two versions of switch detection patchers

Sensor mappings and translation values for fingers 3 and 4 are held in each preset message box so that the range and sensitivity of each of these two sensors are uniquely set for each preset; optimizing the range and expressivity that is required for the performance. Finger sensors 1 and 2 are initiated at the calibration stage, remaining constant for the duration of the piece. The output and range of these sensors do not change from preset to preset as they are always designated to control the volume of the two looping buffers operating with the same sensitivity.

A further four finger switch detectors are employed in the sensor patch so that, in particular, volumes levels do not suddenly jump to a new value on the depression of a bend sensor enable switch (see Figure 22, p. 37). This is achieved by storing the last active sensor value in an *int* object so that on reception of a subsequent sensor enable signal the last sensor value received on de-activation of the sensor would be recalled.

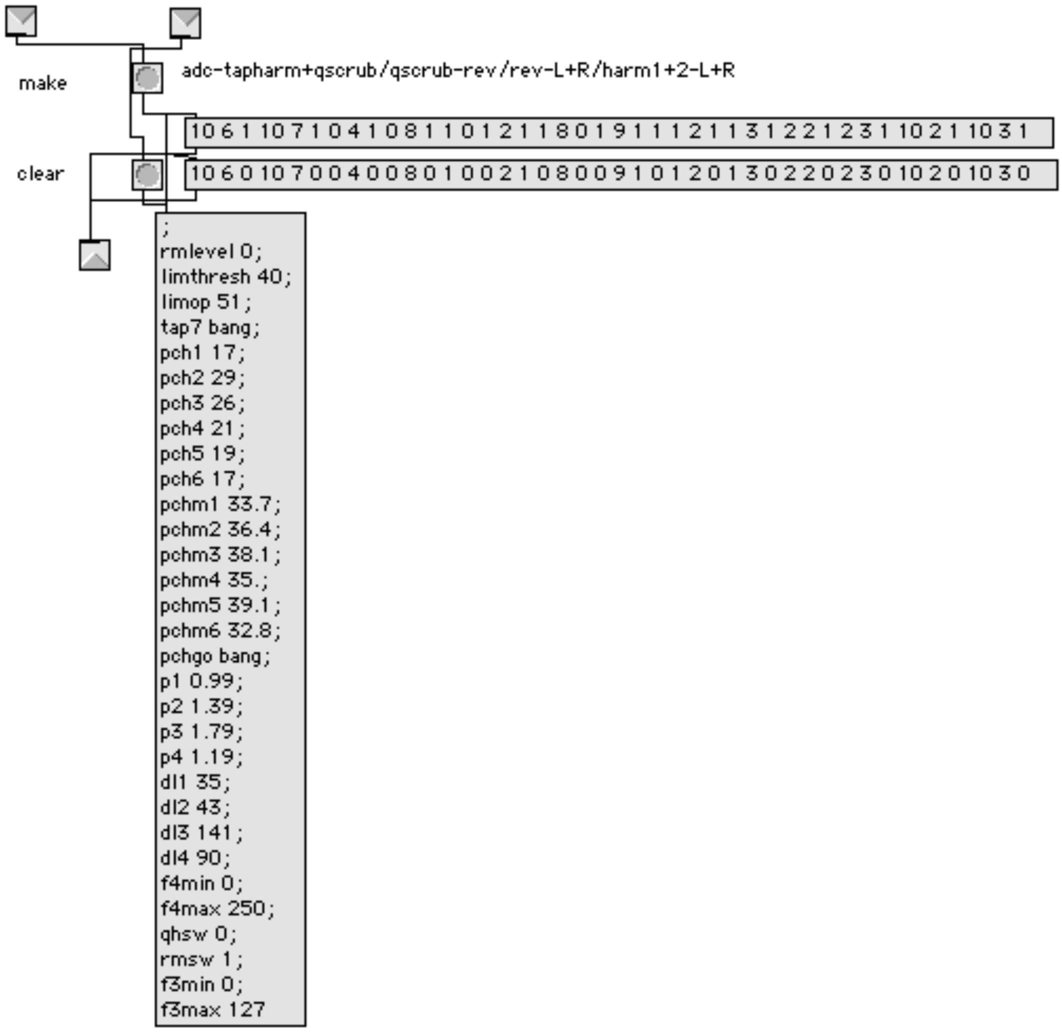


Figure 24. Patcher messages1

The last processing element in the main patcher employs *freeverb~;* a reverberation abstraction designed by Olaf Matthes. The inputs and outputs to *freeverb~* are also connected to the *matrix~* object enabling various levels of reverberation to be applied to any part of the processing chain. Preset variables controlling this patcher comprise wet level (wet), dry level (dry), damping (damp) and room size (rsize).

As previously noted complex or simple processing patching can be recalled by the simple activation of a preset, two examples of which can be seen by referring to Figure 25 and Figure 26, p. 41.

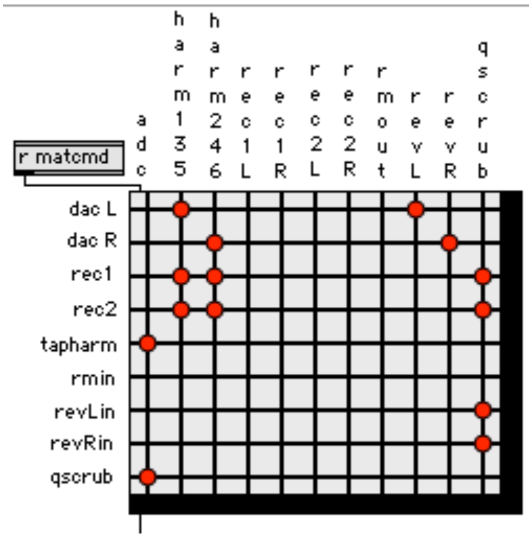


Figure 25. Preset 1 *matrix~* connections

Analysis of preset 1's *matrix~* connections, shown in the diagram above, indicates a complex signal chain whereby the live vocal signal (*adc*) connects to both harmonization processors t*apharm* and *qscrub*). Both harmonizers connect to the inputs of the looping recorders (*rec1* and r*ec2*). The output of the *quadscrub* harmoniser is connected to both inputs of the reverberation processor (*revLin* and *revRin*), the reverberator output (*revL* and *revR*) is mixed with the output of the *harm1-6* processors (*harm135* and *harm246*) and sent to the audio outputs (*dac L* and *dac R*) (preset 1's message box can be seen by referring to Figure 26, p. 40).

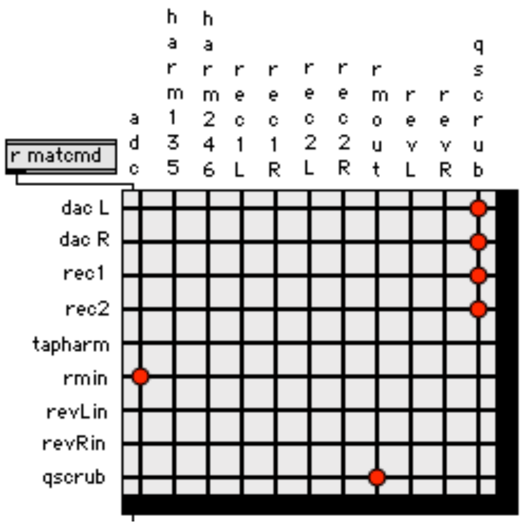


Figure 26. Preset 3 *matrix~* connections

Analysis of preset 3's *matrix~* connections (see Figure 28, p. 41) shows a simple signal chain whereby the live input signal is connected to the input of the amplitude modulator (*rmin*). The output of the amplitude modulator (*rmout*) is then connected to the audio outputs (*dac L* and *dac R*) and also to the inputs of the two looping recorders (*rec1* and *rec2*). In this preset the outputs of the looping recorders are not connected to the audio outputs, however, the input connections enable recording of amplitude-modulated material to be output at a later stage in the piece.

Navigation through the presets is achieved by dedicating a single finger switch; switch 8 (see Figure 27, p. 43) to increment a simple ten-stage counter, the output of which is connected to the preset message boxes. In this way all matrix~ routing and processing settings is recalled by the activation of switch 8. As can be seen by referring to Figure 28, p. 43, the counter values recall non-consecutive presets that were defined during the compositional and rehearsal processes. The presets are recalled in the following order: 2, 3, 8, 7, 2, 10, 6, 11, 2, and 3.

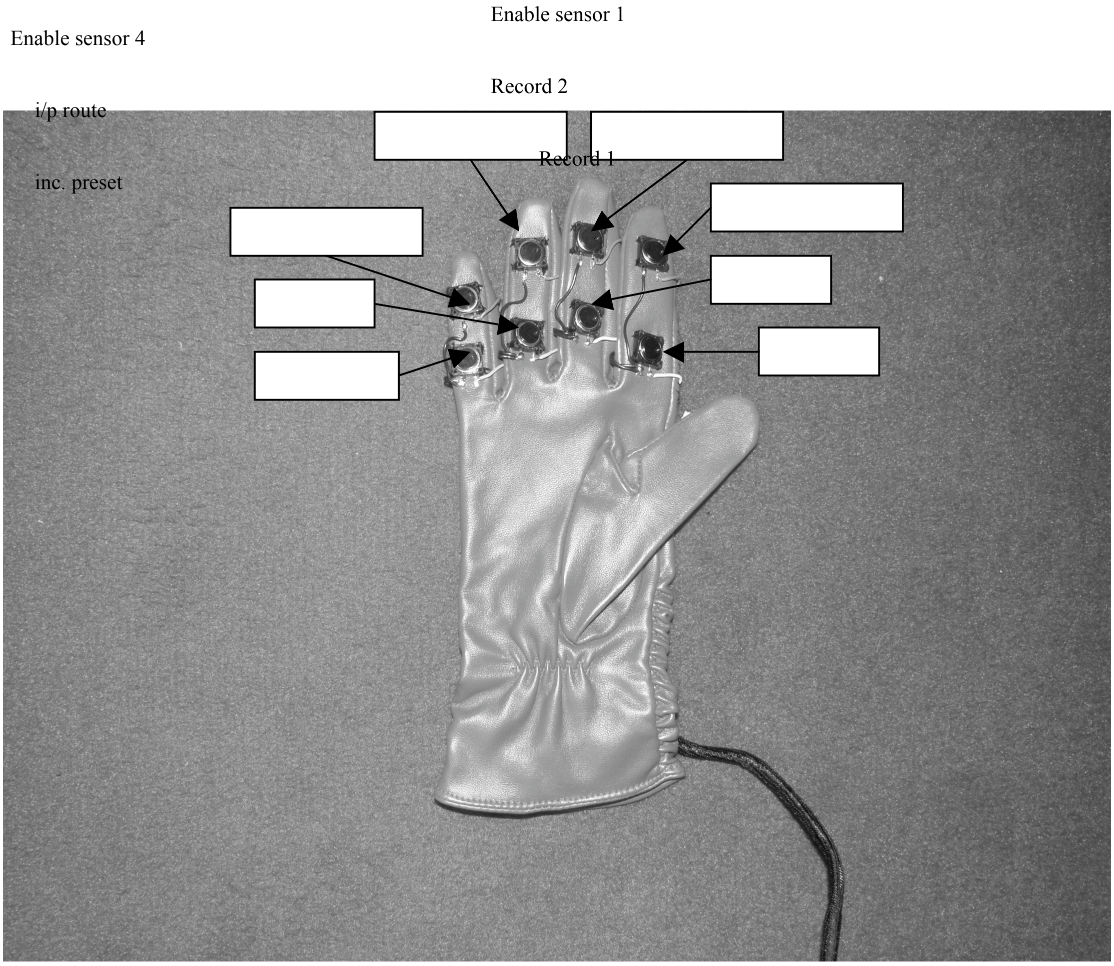


Figure 27. *Hand to Mouth* switch designations

Counter output	Preset recalled
1	2
2	3
3	8
4	7
5	1
6	10
7	6
8	11
9	2
10	3

Figure 28. Preset recall sequence

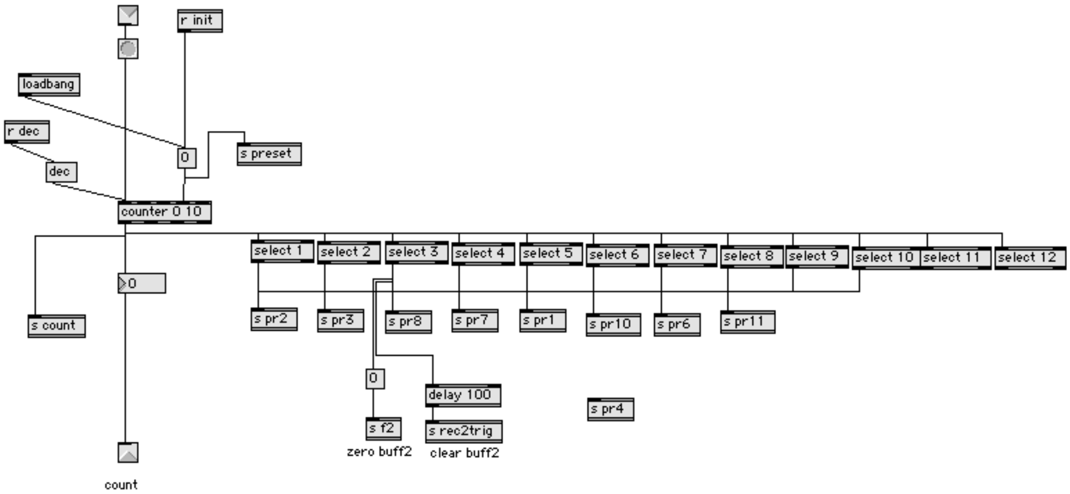


Figure 29. Preset counter

Referring to the preset recall sequence (see Figure 28, p. 43), presets 2 and 3 are recalled both at the start and end of the piece that results in a simple A-B-A form.

Finger switch 7 functions as a toggle to either add amplitude modulation to the processing of the vocal signal or to bypass this stage completely. The frequency of modulation is controlled by bend sensor three and is only enabled via the preset message boxes that send either a 1 or 0 to a gating mechanism (see Figure 22, p. 37). In this way bend sensor 3 can control the amplitude modulation frequency or the frequency of the harmonisation processors. Selection and de-selection of the amplitude modulator results in a fade-in and fade-out of the modulator signal, incorporated to enable smooth transitions between processing elements. This was simply achieved using line objects to fade in and out over a period of half a second.

- **Visual Elements**

As with *The Suicided Voice* the visual component of *Hand to Mouth* is an important component of the piece providing a dramatic backdrop to the physicality of the live performance. In a performance situation it is difficult for an audience to see the small finger movements affected by the performer. These movements are given a large physical presence both by the sound system and the visual projection. Movement is mapped to visual processing using the same gestures as those used to map audio processing. There is, therefore, a direct correlation between sound, imagery and gesture.

A separate visuals patcher is incorporated (see Figure 30, p. 47) that receives a counter value, programmed to increment on a preset change, and used to trigger various images held in an XPose patch on a second Macintosh computer. The link between the Max/MSP patcher and the XPose program is achieved via a MIDI link, i.e. single port MIDI interfaces used to send and receive MIDI data from the Max/MSP patch to the XPose patch. The Xpose patch responds to both MIDI note on/off data and controller data, the note on data triggering the image files. This can clearly be seen by referring to Figure 30, p. 47, whereby on receipt of a counter value of 1 a note value of 50 with a velocity value of 120 is sent to the *midiout* object. This note trigger stays on until preset count 3 is received whereby the note is turned off and a note value of 6 is sent out to the Xpose patch, triggering another visual image. As the Xpose program allows layering and mixing of the visual data this can be achieved be sending numerous note values with separate visualisations being held in each note trigger location. This process can be seen by referring to the highlighted areas in Figure 30. For example on the receipt of a counter value of 4 the previous note is turned off, a note value of 7 is triggered, twenty seconds later a note value of 8 is also triggered and twenty seconds later a note value of 9 is triggered thereby resulting in a layering of three separate images. As various visual mixing processes and attributes can be assigned to each visual clip such as addition, multiplication, subtraction and transparency, complex and effective layering affects can be achieved that can be further manipulated in real time. Assigning two bend sensor data channels to two discrete MIDI controller numbers and assigning these controller numbers to affect various pre-programmed visual effect processes in the Xpose environment achieved the real-time manipulation of visual processing. This routing of sensor data to MIDI controller data can be seen by referring to the far left of Figure 22, p. 37. As controller effect mapping can be pre-programmed as part of the Xpose patch it is not necessary to re-map sensor values for each Max/MSP preset, it is only required to initialise the visual sensor mapping to achieve a minimum value of 0 at minimum sensor bend and a maximum value of 127 at maximum sensor bend.

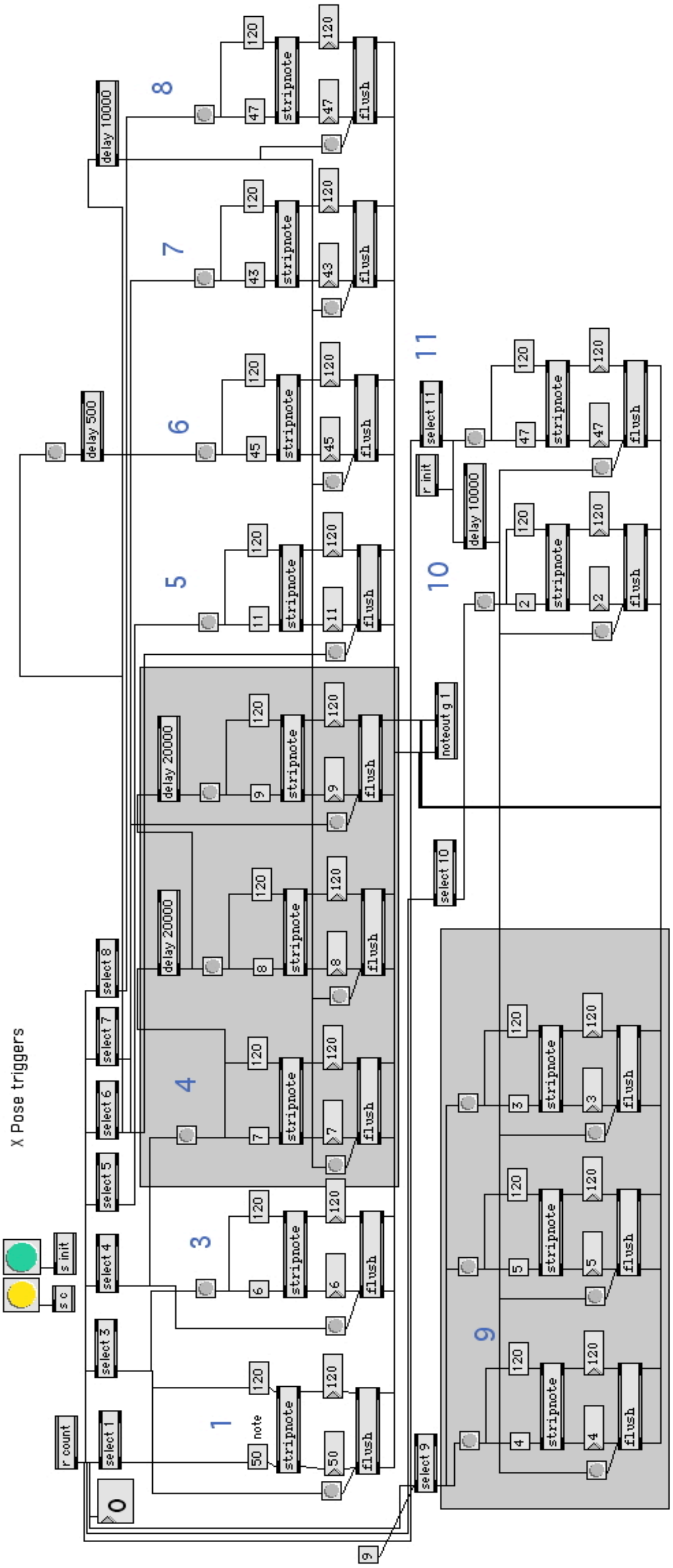


Figure 30. *Hand to Mouth* Visuals patcher

B1.3 *Etch* (2007)

- **Max/MSP design and implementation**

A master patch (see Figure 31, p. 49) includes the processing objects of one of two granular processors, the second of which is located in a subpatcher; *gran2*. The granular patchers are variations on a second generation design implemented by Nobusaku Sakonda and uses eight instances of Sakonda's new *grain~* abstraction to produce eight grain phases, their outputs combined to form a stereo signal. Sakonda's original, first generation *grain~* abstraction was used to good effect in the second movement of *The Suicided Voice* but only used four instances of *grain~* to produce four, equally spaced grain phases. Doubling the instances of the *grain~* abstraction results in a harmonically richer sounding sample that is used to good effect in the piece providing rich timbral material, particularly in the later sections of the work. Additionally, a useful enhancement to the earlier *grain~* abstraction is the ability to actively vary the width of panning of the combined stereo output (see Figure 32, p. 50).

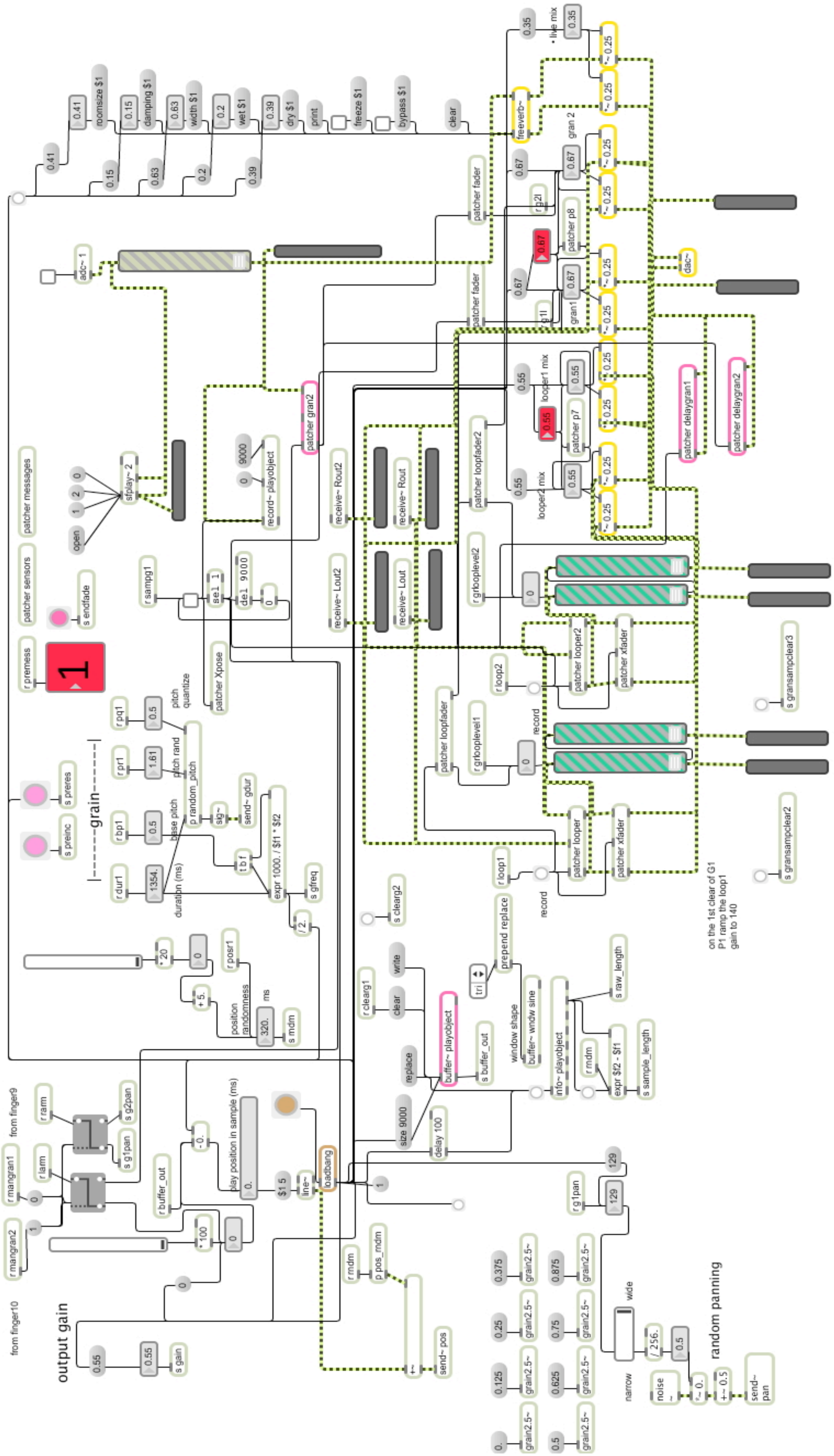


Figure 31. *Etch* main patcher

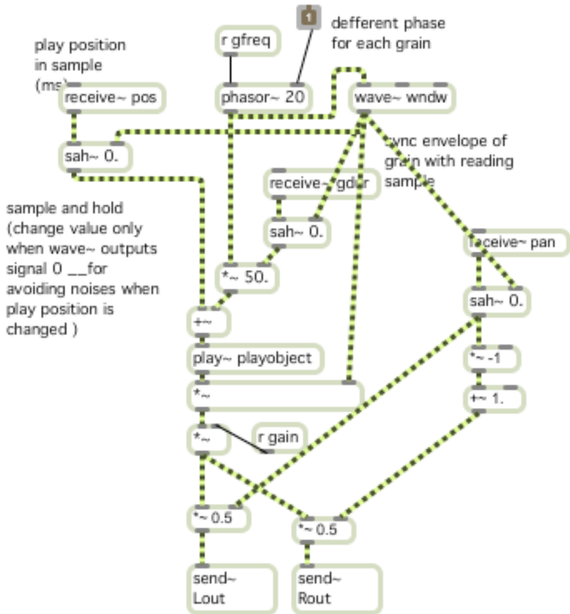


Figure 32. *Grain2* abstraction

Dynamic spatialization of the stereo signal is set by a random function (see Figure 31, p. 49) and is gesturally controlled by a bend sensor, located on the left arm.

The performer can record into either of two, 8 second, granular buffers by the activation of two dedicated finger switches on the left hand data glove, finger 5 sampling into buffer 1 and finger 6 sampling into buffer 2 (see Figure 33, p. 51). The right arm bend sensor controls the scrolling through of either one of the two recorded samples in the two granular buffers. The amount of scrolling pre-programmed for each preset is stored as variables; *g1min* and *g1max* for granular buffer 1 and *f1min* and *f1max* for granular buffer 2 (see Figure 35, p. 55). Selection of which granular buffer will be actively controlled is achieved by depressing dedicated finger switches 9 and 10.

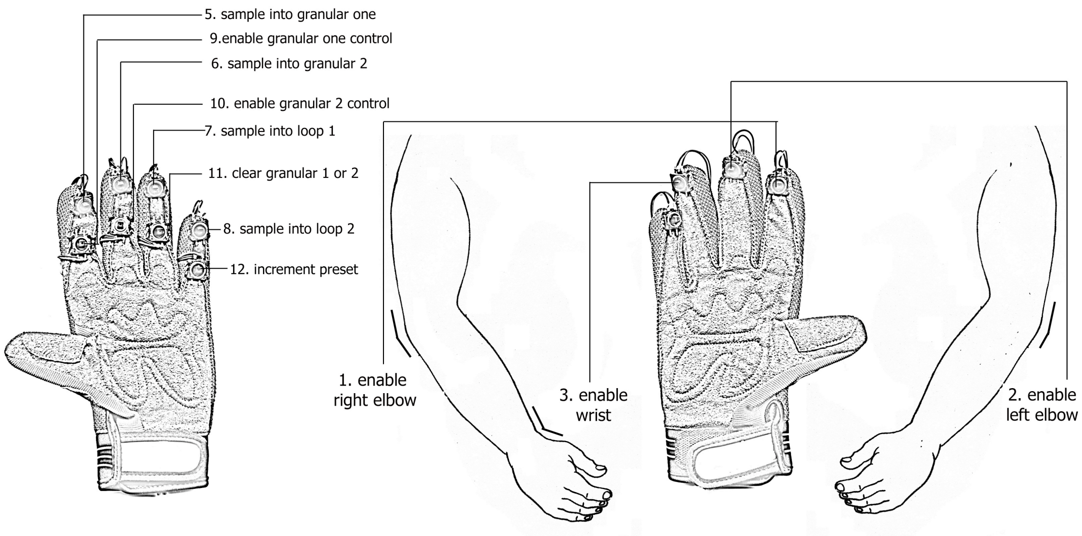


Figure 33. finger switch designations

The vocal material, sampled into either of the two granular buffers, can be recorded at any time into one of two looping recorders - *Patcher looper1* and *Patcher looper2* (see Figure 33 p. 49). Two dedicated finger switches (finger switch 7 and finger switch 8) initiate recording into the looping recorders (see Figure 35, above). The two looping recorders use the *wavefade~* abstraction, described on page 17 of this appendix. New sampled material is recorded into either of the two looping recorders by simply replacing the previous contents of the loop buffers with the material being manipulated in either of the granular buffers. New vocalizations can be recorded into either of the granular buffers at any time but due to the rather dense sonorities being built up during the piece it was also necessary to erase the granular material at various times during the piece. The clearing of either granular buffer is achieved by activating finger switch 11. This Finger switch is arranged to function as a toggle, to alternately clear the contents of each granular buffer.

Eight preset states were stored in a subpatcher containing message boxes to be recalled by the incrementing of a simple counter using finger switch 12 (see Figure 34, p. 53).

The Preset variables stored in the message boxes are:

1. Grain functions for the granular1 processor.

These consist of grain duration: *dur1*, grain base pitch: *bp1*, grain pitch randomization: *pr1*, and grain pitch quantization amount: *pq1*.

2. Grain functions for the granular2 processor.

These consist of grain duration: *dur2*, grain base pitch: *bp2*, grain pitch randomization: *pr2*, and grain pitch quantization amount: *pq2*.

3. Random variation amounts for the playback position of the granular buffers. These are designated as *posr1* and *posr2* for granular buffers 1 and 2 respectively.

4. Scaling values for the right arm sensor control. These are for granular1 scrolling: *f1min* and *f1max* and for granular2 scrolling: *g1min* and *g1max*.

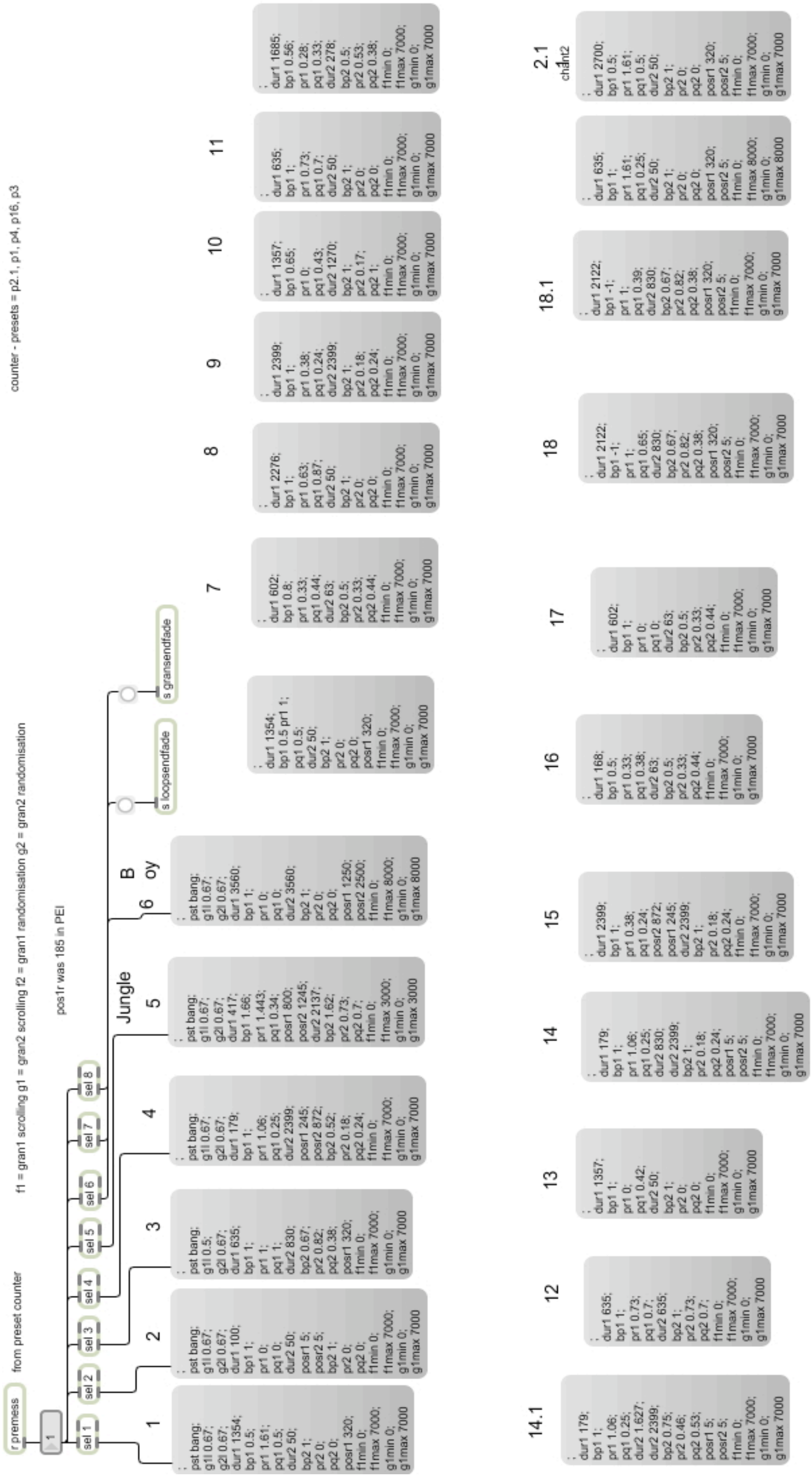


Figure 34. Preset messages

As can be seen by referring to Figure 36, p. 53, there are many unused message boxes left unconnected, resulting in 'ghosts' of early experimentations - employed during early rehearsals of the piece. These presets were formed whilst designing the MSP processing patches but were not deemed suitable for final inclusion in the work. Several *fade* subpatchers are used in the master patch to ensure that, particularly during preset transitions, clicks or abrupt changes in volume levels are not output. The live vocal signal is processed by employing an instance of *freeverb~* (a reverberation processor discussed on page 12 of this appendix) the signal is then mixed into the stereo output together with the audio signals from the two granular and looping recorders.

- **Sensor translation and scaling**

Etch employs only three proportional sensors, a bend element located on each elbow and a small bend element located on the right hand wrist. Data from the bend and switch sensors are received via the *otudp receive* object and formatted to the OSC protocol via the *OpenSoundControl* object. The OSC messages are first unpacked, the bend sensor data then connected to a simple calibration system that ensures that the full range of the proportional sensors are available. As was the case in the two previous pieces this calibration is performed at the start of the piece and requires the performer to locate both arm sensors and the wrist sensor at their minimum positions, i.e. straight arm/wrist positions, these values being stored in integer number boxes and then locate each sensors at their maximum positions, i.e. fully bent positions and again store these values in integer number boxes (see Figure 35, p. 55).

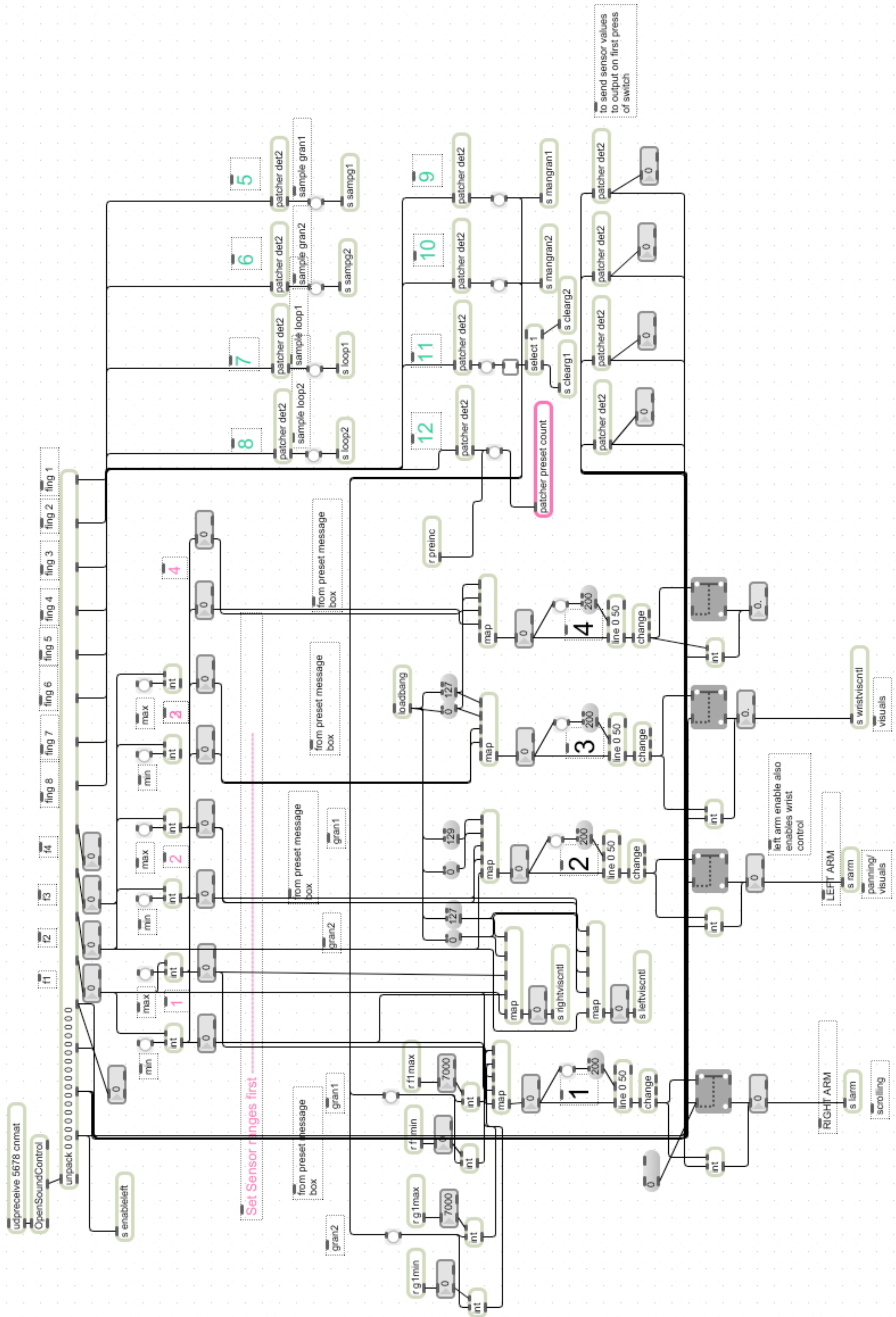


Figure 35. *Etch* sensor patch

Eight switch detector sub-patchers are employed to receive the data from finger switches 5 to 12, the need for these detector patchers have already been discussed in detail on page 36 of this appendix. A further four switch detector sub-patchers have been employed (Figure 35, p. 55) to ensure that the last recorded output of sensor values are sent out on the next depression of each of the sensor enable switches.

- **Visual Elements**

As with the previous two pieces in the *Vox Circuit Trilogy* the visual component of *Etch* is an important component of the piece, providing a dramatic backdrop to the physicality of the live performance. A large number of digital images were recorded in Montreal, Quebec City and on Prince Edward Island, edited extensively to provide material for the piece.[3] A separate visuals patcher is incorporated (see Figure 36, p. 58). The visuals patcher is configured to detect various sample commands within a defined active preset, these are used to trigger the various images stored within an XPose patch on a second Macintosh computer. The link between the Max/MSP patcher and the XPose program is, as usual, achieved via a MIDI link, i.e. small, single port MIDI interfaces are used to send and receive MIDI data from the Max/MSP patch to the XPose patch. The Xpose patch responds to both MIDI note on/off data and controller data, the note on data triggering the image files. Real-time manipulation of visual processing is achieved by assigning three bend sensor data elements, located on both elbows and left wrist, and mapping these to three discrete MIDI controller numbers and assigning these controller numbers to affect various pre-programmed visual effect processes in the Xpose environment. Routing of sensor

[3] Julie Wilson-Bokowiec was responsible for editing and compiling the visual data for use in all three pieces comprising the *Vox Circuit Trilogy*.

data to MIDI controller data can be seen by referring to the left of Figure 35 p. 55. As controller effect mapping can be pre-programmed as part of the Xpose patch it is not necessary to re-map sensor values for each Max/MSP preset, it is only required to initialise the visual sensor mapping to achieve a minimum value of 0 at minimum sensor bend and a maximum value of 127 at maximum sensor bend. As both arm sensors are also used to control the granular panning and scrolling functions, two additional *map~* objects are simply connected in parallel to enable control of the XPose visualisation parameters. Uniquely for this piece, the visualisations are not triggered by detecting preset increments, but by detecting the onset of the either of the two granular sampling processes. To achieve this, two ten stage counters are employed with each counter being incremented by one of the two sample triggers. The output of each counter is connected to various *stripnote~* objects to enable dynamic and complex combinations of visualisations, this can be seen by referring to annotations in Figure 36, p. 58. Several graphic switches (*gswitch~*) are employed (seen by referring to the top of Figure 36) to ensure that certain visual states are triggered only whilst a unique main preset state is active. The process of using MIDI note on/off information to activate events hosted by the Xpose program has already been outlined on page 26 of this appendix.

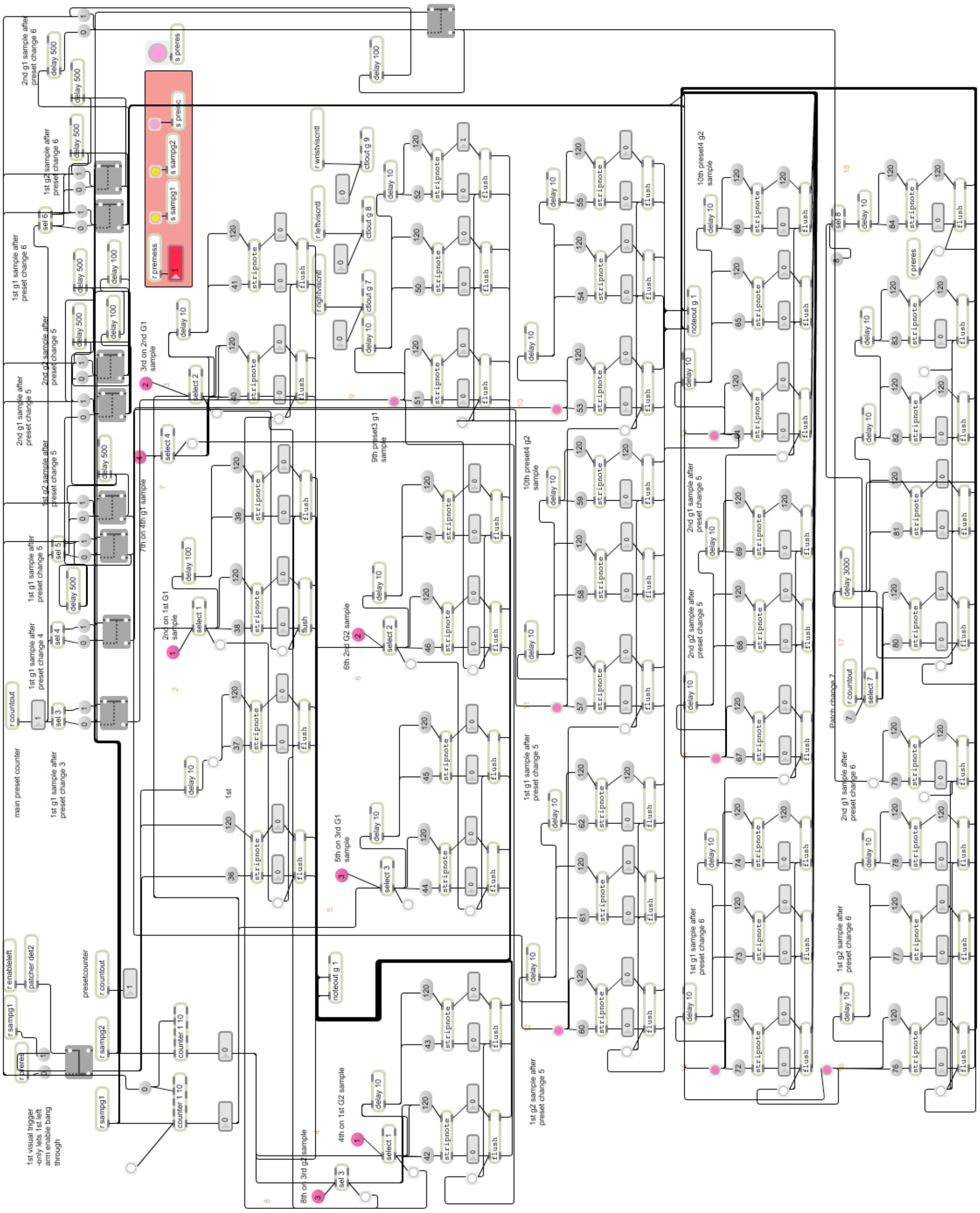


Figure 36. *Etch* visual patcher

Appendix C

Recordings and Max/MSP patches

The video, audio and Max/MSP files are stored on three accompanying DVDs to this submission. The content of the DVD’s are listed on the next page.

Disk 1

Vox Circuit Trilogy

Hand to Mouth – Recorded at Watermans Art Centre, London, 22/11/07

The Suicided Voice – Recorded at Sonic Arts Expo 966, Scarborough, 18/06/05 and University of Huddersfield, 28/06/05

Etch – Recorded at Watermans Art Centre, London, 22/11/07

Disk 2

Early Interactive Works

The Navigator (interactives excerpt) – Recorded at The Lawrence Batley Theatre, Huddersfield 10/02/95

Zero in The Bone – Recorded at St Pauls Hall, University of Huddersfield, 25/04/97

Lifting Bodies – Recorded at The Trafo Theatre, Budapest, 09/10/99

Spiral Fiction (excerpt) – Recorded at The Green Room, Manchester, 04/04/02

Disk 3

Audio Recordings

Hand to Mouth

The Suicided Voice

Etch

Lifting Bodies

Zero in The bone

Max/MSP Patches and Externals

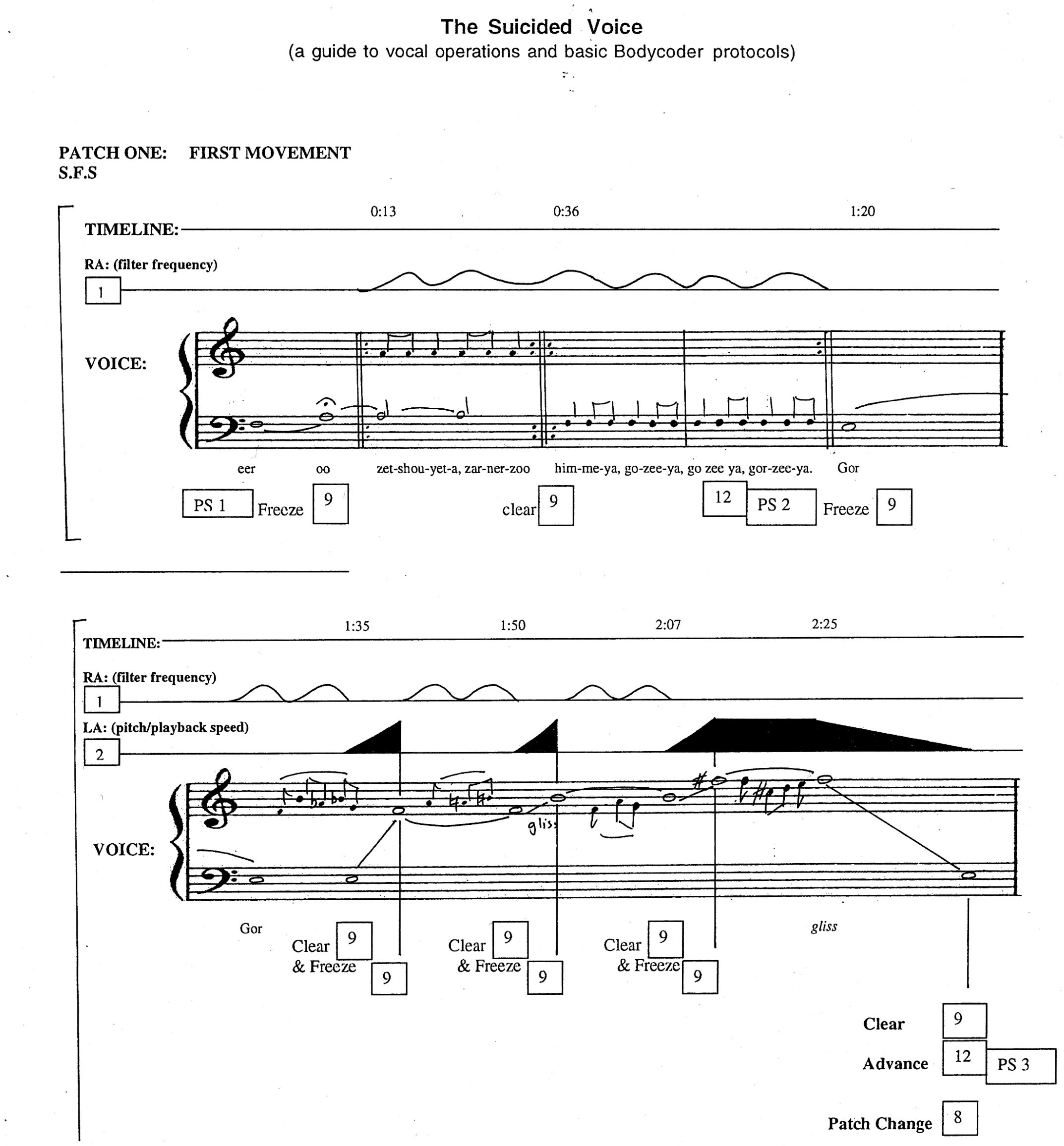
Hand to Mouth

The Suicided Voice

Etch

Appendix D

The Suicided Voice Performance Score



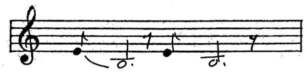
PATCH THREE: SECOND MOVEMENT
GRANULAR

(* free extemporisation using speech and harmonic cells, architecture as indicated)

TIMELINE: 2:45

PS 1

Sample 5 **VOICE:**



This bow, this sound

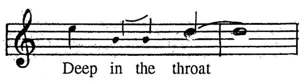
TIMELINE: 3:00 3:09

Scrub sample RA: 1

12 PS 2 Scrub sample RA: 1 Freeze 'Boooo' 9 Pitch change on Wrist: 3 to achieve pedal one:

TIMELINE: 3:45

Sample 5 **VOICE**



Deep in the throat

TIMELINE: 4:06 4:15

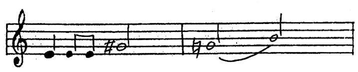
Scrub sample RA: 1

12 PS 3 Scrub sample RA: 1 Sample scrub movement in 10 to achieve rhythmic texture layer

Vocal Textures – extemporised PS 1 to PS 6

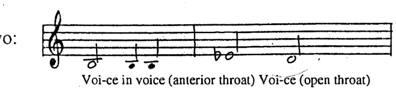
TIMELINE: 4:33 5:34

One:



Tra-veling. O (harmonic overtone) O-cean (covered voice)

Two:



Voi-ce in voice (anterior throat) Voi-ce (open throat)

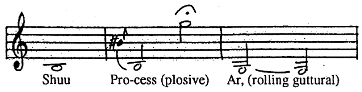
TIMELINE: 6:51

Three:

Voi – mor – yar Voi (covered head voice)

7:59 — 8:18

TIMELINE:

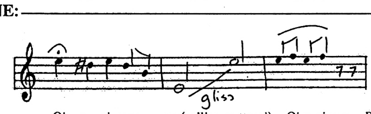
Four: 

Shuu Pro-cess (plosive) Ar, (rolling guttural)

RA: scrub [1] clear [10] and Re-sample in [10]

9:31 — 10:29 — 10:47 — 11:40

TIMELINE:

Five: 

Oi – e – oi- you eer(rolling guttural) Oi-e-oi-you Process

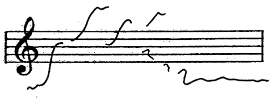
Patch Change [7]

PATCH TWO: FOURTH MOVEMENT
SS8PR (Stutterx2-Scrubx2-patcherecordx2)

Enter at: [PS 1]

14:25 — 15:00

TIMELINE:

VOICE: 

Sample [9]
(12 second sample that comes back with pitch changed several octaves lower)

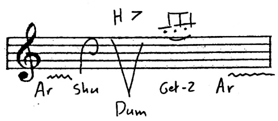
[12] [PS 2]

Rolling guttural textures with sharp harmonic head voice sweeps, incorporate breath and visceral noise of throat working muscularly across the vocal range.

15:56 — 16:15

TIMELINE:

[12] [PS 3]

VOICE: 

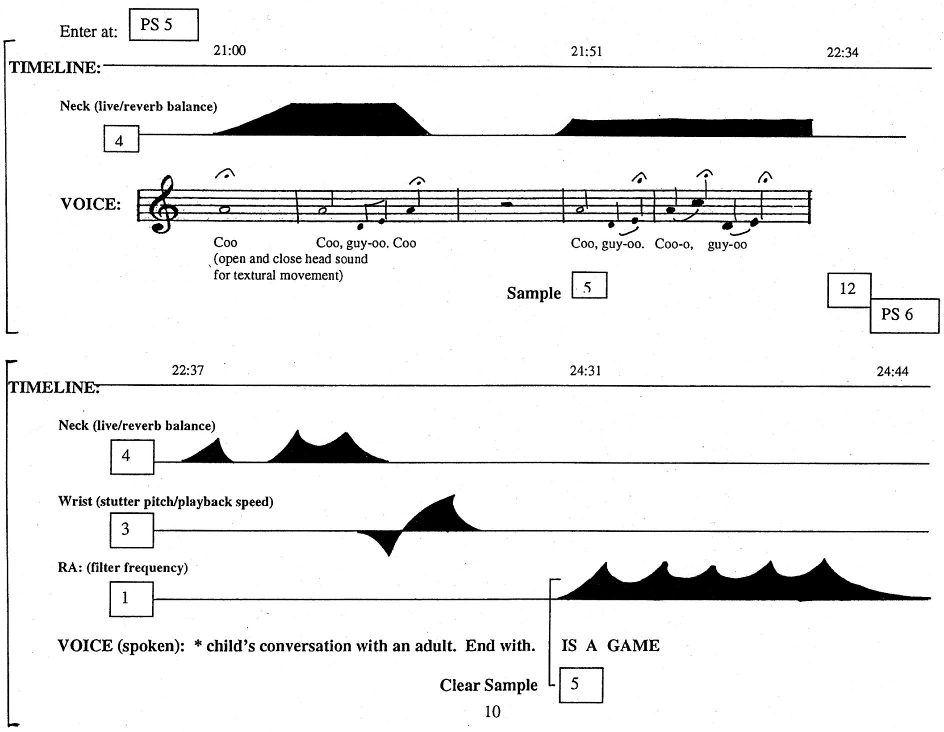
Sample [5] (16 second sample)

[12] [PS 4]

Rolling guttural AR…finishing with a moving SH and spoken GET-Z SHE RAY-GA Heavy exhalation and verbalised plosive DUM Followed by rolling guttural sound.

7

PATCH ONE: **FIFTH MOVEMENT**
S.F.S



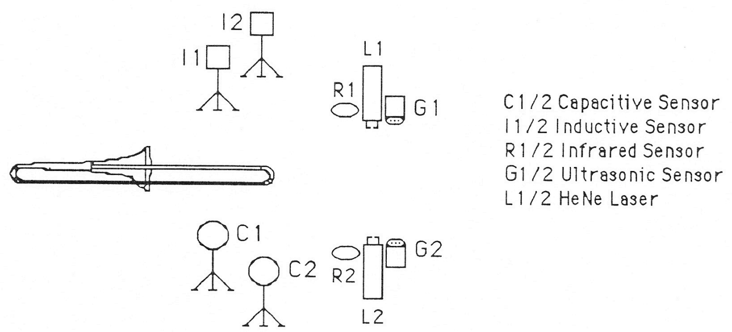
Appendix D

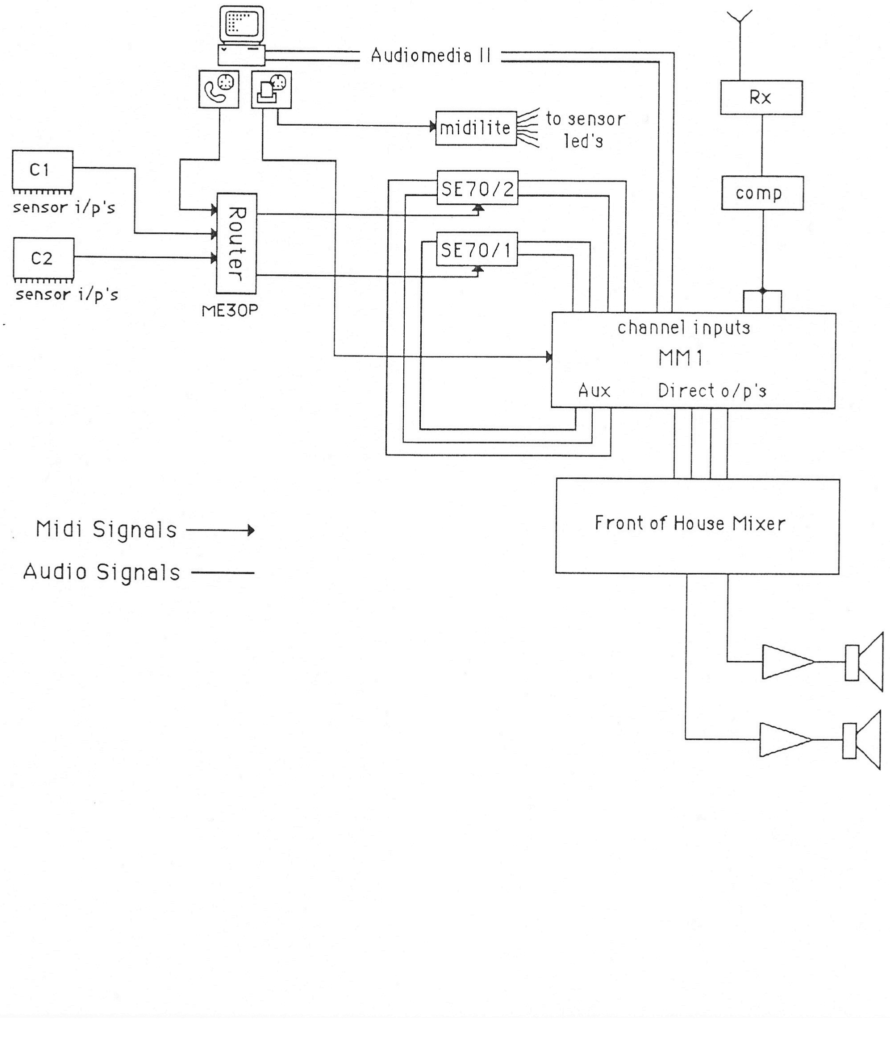
Zero in the Bone Performance Score

Zero in the Bone

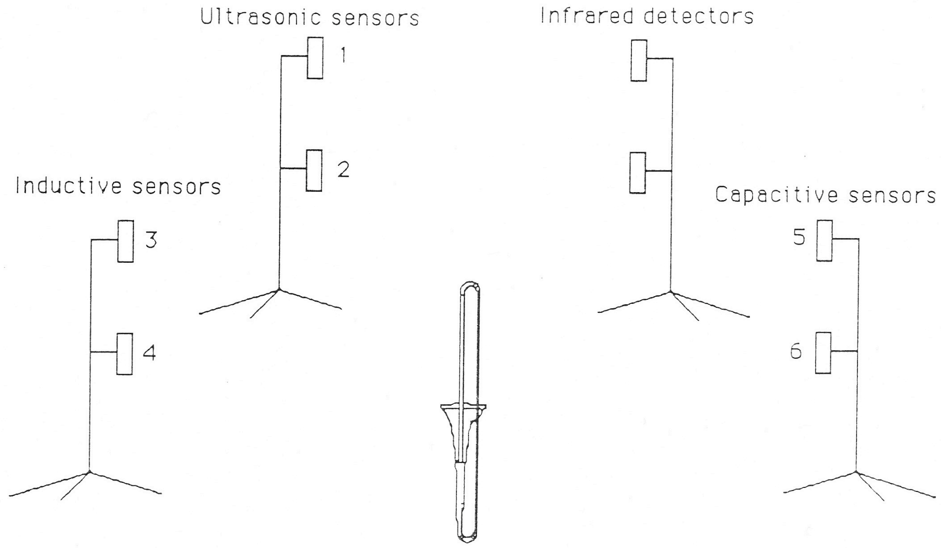
A piece for live trombone and interactive computer electronics

Zero in the Bone - Performance control setup





Performance Notes

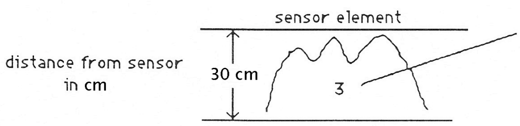


Position of performer

NB. Performer stays centrally between the sensor array until the score dictates a movement to a sensor element 1 - 6.
Light emitting diodes mounted on each sensor will light when the performer is required to move the trombone slide towards that sensor.
The visible lasers assist the performer to enter,move and exit the ultrasonic beam.Marking tape on the floor between the ultrasonic sensors and the infrared detectors indicate maximum and minimum sensor range

Key to sensor orientation

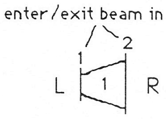
Inductive (I)



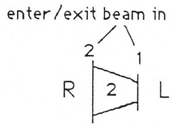
3=Upper sensor
4=Lower sensor

Ultrasonic (G)

1=Upper sensor
2=Lower sensor



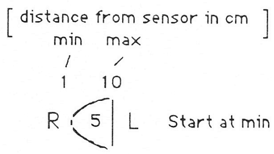
Start at min and move to max distance from sensor ⟶



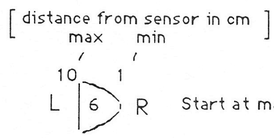
Start at max value and move to min distance from sensor ⟵

Capacitive (C)

5= Upper sensor
6=Lower sensor



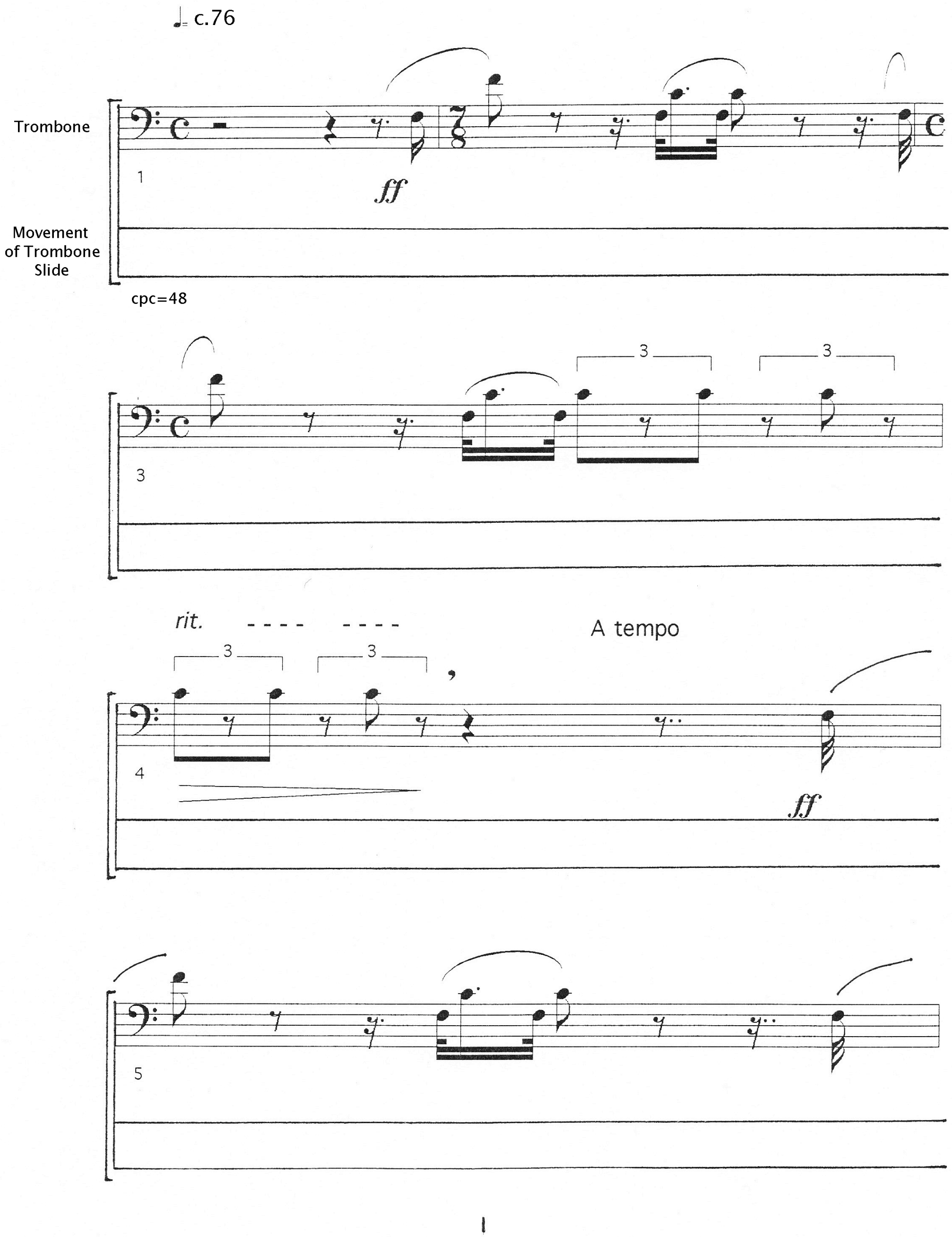
Start at min and move to max distance from sensor ⟵

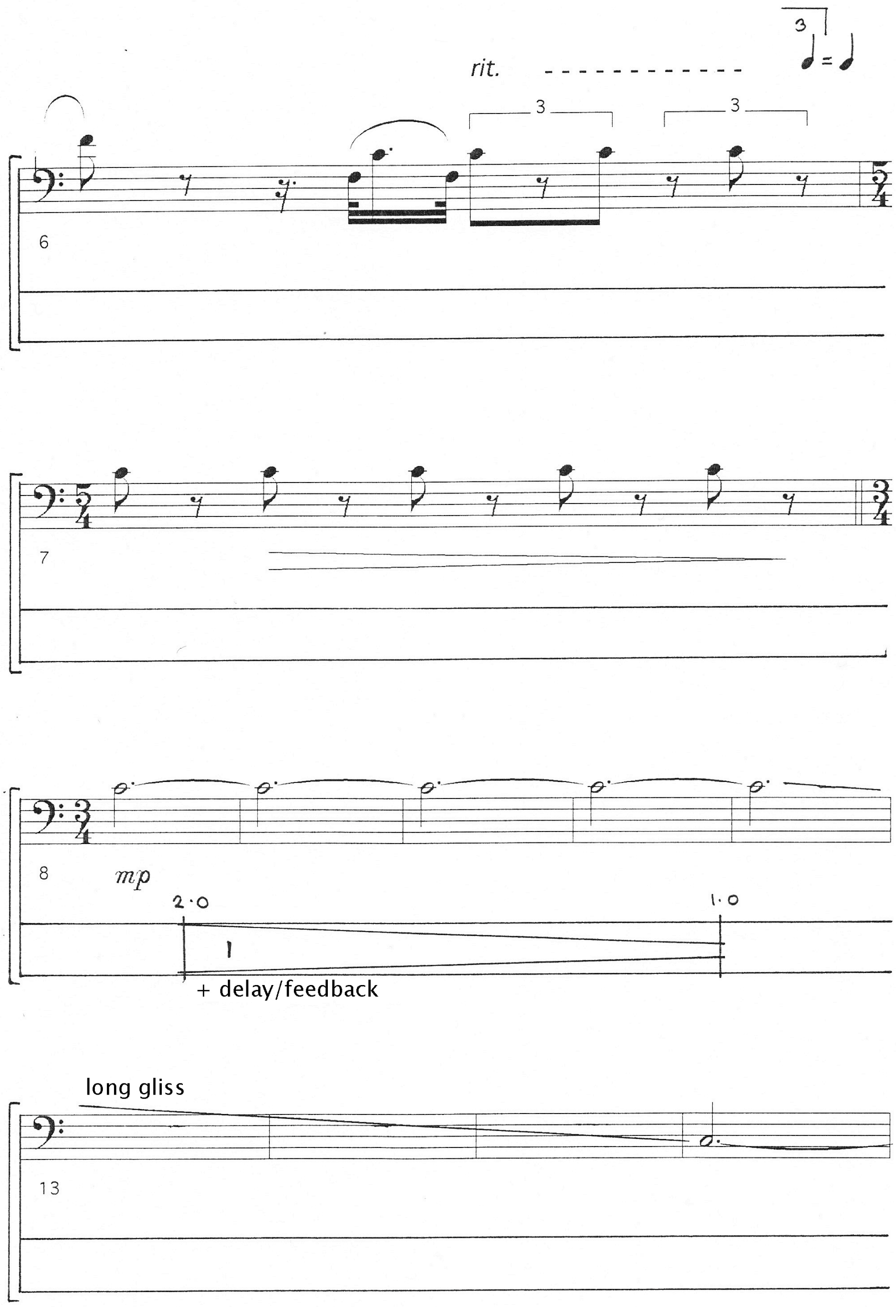


Start at max value and move to min distance from sensor ⟶

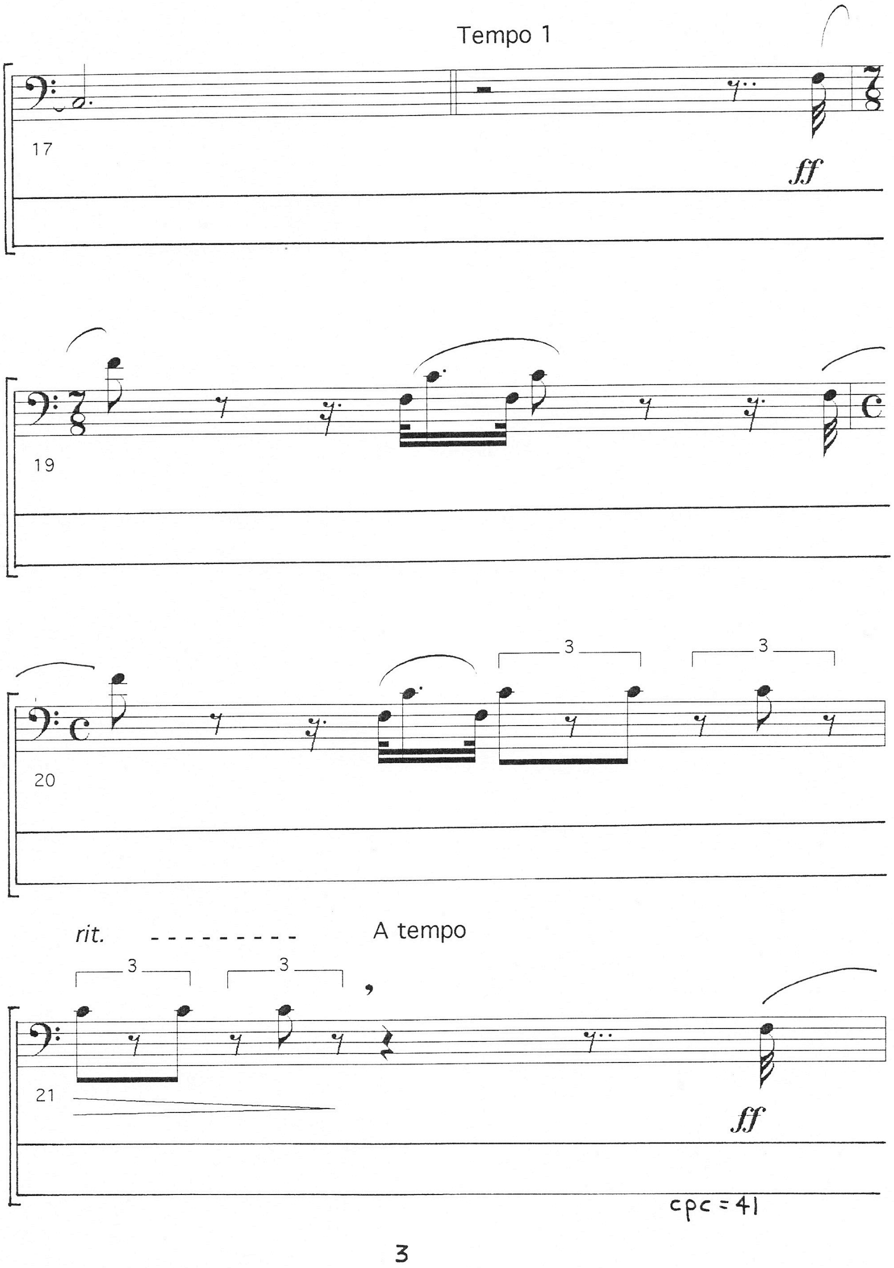
cpc(n) computer program change to SE01/02 effect unit.
n = number of custom multi effect.

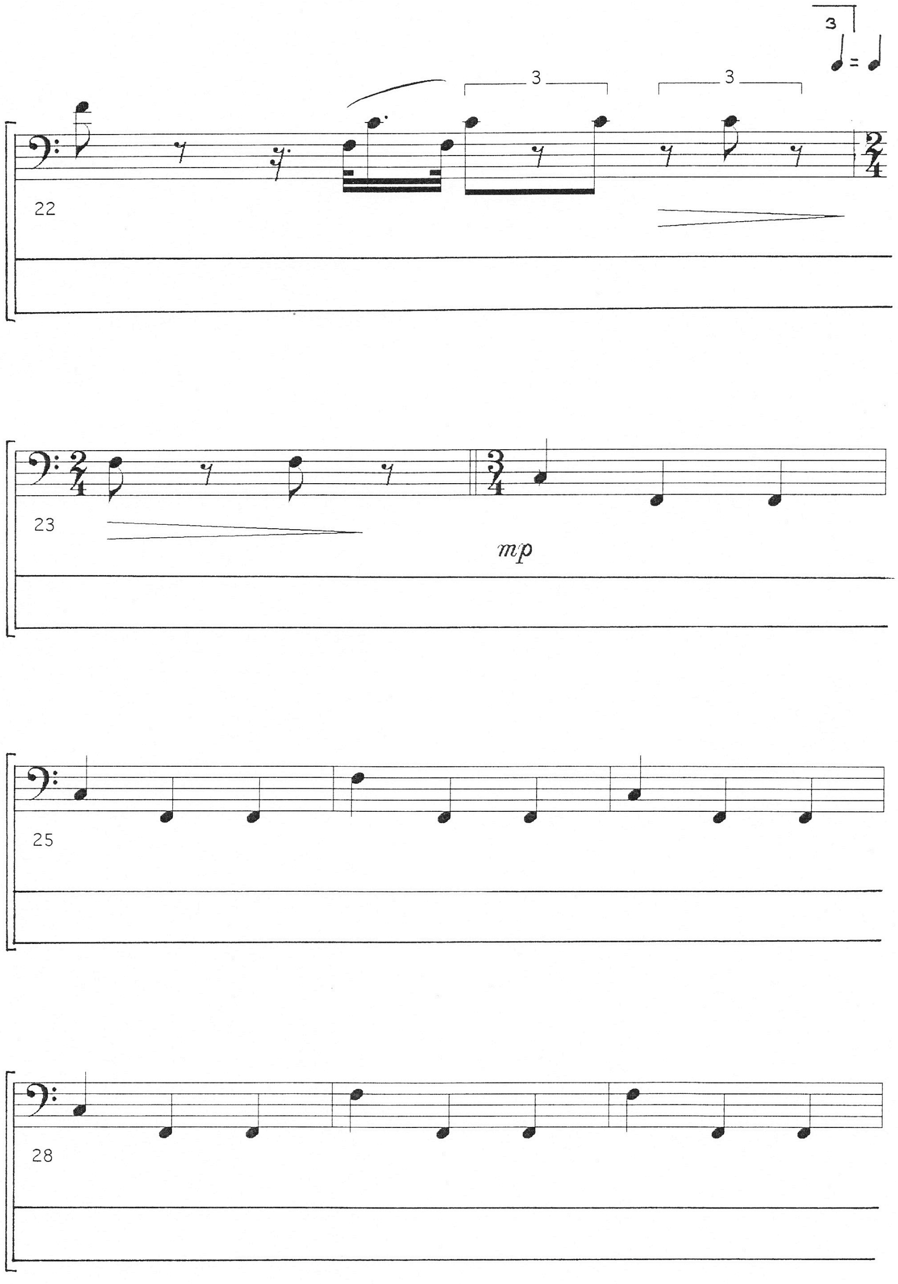
Zero in the Bone

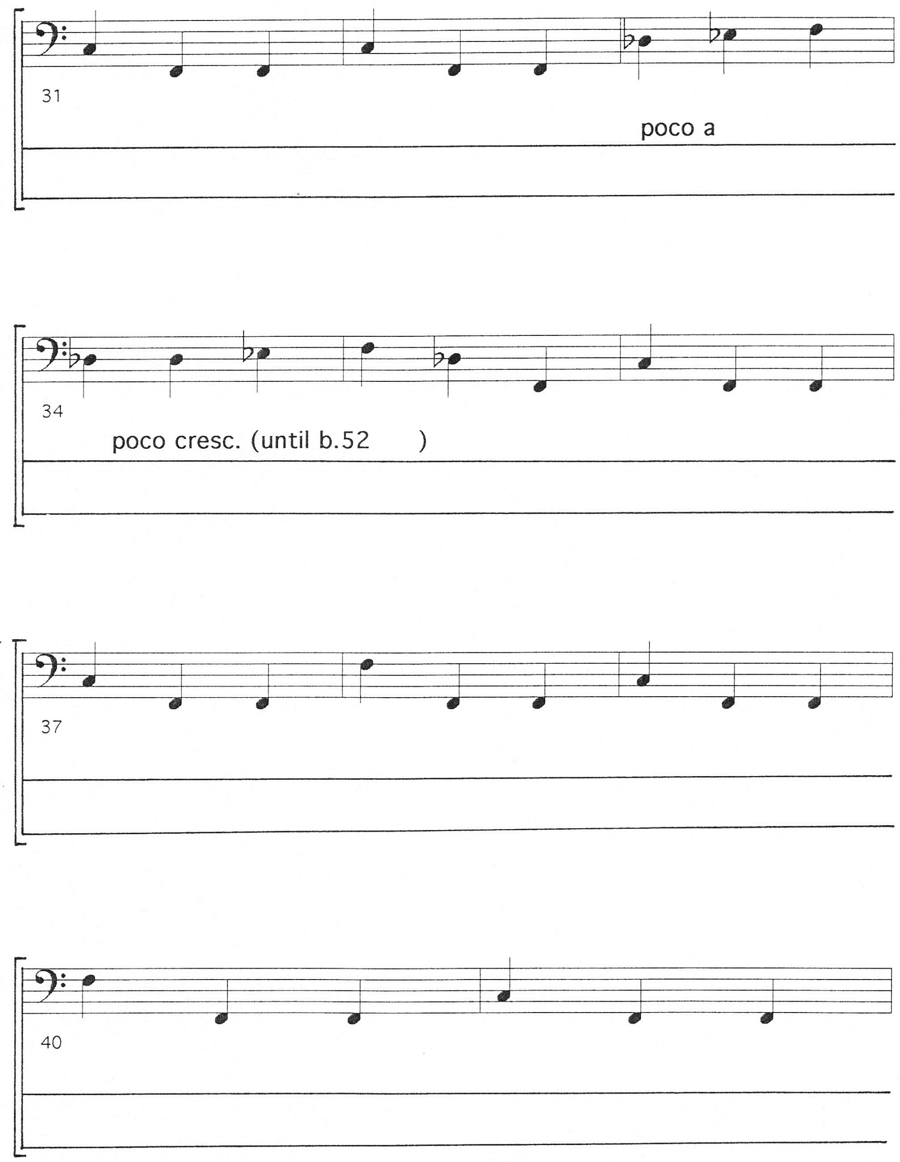




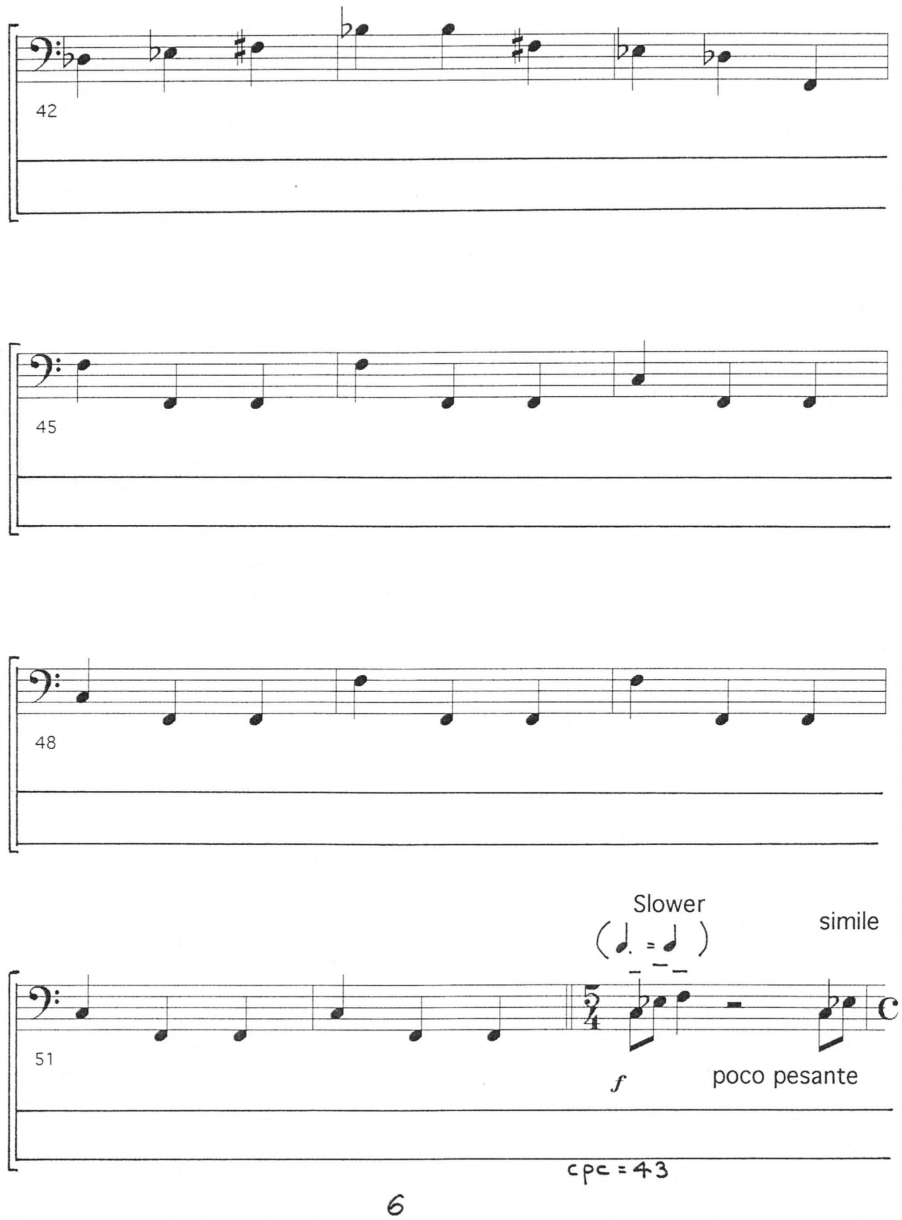
2


Tempo 1
17
ff
19
20
3
3
rit.
A tempo
3
3
21
ff
cpc = 41
3

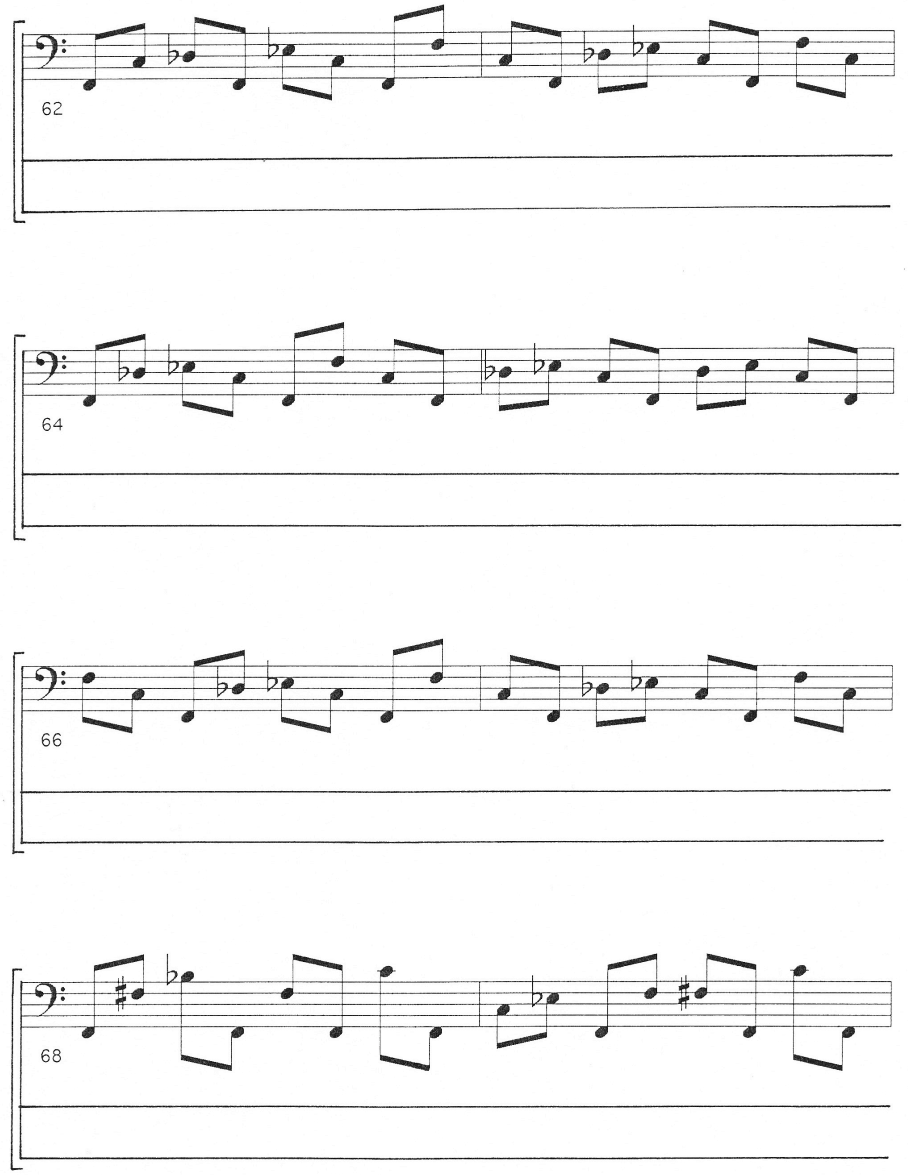

3
22
23
mp
25
28
4



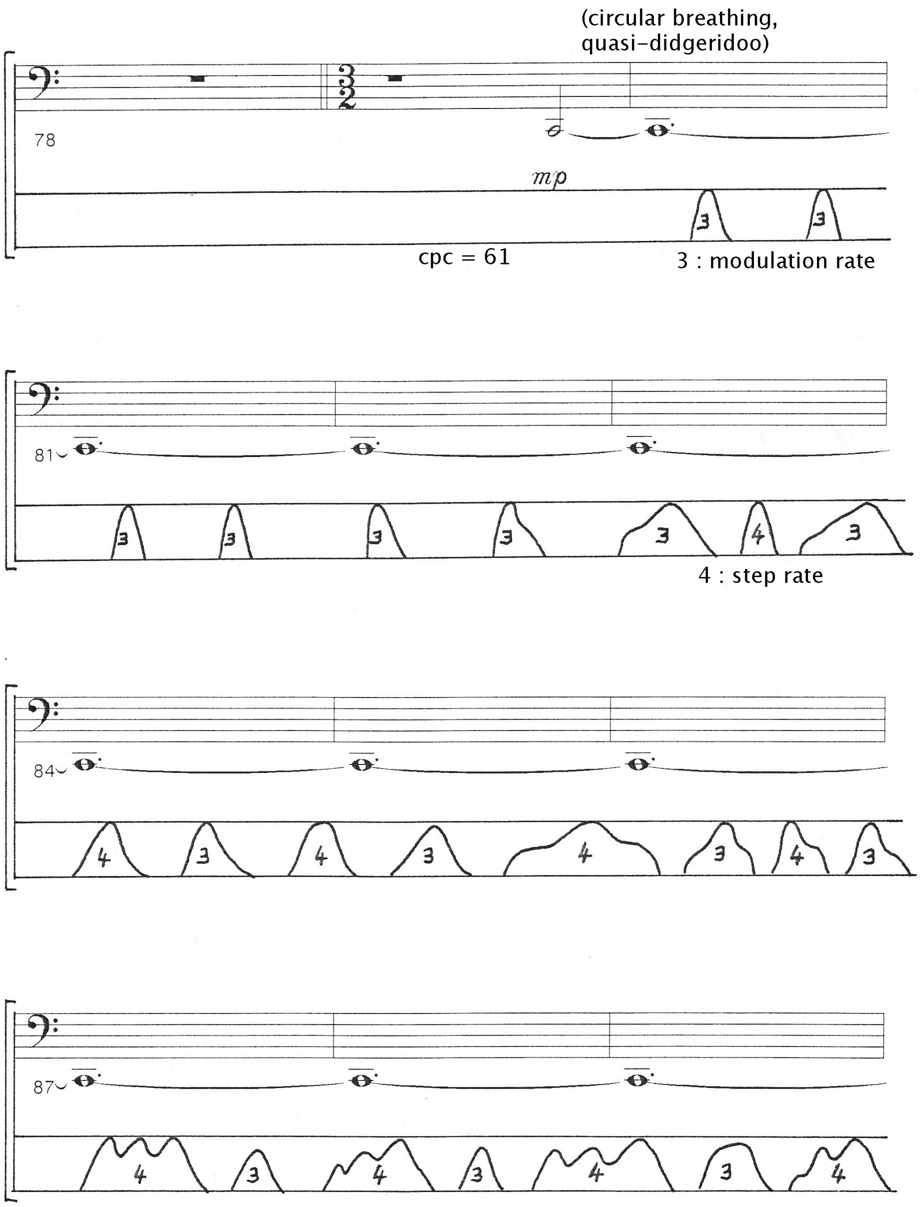
5


42
45
48
Slower
simile
51
f
poco pesante
cpc = 43
6

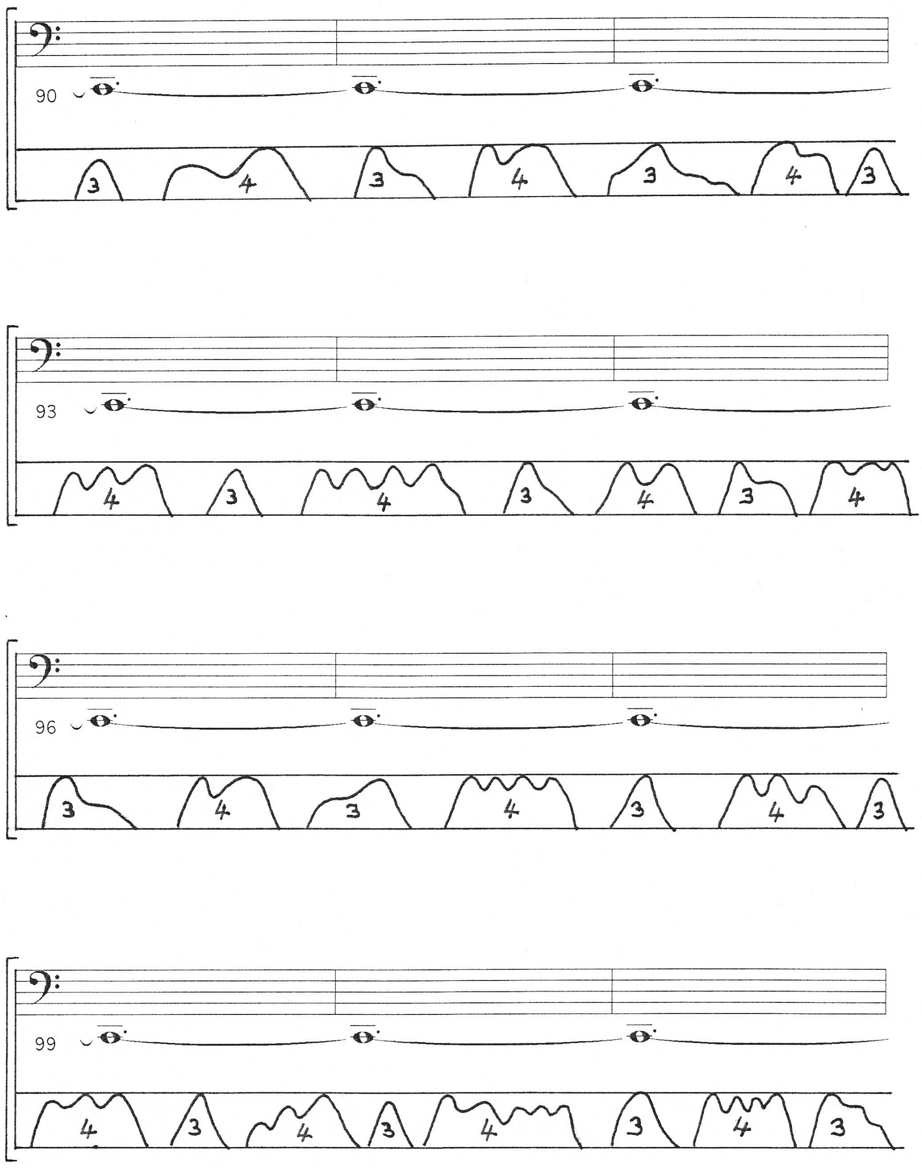

54
56
58
60
simile
7


62
64
66
68

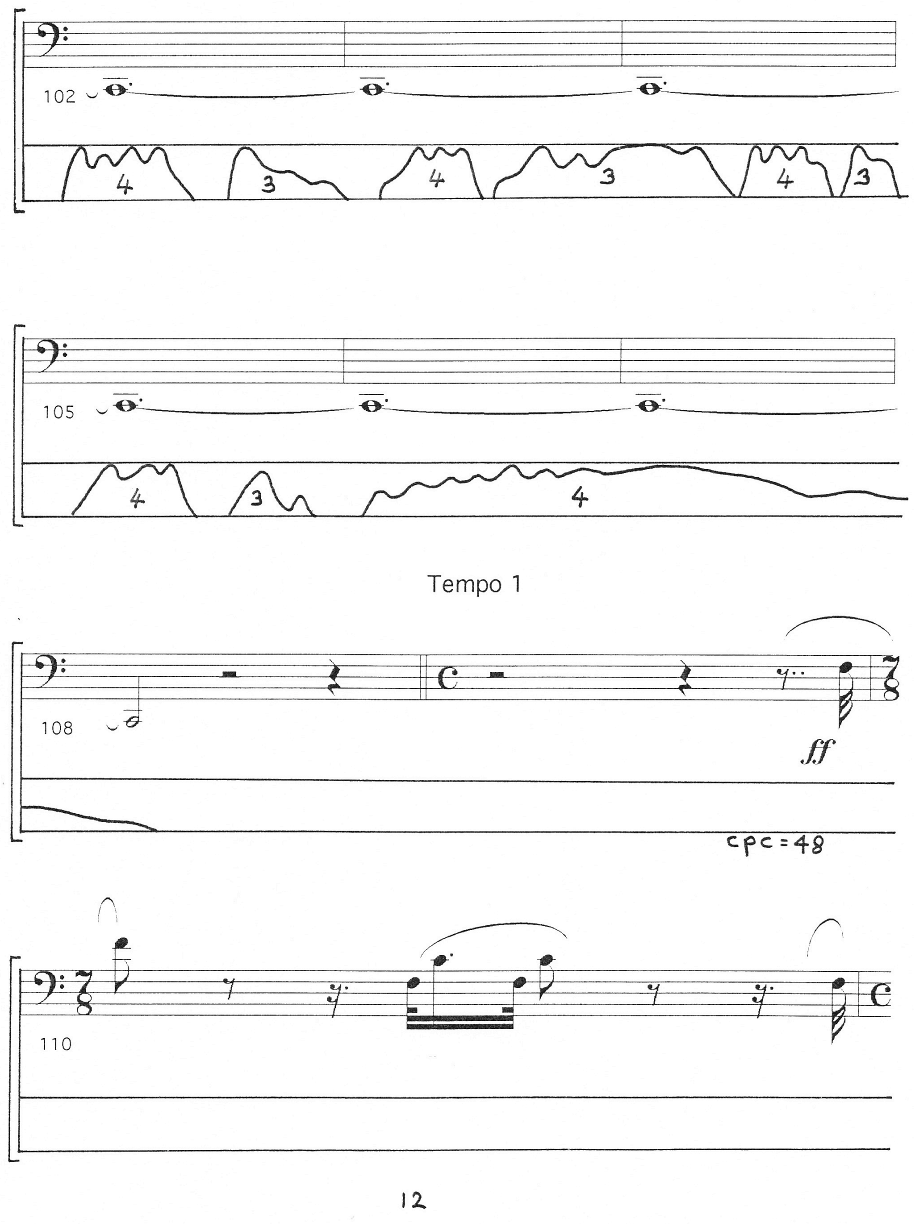

70
72
74
76

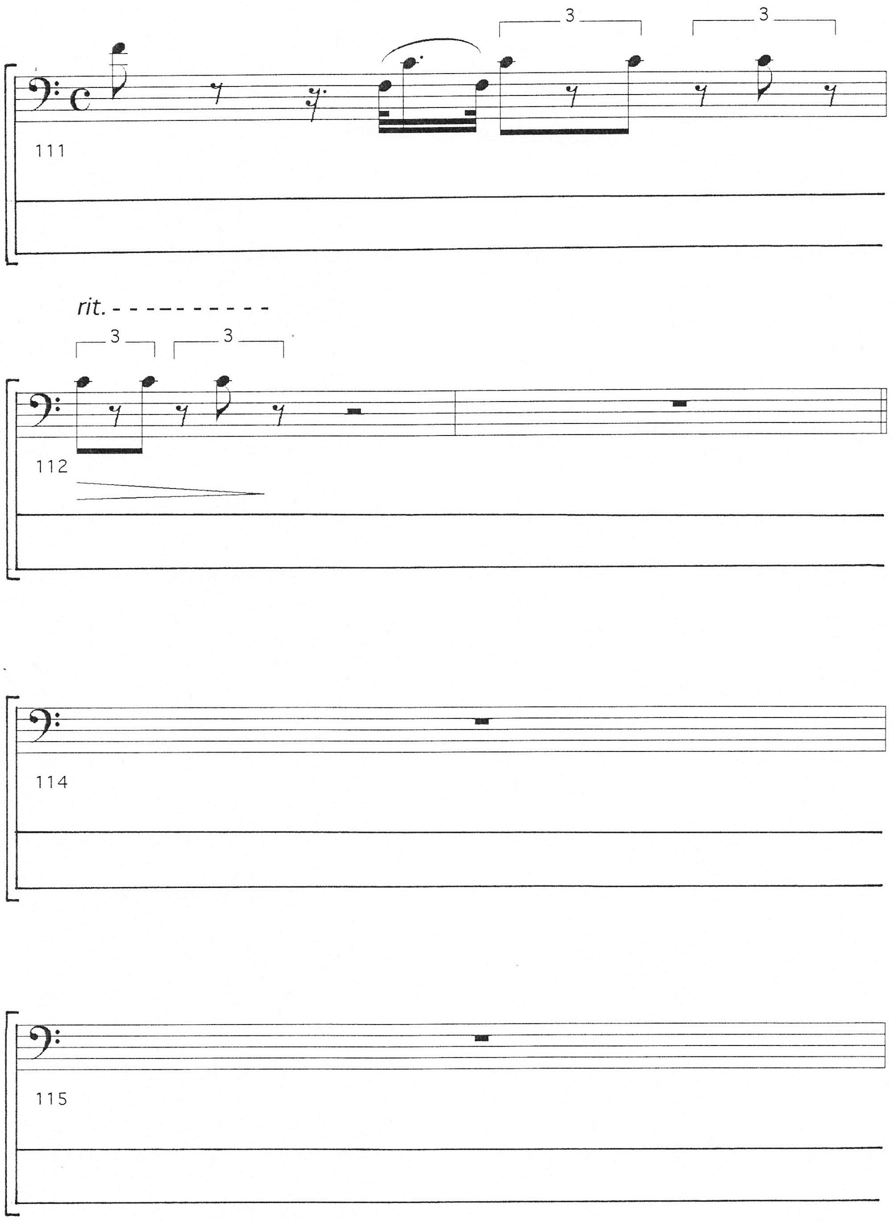

(circular breathing,
quasi-didgeridoo)
78
mp
cpc = 61
3 : modulation rate
81
4 : step rate
84
87

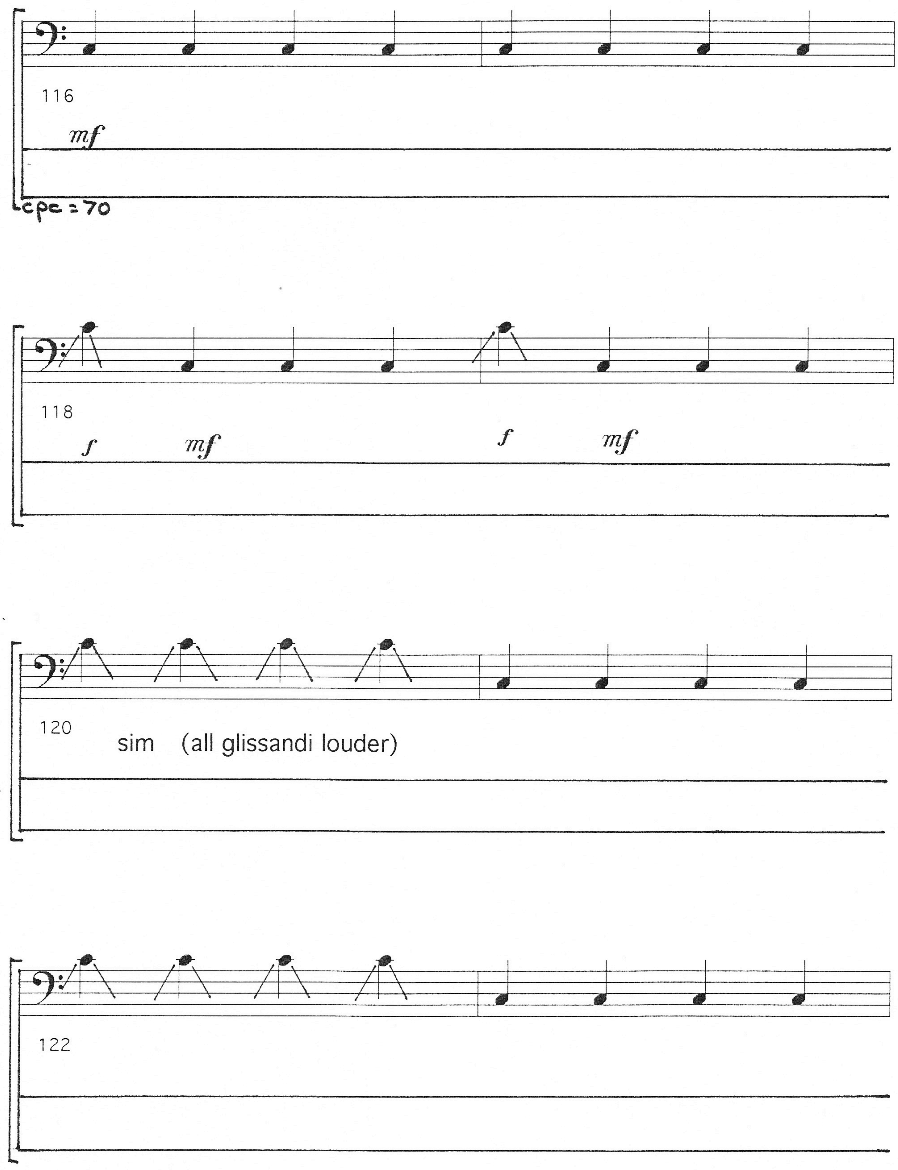
10

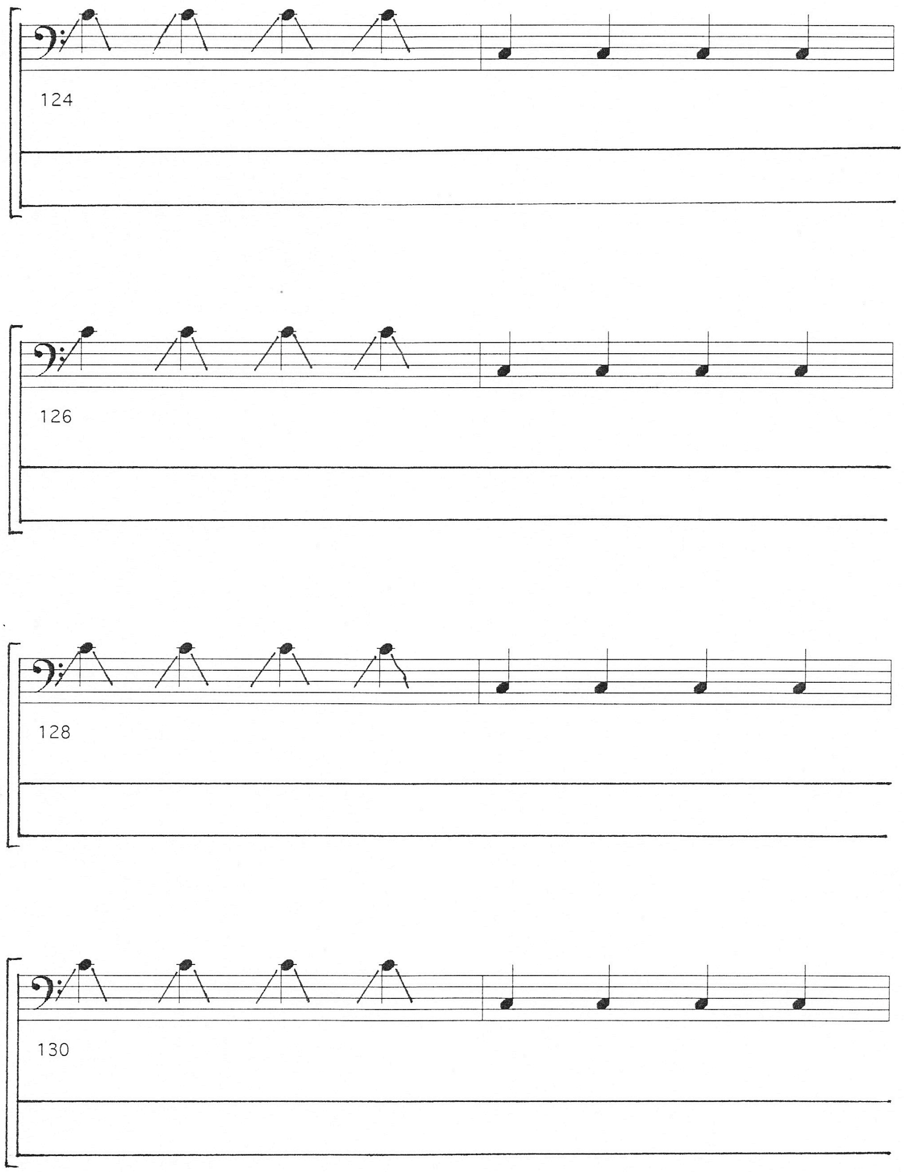


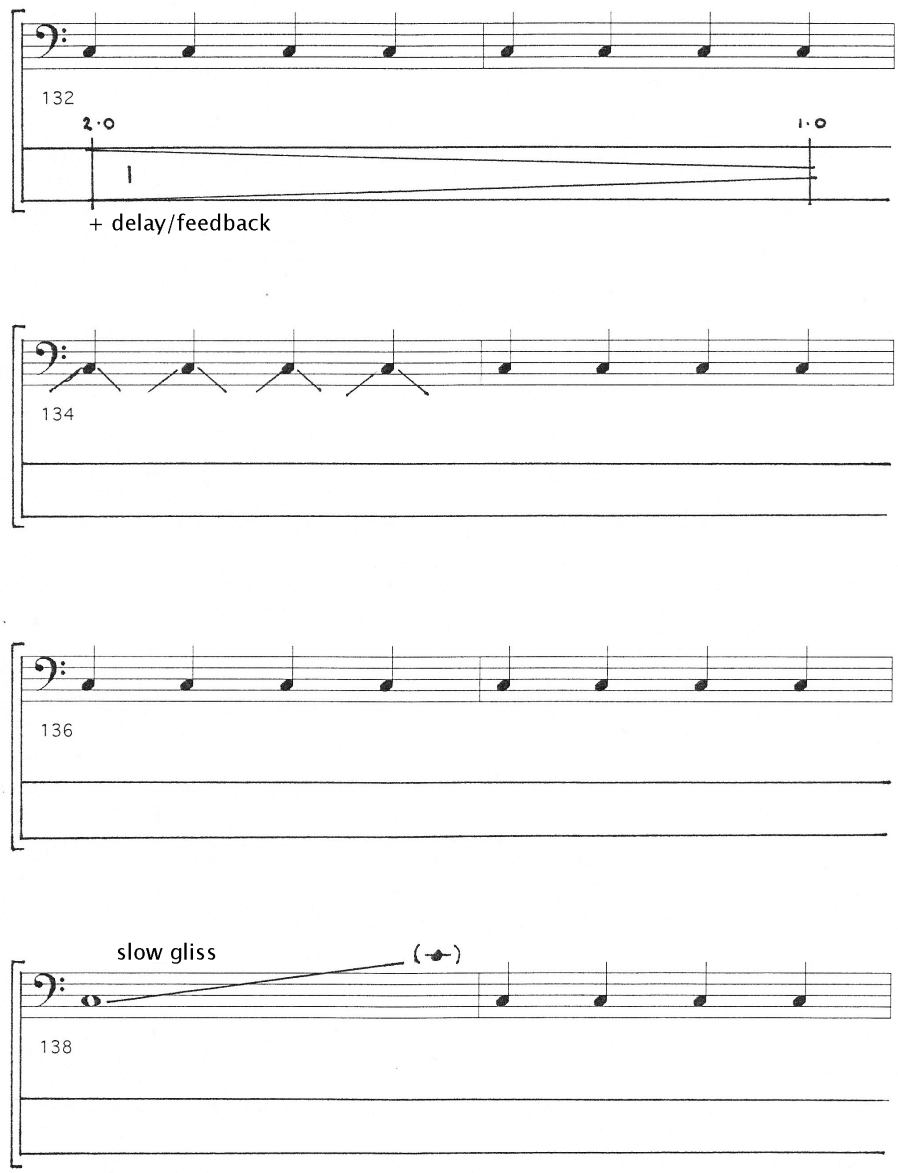
11

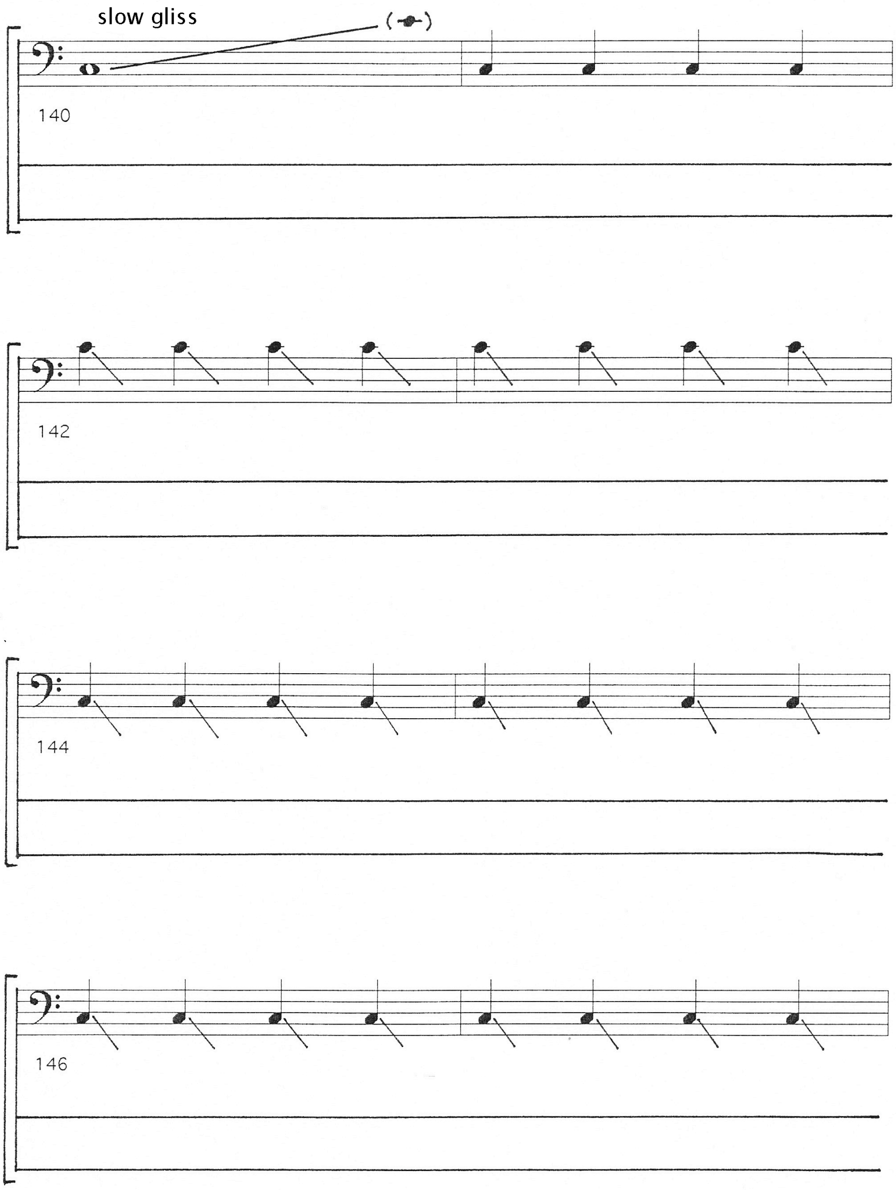

102
4
3
4
3
4
3
105
4
3
4
Tempo 1
108
ff
cpc=48
110
12


3
3
111
rit. - - - - - - - - - -
3
3
112
114
115

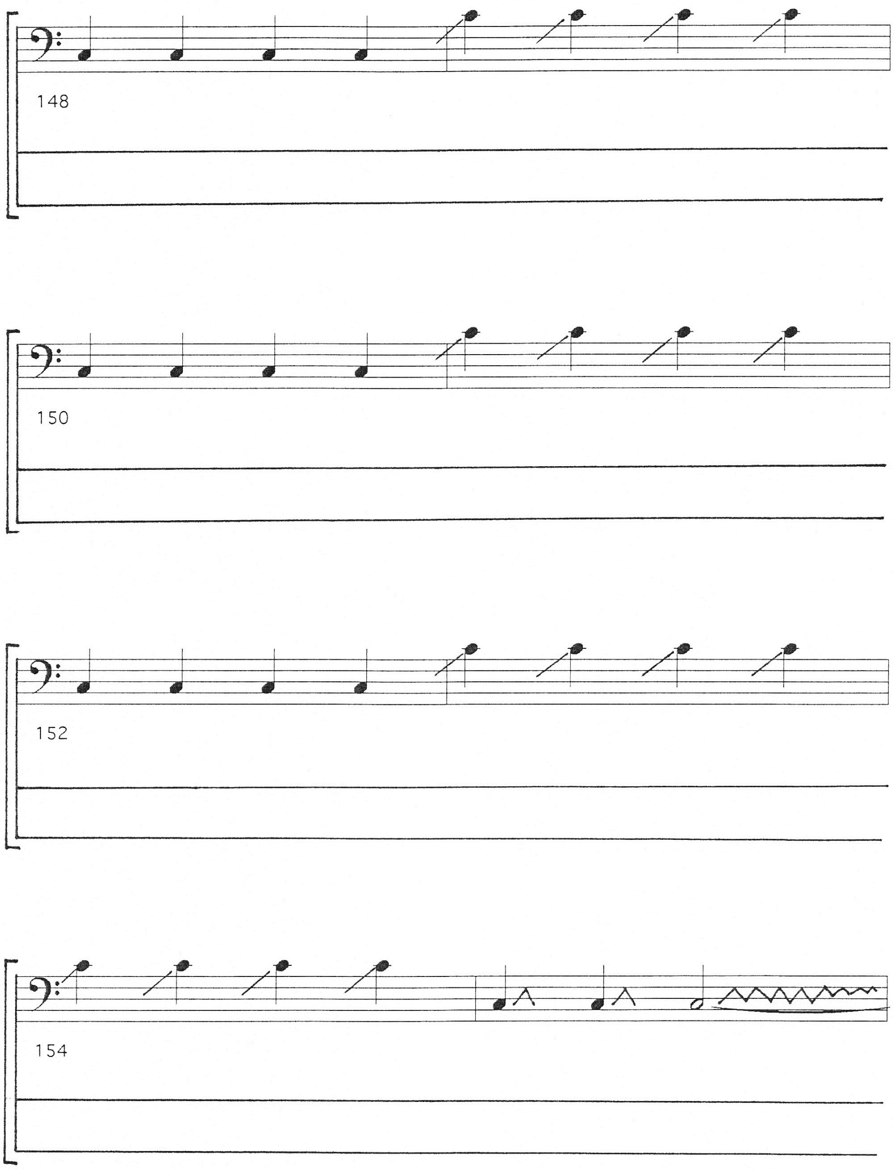

116
mf
cpc = 70
118
f
mf
f
mf
120
sim (all glissandi louder)
122

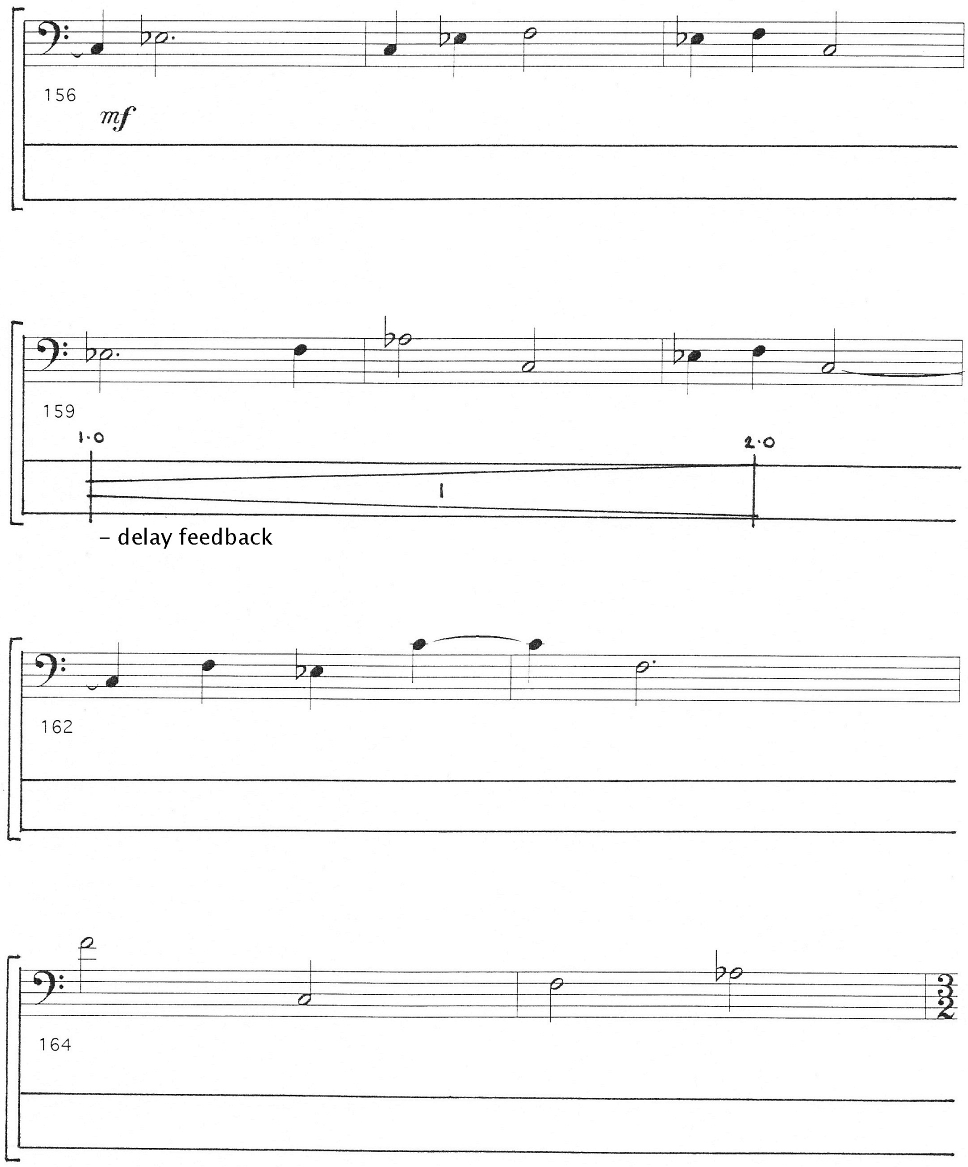

124
126
128
130

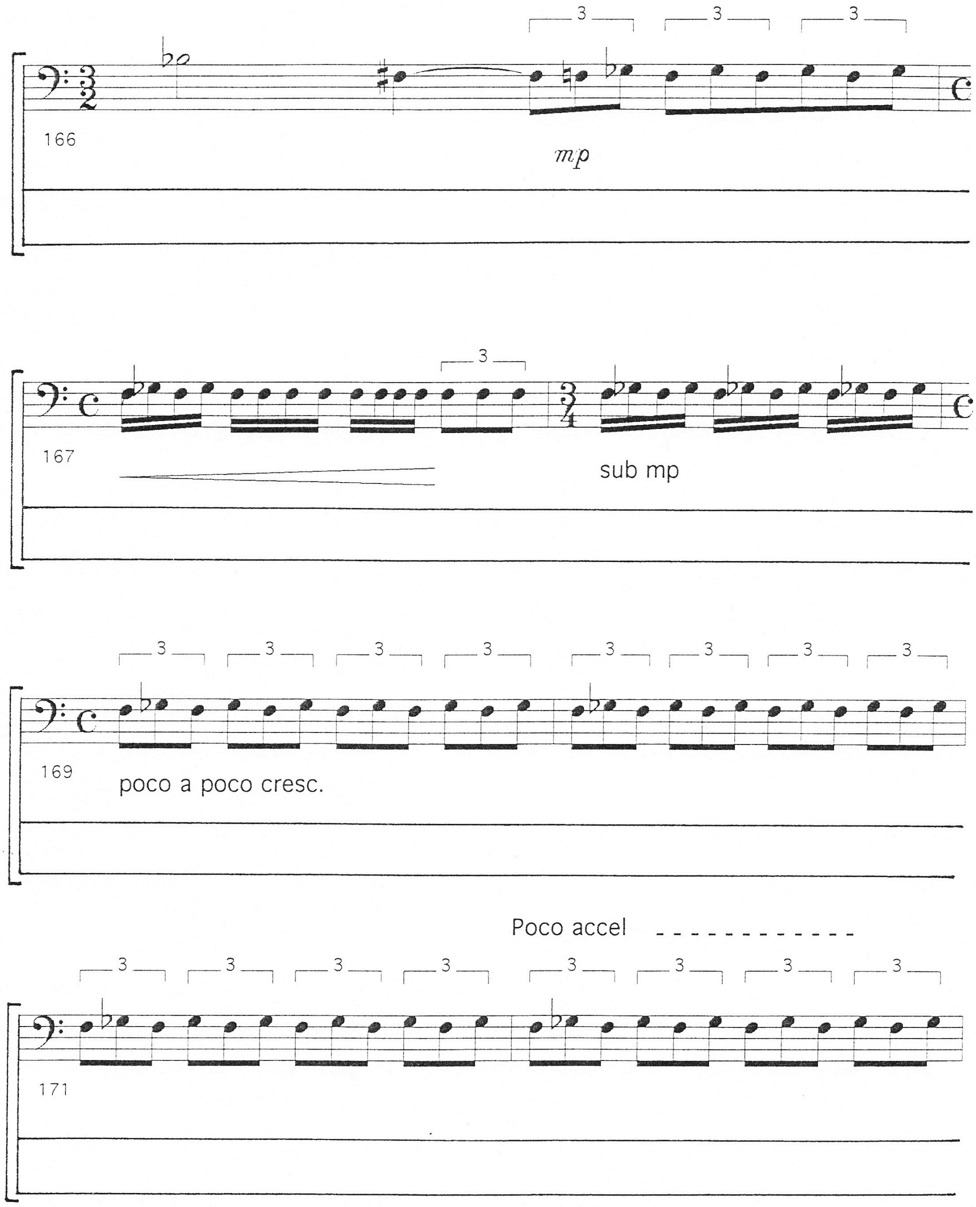

132
2·0
1·0
+ delay/feedback
134
136
slow gliss
138



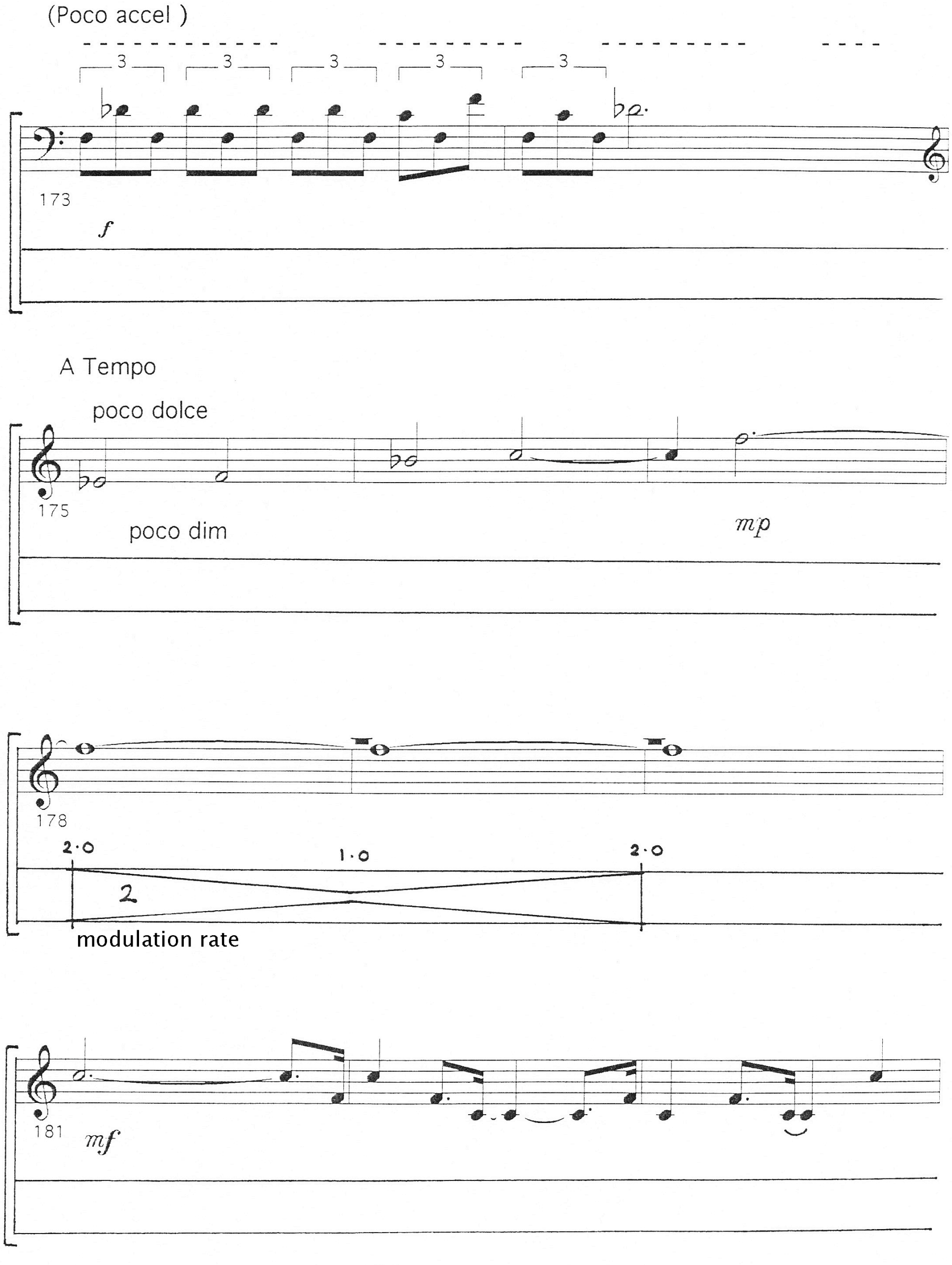
17

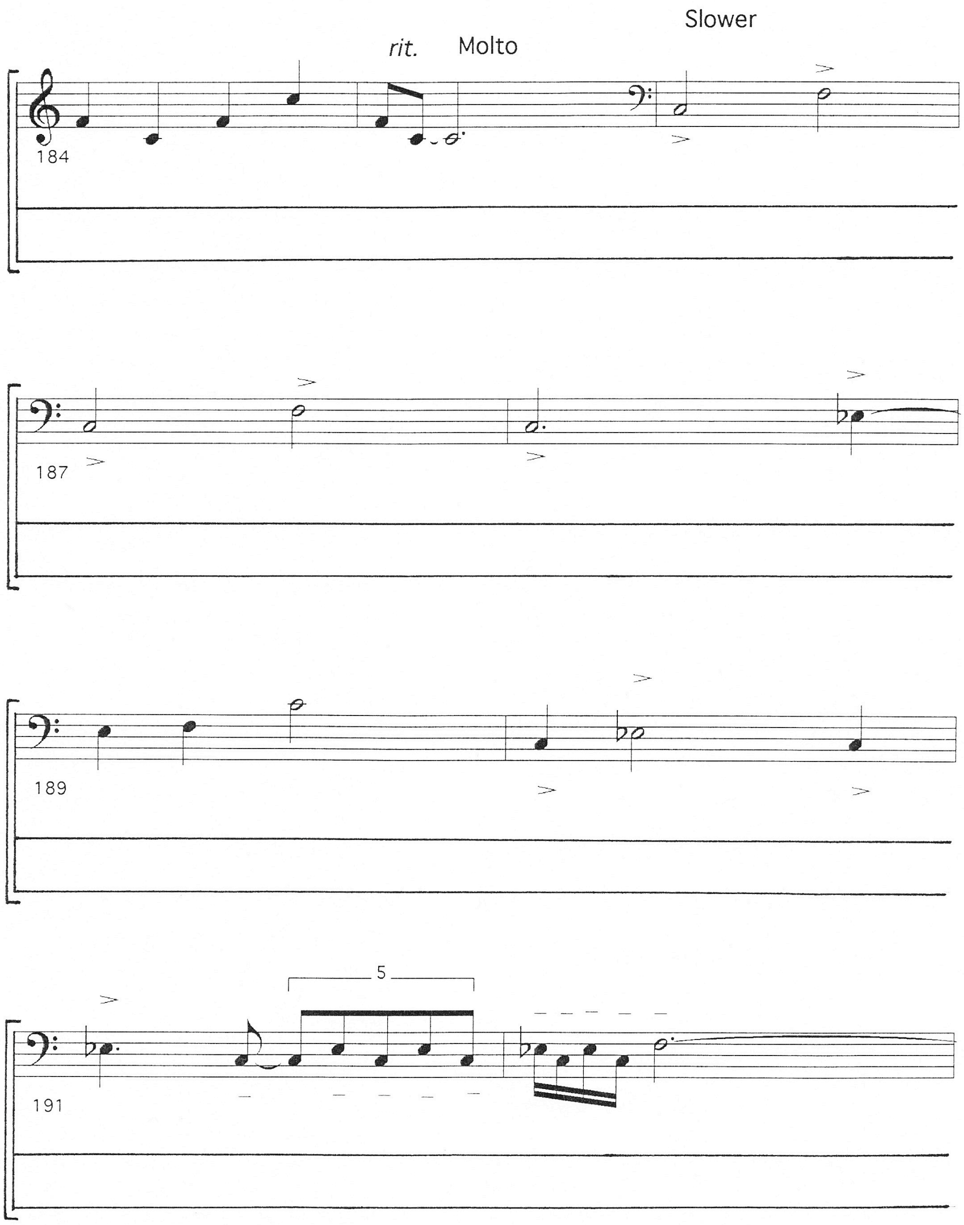

148
150
152
154

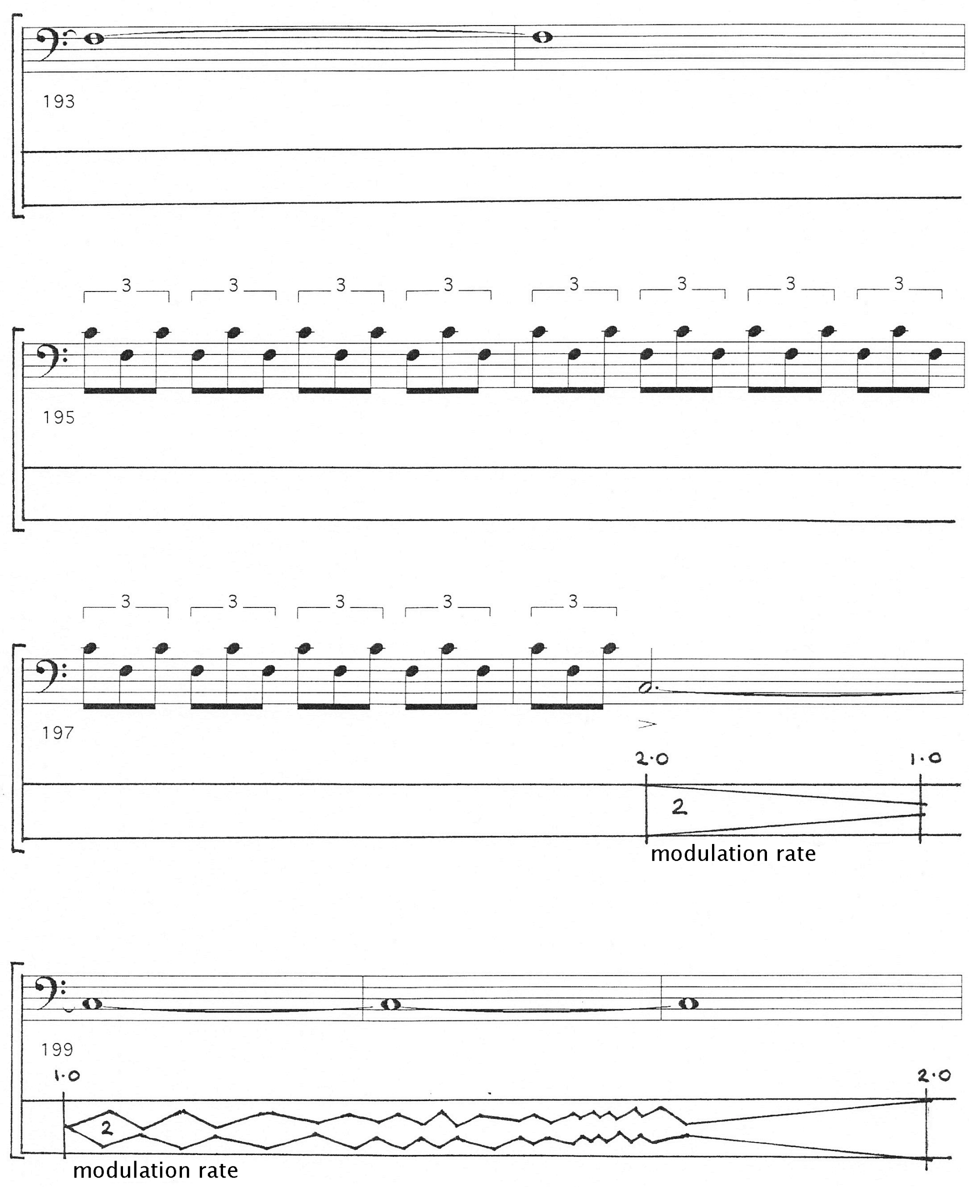

156
mf
159
1.0
2.0
1
– delay feedback
162
164

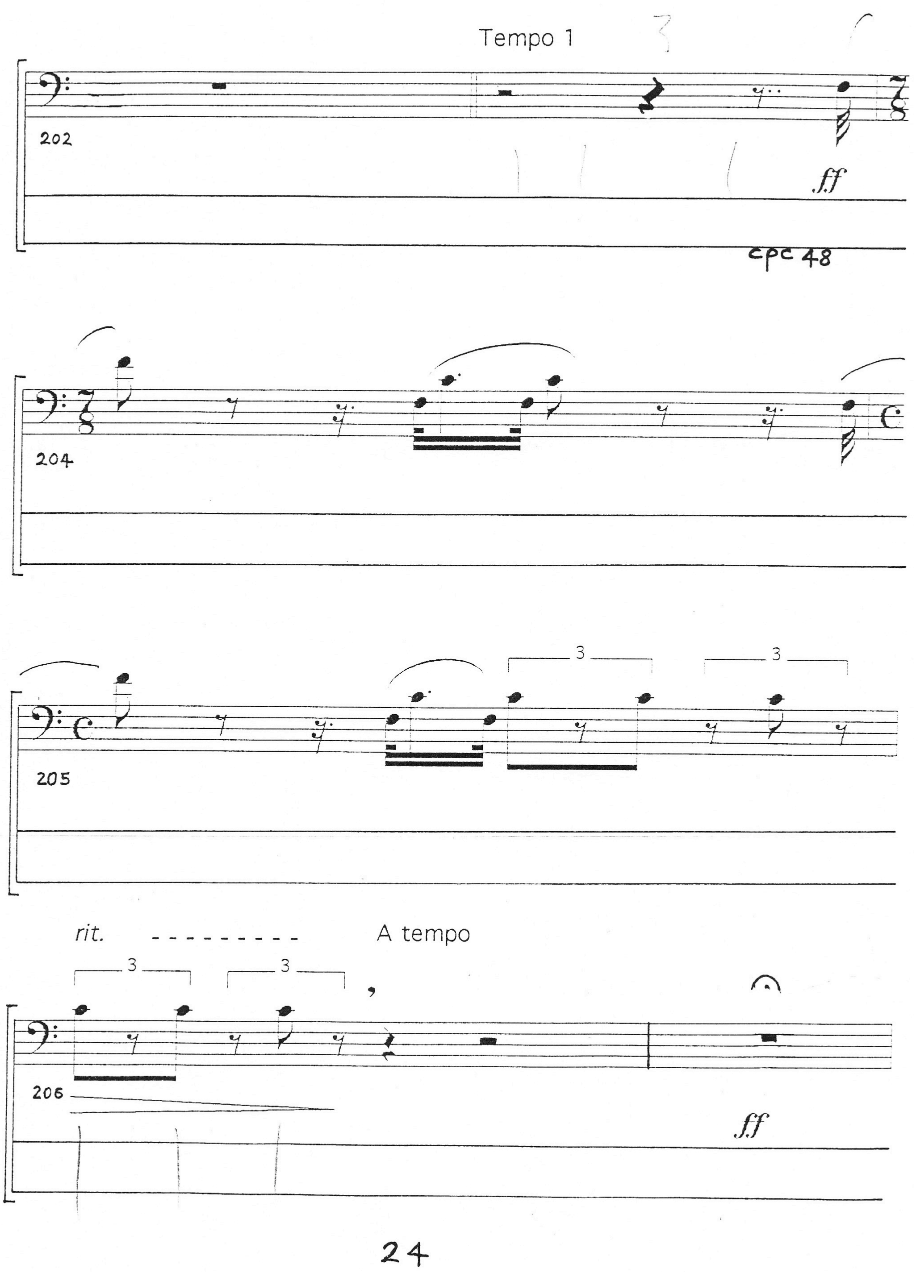


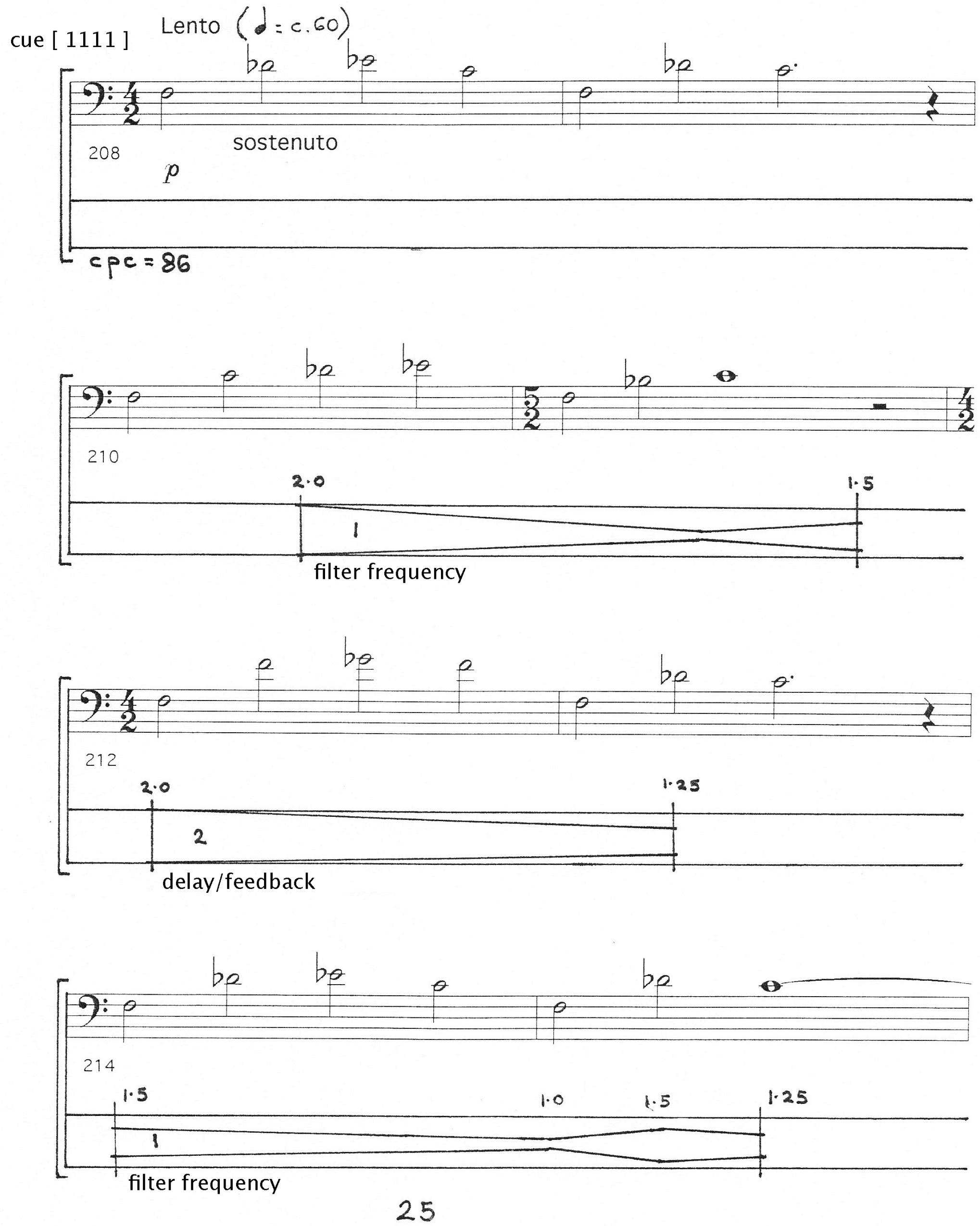
20

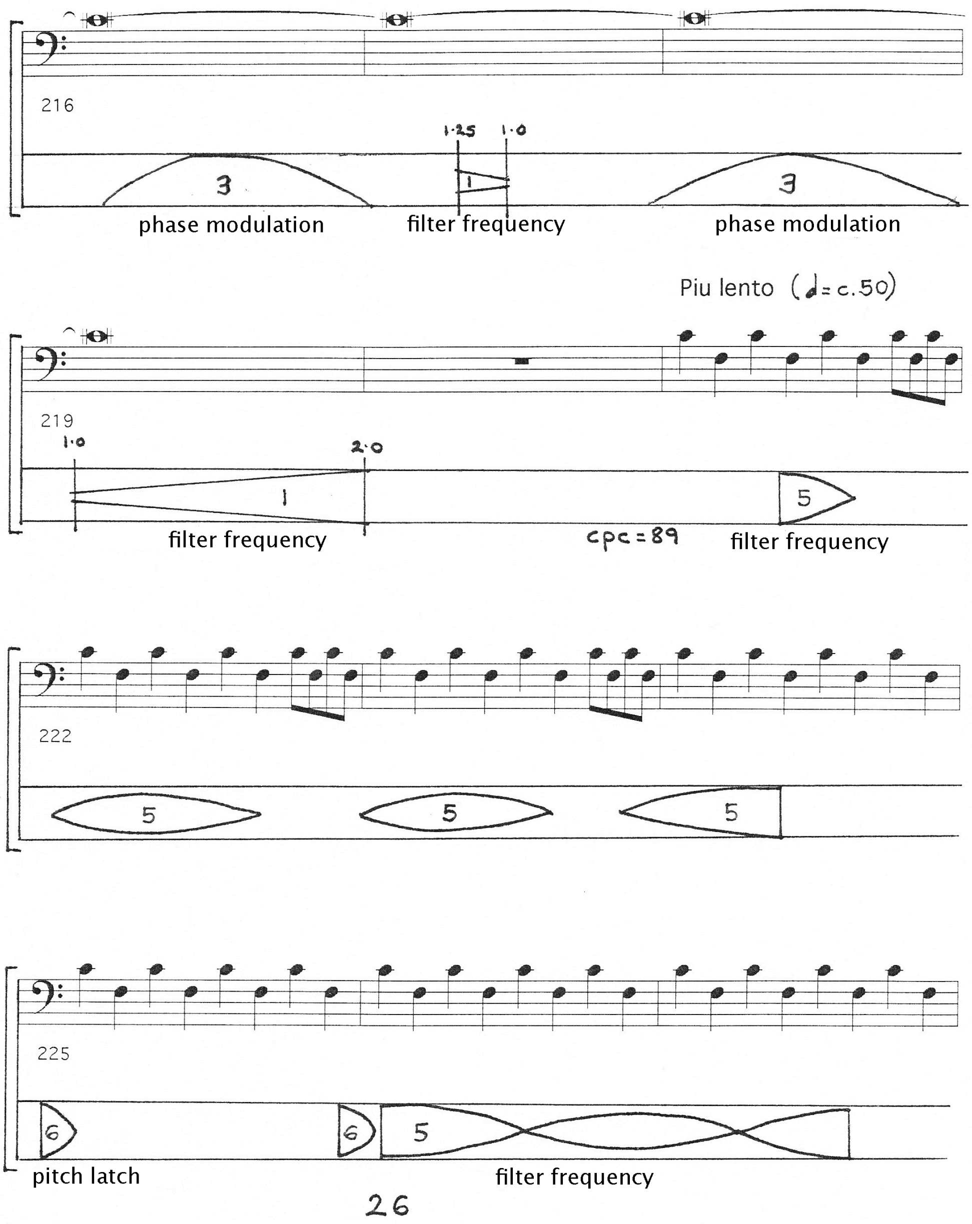

(Poco accel)
173
f
A Tempo
poco dolce
175
poco dim
mp
178
2·0
1·0
2·0
2
modulation rate
181
mf

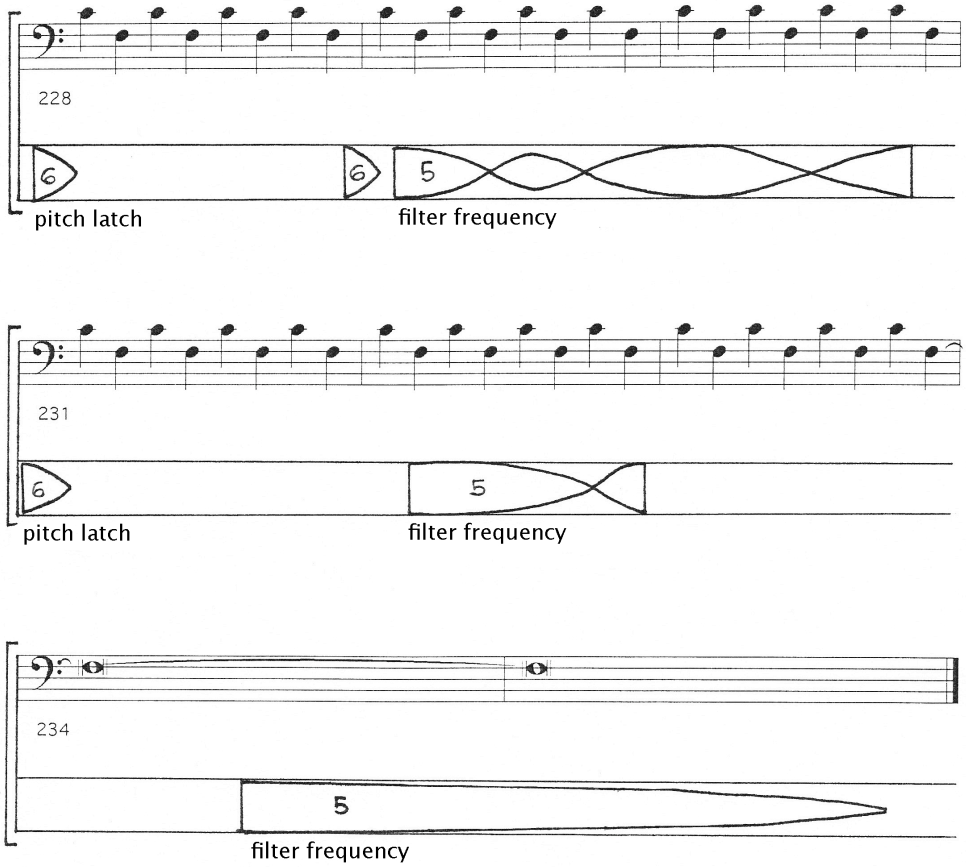

Slower
rit.
Molto
184
187
189
5
191


193
3
195
3
197
2·0
1·0
2
modulation rate
199
1·0
2·0
2
modulation rate


Tempo 1
202
ff
CPC 48
204
205
3
rit.
A tempo
206
ff
24


cue [1111]
Lento (♩ = c.60)
sostenuto
208
p
cpc = 86
210
2·0
1·5
1
filter frequency
212
2·0
1·25
2
delay/feedback
214
1·5
1·0
1·5
1·25
1
filter frequency
25


216
1·25
1·0
3
1
3
phase modulation
filter frequency
phase modulation
Piu lento (♩= c.50)
219
1·0
2·0
1
5
filter frequency
cpc=89
filter frequency
222
5
5
5
225
6
6
5
pitch latch
filter frequency
26


228
6
6
5
pitch latch
filter frequency
231
6
5
pitch latch
filter frequency
234
5
filter frequency