Performance Ecosystems: Ecological approaches to musical interaction.

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Music is understood as a dynamical complex of interacting situated embodied behaviours. These behaviours may be physical or virtual, composed or emergent, or of a time scale such that they figure as constraints or constructs. All interact in the same space by a process of mutual modelling, redescription, and emergent restructuring.
(Impett, 2001)

As will be self-evident, this is a work in progress. The text is structured around the paper presented at EMS07 in Leicester, but draws freely on a preceding presentation, at the Sonorities *Two Thousand +SIX* Symposium[1], to provide context for and elaboration of, some of its main points. The notion of the *performance ecosystem* is presented as a fruitful tool for the understanding and analysis of current musical activity[2]. It is suggested that this mode of understanding usefully alerts us to connections with historical music practices, while enabling us to address the realm of the virtual. The paper will look at a selection of practical projects and performances which have formed a nexus of activity at the University of East Anglia over the past five years, addressing contiguities between composition and performance, performer and instrument, instrument and environment. The bulk of this activity has been the work of research students and academic staff based at UEA, but a continuous programme of visiting artists, performers and lecturers has significantly influenced that activity, and funding from AHRB[3] and EPSRC[4] has informed the focus of the practice. The instances selected[5] therefore include a variety of hybrid virtual/physical feedback instruments developed specifically under the banner of the latter funding stream, while also presenting glimpses of the work of visiting practitioners such as Nic Collins and Agostino di Scipio which have provided context and inspiration.

Like much of what I do this paper is driven by a sense that those whom compose or perform, particularly in highly technologised environments, are wont to celebrate the technological, and to be reductive about (or at least less attentive to) the nature of music as an activity (as

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[1] At SARC (Sonic Arts Research Centre), Queen's University, Belfast

[2] No originality is claimed here for the term, which became a specific focus for thought and activity following its use in a lecture by John Bowers at UEA in July 2001 as part of the *Hybrids* Festival.

[3] Notably for the ARiADA (*Applied Research in Aesthetics in the Digital Arts*) project, for which Martin Dixon and (subsequently) Matt Rogalsky were Research Associates.

[4] The *Interactivity, Ubiquitous Technology and Music Performance* project, for which Professor John Bowers was Research Fellow.

[5] and necessarily representing only a small fraction of the activity during the period in question,

practice) – tending to consider the acoustic fact at the expense of social and cultural context. I'm particularly concerned with the tendency to mask or suppress cultural and historical factors when looking at the distinctions between performer, instrument and environment which so many practitioners are so keen to draw so clearly (albeit that they may draw the distinctions in quite different places).

The musical specialisms (the sometimes distinct notions of composer, player, performer, audience etc) emerged as the response to quantum shifts in music's storage – from the body, to the text, to the recording – with which we're familiar particularly from the writings of Simon Frith (1996), and of Jacques Attali (1985). Much current research effort (including my own[6]) has been expended on the contiguities between composition, performance and improvisation which can be seen to be afforded by current technologies, social tendencies and dissemination systems. I see the separations and distinctions as essentially symptomatic of a very short period of musical history in a fairly localised geographical area, and I regard current developments (DJ culture, turntablism, downloading, sampling, real-time composition & improvisation, lap-top performance etc). as part of a socially self-regulatory negative feedback process returning us to a 'joined-up' situation of music as practice. In this regard you could say that I'm still ideologically naïve enough to feel that Attali's fourth category of music's political economy – what he calls *composition* – the empowerment of humans to participate in and explicitly to construct their own musical meaningfulness – is a realistic possibility.

So you'll understand from this that I follow Impett (above) in understanding music as a complex dynamical system, whether one is talking about its organisation as acoustic fact, or about its consolidation in culture as a (social) practice embodying behaviours, beliefs and actions. And here I'm concerned to apply this model for understanding complex interactions to the distinctions between the terms:

> *performer*, *instrument*, and *environment*.

The terms reify the corporeality (bodilyness) of the first, the goal-orientedness of the second, the otherness of the third. What is *lost* in this set of distinctions? What is masked, covered, generalised away in the mute acceptance of these separations…..

One victim is an important ambiguity, the fragility of the performer-instrument articulation – the specificity of an individual's 'touch' – which results not only from the physiology of the player, but the complex feedback into that player's body of vibrating materials, air, room, and the physiological adaptations and adjustments in that body and its 'software' which themselves feed back into the vibrating complex of instrument and room. Think of the extension of an instrument's capacity back into the body and physicality of the performer (the tube of the flute, which I was taught at age eight to think of as starting at the diaphram and extending into the room). Think of the multiple affordances[7] of the instrument: Although the modern Boehm clarinet is 'designed' as an equal temperament device, this cultural expectation is carried as much in the performer's body as in the acoustic system of the

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[6] (Waters, 2005)

[7] Gibson's (1979) concept of affordance describes, as Christian Hubert puts it (Hubert, ongoing): 'the dispositions and powers of physical systems in response to human requirements.' The use of the term in this paper also embraces discussions of social or virtual systems.

physical object, and in the hands of a South Indian musician the same device affords entirely idiomatic delivery of a music which is subject to entirely different principles (of pitch subdivision and much else). My point here is that the constraints and constructs upon which music depends are not only, not even mostly, to be found in the physical object of the instrument, but in the physiology of this particular body, in the algorithms which operate in this particular piece of warm wet meat, and in the many relationships between all of these and a particular acoustic and social environment.

A brief aside: The baroque flute – which to some extent I play – requires a live acoustic for survival. To quantify this I would say that perhaps 40% of the sound depends on the instrument, 30% on the acoustic, and 30% on the player negotiating a relationship of reinforcement between the two through appropriate technique. The interactivities, interdependencies, interpenetrations, and feedback loops here are not so hugely different from those I experience when performing with a laptop, and the distinctions between bodily self, environmental self, virtual self and physical engagement with a particular object are similarly difficult to identify. Of course this is partly an ideological position on my part in my role as performer. In the nineteenth century one can identify a counter-tendency in instrument design - towards uniformity of timbral production and response, and relative portability (in the sense of relative independence of a given acoustic) as ideals which mirror not only the increased mechanisation and standardisation of manufacture, but more significantly the tendencies in musical forms and musico-social structures of the time.

Obviously there are interactions (feedback loops in both directions) between instrument and environment (particularly acoustic environment) which are palpable to listener and player (and can fundamentally alter what the instrument affords the performer). But there are interactions between the acoustic fact of a piece of music even as a recording, and the social environment of its presentation, which afford particular types of interpretation at the expense of others. I've always noted how difficult it is to play some kinds of pop music in an academic lecture situation without perceptual inverted commas emerging around the music and preventing its apprehension in the manner which the majority of that audience would easily manage at home.

And the very word instrument emphasises the specifying quality of instrumentality – the design of a device to achieve a specific end. Yet, as Richard Barrett[8] among many others has noted, what musicians tend to be interested in and good at is using devices in a manner which operates at the edges of or outside the design brief – indeed what comes to constitute expressivity in music at any particular historical moment is often to do with making explicit some of this transgressive behaviour, whether this be in the virtuosity of the nineteenth century, or in the whole of pop music which emerges from the amplification and projection of the intimate human voice (intimate in terms of proxemics) in which forensically close-miked breath sounds which were previously the preserve of porn movies and tinselly fret noise have come, in our simulacral world, to connote honesty, integrity, directness of connection, lack of illusion, unpluggedness, unprocessedness. To reframe this, what Barrett is identifying is ultimately the notion of emergence – of systems or devices which, in Cariani's terms (1992, 776), outperform the designer's specifications. Situations in which the behaviors which are afforded cannot be accounted for solely by the designed outcome. And this in turn can be

[8] In a lecture at UEA on 03 April 2006.

understood as a critique of the simple notion of instrument and its immediate relation – instrumentality.

The relationship between performer, instrument and environment becomes notably mutable in situations in which component elements are assembled in the real time of performance. Bowers & Villar (2006) document an instance in the practice of improviser Eddie Prévost in which accumulative assemblages of small cymbals on the head of a large bass drum afford precise acoustic behaviours (the amplification and filtering by the drum of the cymbal frequencies, the addition of low frequency vibration by the elasticity of the drum head) combined with unpredictable event activity (as the head's vibration moves the cymbals with respect to each other, causing collisions). Prevost's gradual addition and removal of the cymbals ensures an absolute contiguity between design and assembly of the 'instrument/ environment' and design and performance of the music.[9]

Our sense of mutability between performer, instrument and environment is heightened by our engagement with computers, and our confusion in this regard is evident in our vernacular with regard to their place in performance. We habitually refer to computers (and associated software, or just the software) as instruments. We refer to just the same elements as 'performing or composing environments'. And in some circumstances we imbue the computer with sufficient agency that we regard it as 'performer'. The incommensurability of digital hardware and software with the habitual divisions of 'attention' or responsibility in musical practice may not have prevented much research into replicating the perhaps archaic notions of 'conductor', 'score follower', etc., but the extent to which such concepts inadequately represent the algorithmically-equipped world is clear. The uncertain status of current lap-top performances, the activities within which may vary from simple event-triggering through to 'live coding'[10] is instructive here, the latter making distinctions between performer, instrument and environment particularly difficult to sustain. Bowers and Villar's *Pin&Play&Perform* system (ibid), in which physical electronic components are assembled into digital circuits during the time of performance, is a conscious attempt to build 'ad hoc instruments' which are precisely analogous to Prévost's activity describe earlier. The authors describe their task - the real-time building of relationships between the physical and the virtual - as 'the re-enchantment of dials, sliders and buttons'. [11] (ibid)

The notion of Performance Ecosystem enfolds all three concepts (performer, instrument, environment) and allows room for the undecideabilities of the virtual domain – whether as algorithmic intervention or in the form of the non-physical territorial expansion offered by the

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[9] This may be heard on AMM's 2005 CD recording *Norwich* (Matchless MRCD64). The relationship between performer, instrument and environment is similarly intimate, if more temporally distributed, in the 'preparing' of pianos, and in other types of preparatory instrumental 'assembly'.

[10] The Live Algorithms for Music Network hosted at Goldsmiths College has formed an important forum for such activity.

[11] The 'reactable' developed at Pompeu Fabra University, Barcelona, offers a contrasting approach to a similar project. It is described thus at http://mtg.upf.edu/reactable/ : 'The reactable is a collaborative electronic music instrument with a tabletop tangible multi-touch interface. Several simultaneous performers share complete control over the instrument by moving and rotating physical objects on a luminous round table surface. By moving and relating these objects, representing components of a classic modular synthesizer, users can create complex and dynamic sonic topologies, with generators, filters and modulators, in a kind of tangible modular synthesizer or graspable flow-controlled programming language'.

web[12]. It acknowledges more fully the role of the 'software' – which might mean the concepts which are brought to bear on a particular instrument by a particular player or a particular set of historical baggage, but might also refer (in performance contexts involving computers) to software in the more literal and mundane sense. Another way of putting this is that, faced with the conundrum of adding the *virtuality* of the digital domain to the *physical* reality of the performer/instrument/environment triumvirate, we become peculiarly aware that there are virtualities to take account of even within more historically-situated versions of these concepts.

It enables us to deal with instrument as a tool, instrument as prosthesis (mimetic, relating to a perceived 'lack', and integral to a specific body), instrument as sensor (and thus integral to our intersensoriality[13]) and instrument as a measure of engagement (the violin as a lie detector[14]). It allows us to acknowledge that precise acoustic conditions and aggregates of bodies have been critical for much musicking: not just for Agostini di Scipio, Nic Collins and Alvin Lucier, but throughout the long history of site-specificity in music's conception and development, notably in Giovanni Gabrieli's *Sonata pian' e fort* and the entire Venetian polychoral tradition. Indeed in pre 19C music some degree of site-specificity may be said to be the rule rather than the exception. There is usually a dependence on specific types of acoustic and social space. Wagner's Bayreuth, despite its iconic status as a locus, paradoxically marks the beginning of a shift in expectation - the emergence of a notion that music should be independent of the site of its performance – an ideal of portability to any hall where the orchestra can be hidden away- a tendency which could be said to reach its zenith in the I-pod.

In a previous paper (Waters, 1994) I observed that it was precisely the success of commercial popular music in affording the possibility of making (some) sense irrespective of the conditions of its perception that led to its ubiquity within the broader mixed ecology of music – that it is largely site-independent – whereas listening to Boulez or acousmatic electroacoustic music on a portable boom box, or even on an I-pod in most urban environments is an unrewarding experience. A consistent strand of writing in the field of auditory research (Ellis 1996, Bregman 1990) and composition projects growing directly from this area (Keller, 1999) regard the very notion of a sound 'source' as problematic, suggesting that, even when considered from a reductively acoustic perspective, music should be considered as a complete auditory scene, rather than treating source and background as unrelated acoustic phenomena, not least because of the extent to which 'sources' are modified by the space in which they occur, and interact with other sources. As Bregman (1990, 488) puts it: 'timbre is not a result of a certain acoustic input…[but].. is to some degree created by our processes of auditory scene analysis.' This leads to another productive sense of an ecology

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[12] Both of these will be elaborated below.

[13] Developed most eloquently by Connor (2001)

[14] I'm indebted to Bennett Hogg for the provocative phrase 'the violin is a lie detector' There's a link here to another of my current concerns – proxemics: To the notion that sounds are a species of touch, a variation on touching, in that they have a capacity to penetrate the body, not just through the aural system, but through the physical vibration of organs, bone conductivity etc., and that they are subject to the same social/territorial scheme of intimate, local or environmental connotation proposed by Edward T. Hall. This concept is developed in some of my recent works, notably the installation *Proxemics: The World is a Deaf Machine* for the Sainsbury Centre for Visual Arts in November 2006, and in a paper presented at Sonorities *Two Thousand+Seven* Symposium at the Sonic Arts Research Centre, Belfast (Waters, 2007).

of music – that pursued by authors such as Clarke (2005) – which accounts for (aspects of) perceptions of musical meaning in ecological terms, looking at what interpretations are afforded by particular instances of listening. But this is beyond the scope of my current paper.

Incidentally the notion of performance ecology is in no way restricted to music – various theorist-practitioners in theatre – notably Richard Schechner (Schechner, 1988) in the US, and Eugenio Barba (Barba & Savarese, 1991) and Jerzy Grotowski (Grotowski, 1968) in Europe – and many performance artists since - have made similar suggestions.

Thumbnail case studies

Nic Collins: from hardware to software

Nic has been a frequent and influential visitor to UEA over the past five years or so, lecturing, performing, running seminars and 'hardware hacking' workshops, and collaborating with staff and research students from UEA in numerous performances and projects elsewhere. In one such seminar[15] he talked about his early experiences as a student with Alvin Lucier, and their shared interest in feedback (around 1972 – roughly around the time of the latter's *I am sitting in a room*): 'I got very interested in the interaction of architectural and instrumental acoustical properties and compositional and performance strategies'. I was immediately struck by the number of interactions he had packed into a simple sentence. What was being suggested was not a binary interaction but a complex of four elements.

An early Collins work, *Pea Soup*, from around 1974, explored the interrelations between those four elements using a hardware phase delay network (with settings allowing precise control of delays in the domain of small percentages of waveform cycles – from half a cycle to around three cycles) activated by an envelope follower riding the amplitude of the signal, acting as a sort of negative feedback 'governor' on the (positive) acoustic feedback. He found that: 'it was hypersensitive to acoustical factors, and these could be anything from a draught in the room, or somebody taking a step, or someone playing a note'.

In around 2000 Collins made a MaxMSP software clone of the piece which had originally operated in hardware. In a useful aside about this experience he noted the systemic social distributedness of programming in an environment such as MaxMSP, in which interested individuals post objects in which they may have invested huge amounts of time - and also the reciprocity involved, in that beginner members of this virtual community who initially take objects frequently end up later as contributors to the shared pool of resources. More pertinent here are his observations about the hardware to software transition:

> The nice thing I should mention about software emulations of hardware is that they will never actually have the same sound - that you have to accept. But you get away from certain limitations that you have in hardware. Pots only go *so* far – you have a point. [With] mice you can just *-phew-* fly off the table -so issues having to do with range get changed seriously when you work in software. Certain aspects of resolution of course you lose on, like the bit resolution of encoding and decoding [which] is never perfect. But certain aspects of control - you come up with a larger range, and so you take your original circuit and it's sort of like pushing the box – literally making

[15] On 01 November 2002. All the quotes in this thumbnail are from the same seminar.

> the box larger - bigger pots. So that was sort of interesting because for the first time in thirty years or so I was actually able to go back and see: 'What were the limiting parameters? What were the parameters whose limitation made the piece interesting?'

Collins refers to the preoccupation in the seventies with the notion of site specific work, and acknowledges its move from the visual to musical domains: 'I'm a live performance person. I'm not a recording person. And from the outset I was interested in music that somehow took advantage of the location, and made itself special according to the spot.'

Agostino di Scipio: Audible Ecosystemics

In his development of a series of works which he calls *Audible Ecosystemics,* Di Scipio uses feature extraction within a feedback system which is superficially similar to that of Collins in its conjunction of microphones, loudspeakers, computers and rooms, but in which the feature extraction generates low rate control signals which drive synthesis or transformations of the sound material. In addition the computer cross-compares microphone input signal and system output, generating difference signals which are also fed back into the system as controls, so the system can be said to develop a sense of its own history. Di Scipio rejects many current notions of interactivity as meaningless, reformulating it as a network of 'dynamical interdependencies among system components'(Di Scipio, 2003)

> The idea that a computer reacts to a performers gesture is replaced with a 'structural coupling' of system and environment. The system *acts upon* the environment, observes the latter's reactions, and then reacts based on the environment's response. (ibid)

The system also develops an 'evolutionary' perspective:

> By tracking down its own previous internal states, and previous interactions with the ambience, it develops based on its own history, i.e. 'cognizant' of the past (system's *memory*, long term effects, etc). (ibid)

Di Scipio is keen to stress what he calls the bio-ecological principles involved, particularly energy exchange, structural closure, organisational openness and coupling of system and environment. Note the similarity of his reformulation of interactivity as 'a network of interdependencies among dynamical system components' and Impett's formulation for musical activity at the head of this paper.

Stef Edwards: Davros

Davros is an exercise in shared agency and exchanged prosthesis. A human agent, the system's 'composer' Edwards, stands encased in a steel frame to which are attached various control devices (knobs, buttons and switches), a microphone, and a system of electric motors and pneumatic devices. The motors drive nylon lines which are attached to the performer's cheeks, and inflatable 'inner' lips are fed by the pneumatics, altering the resonant cavities and labial characteristics of the mouth. A laptop computer on a plinth next to the performer provides all the impulses for the control of these physical manipulations of the human performer, who reads from a text which is displayed in front of him according to algorithmic processes related to those which manipulate his vocal production. In a 'mirror' procedure, the performer controls the buttons and switches which algorithmically transform (in pitch, formant filtering etc.) the speaking voice of 'Fred'- the laptop's generic speech synthesiser,

who reads from fragments of the same text as the human performer, delivered by the same algorithmic system, in a sort of dysfunctional poetic dialogue.

The composer's concerns in *Davros* are to avoid what he regards as 'flabby notions of interactivity':

> As a performer I'm looking for a different relationship with technology than that which I'm used to. I decided that the computer and I should both make sound – that we should both make the same type of sound – that we should both have a voice. Then I set about finding ways in which we could influence each other's behaviour, seeking to minimise the difference between us, while acknowledging that the 'relationship' isn't equal.[16]

It is characteristic of a composer who shares with other members of his research community an interest in the 'deferral of interpretation' that he espouses an interest in 'programming for unexpectedness' (to himself) - in 'making a system sufficiently complex that one can't know what will happen'. Another of his projects, *Radio Pieces*, encourages listeners to phone into a radio station while keeping their radios – tuned to the same station – as near to the telephone as possible. The resulting acoustic feedback from the open phone-lines, mixed and balanced by the composer at the radio station as it happens, animates this 'central' space with the influence of the distributed, external spaces occupied by the listeners, providing the 'silent' core with 'content' to broadcast.[17]
The social elements – distributedness and emergence- are as significant here as the sonic components. The ecosystem is both sonic and social.

Jonathan Impett: Metatrumpet
Impett's Metatrumpet (Impett,1994) involves a series of sensors[18] attached to a concert instrument, running through an I-Cube interface[19] to a Macintosh Powerbook equipped with Max/MSP, generating control data for a swarm system whose behaviour in turn governs granular synthesis and further processing of the trumpet sound. These allow for real-time composition in which every aspect of the work emerges as a result of the interaction between live performance activity and the emergent, complex system behaviour. The strengths of Impett's project grow out of his exploration of a particular and personal set of skills and interests over a considerable timespan. Paradoxically, while there may have been no intention to develop anything other than a personal tool, what can be learned from this particular instance of interface-building has a value which outweighs more idealistic attempts to produce 'generic' solutions[20]. What the project illustrates with clarity is that aesthetic value is increasingly bound up with *specific* instances of mappings and behaviours - that as digital tools are open-ended mapping (and remapping) machines, there is no longer any virtue *in itself* in the fact that one particular set of inputs can be used to control or intervene in a set of

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[16] Stefan Edwards, in a seminar at the University of East Anglia, 10.03.03.

[17] *Radio Pieces* was first broadcast in June 2002 by Resonance FM, a limited coverage London-based station.

[18] Mercury switches, pressure, ultrasound, Hall-effect, acceleration and breath sensors are used, and pitch to MIDI devices and envelope followers also operate on the acoustic signal.

[19] http://www.infusionsystems.com/

[20] As evident from recent commercial interest in the project.

outputs. What is significant is *the nature of* the controls and interventions - their appropriateness to the physicality of the input, and the legibility of the relationship between such input and the system's interventions and outputs in the social space of performer and audience. Impett distinguishes metainstruments from Machover's Hyperinstruments, or from notions of prosthetic extension of the instrument, by his insistence that the data streamed from the sensors is a supplementary component of an *existing* musicianliness. In (Impett, 2001) he describes thus the development of a model for interactive music – music instantiated in real-time on the basis of local performance and environmental information: 'Music is understood as a dynamical complex of interacting situated embodied behaviours. These behaviours may be physical or virtual, composed or emergent, or of a time scale such that they figure as constraints or constructs. All interact in the same space by a process of mutual modelling, redescription, and emergent restructuring'.

Adam Green: A 'Suit' for performance.

Developing a portable performing environment is not unusual as a compositional motivation. In Adam Green's system two types of 'guiding behaviours' are modelled, both of which have the capacity of imbuing activity with characteristics from observations of the natural world. 'Boids' – a term coined by Reynolds[21] - are agents which exhibit streaming and flocking behaviour in virtual 3D space, but in which the individual behaviour of each 'boid' element might at any point counteract the general movement tendency – as Green puts it: "I give a global impression to the boid flock and the individual elements 'decide' to what extent they will follow". The parameters actually controlled for each boid element with respect to other 'flock members' are separation, alignment and cohesion. Cellular automata are 2 or 3 dimensional 'grids' in which any of the cells may at any time be 'on' or off'' but in which at all times each cell exhibits strong influence over the behaviour of its near neighbours. This leads to the 'spread' of data in a manner which is somewhat predictable, and controllable by intervention in the cell data, but which has its own dynamics. Metaphors for these two types of control might be bird flight and the spread of a microbe culture on a petri dish, and it is the similarities of these at a systemic level to some aspects of musical construction which has led the composer to wrap them within a Max/MSP environment which takes data from his trumpet (microswitches in the base of the valves indicate valve combinations, a microphone provides data for pitch analysis, while simultaneously streaming the live trumpet sound into buffers in the computer). By careful mapping of some aspects of signal processing (pitch transformations, filtering, delay functions, buffer selection, granular synthesis, triggering of samples both 'live' from trumpet and pre-stored) to controls from both the boid system and the cellular automata, Green has built a system which has considerable musical autonomy, but which he can 'guide' by his playing towards preferred outcomes. The preferred outcomes however are not only selected by prior experience with the system, but may also be 'in-the-moment' performance decisions. The system has a responsiveness which approaches that of (a number of) human agents, but is almost entirely dependent upon the input of a single performer/composer.

David Casal: *Frank*

Casal is unusual in being a gifted pianist and improviser and a programmer of considerable insight. His initial motivations for what has become a substantial project (Casal & Morelli, 2007) were initially 'to have someone I'd enjoy playing with, who wouldn't get tired of me, and vice versa', 'to provide a prosthetic extension of the rhythmic principles already evident

[21] http://www.red3d.com/cwr/boids/

in my own playing' and to 'extend these beyond the realm of virtuosity'[22]. Casal and Morelli's point of departure is that 'musical improvisation is driven mainly by the unconscious mind, engaging the dialogic imagination to reference the entire cultural heritage of an improviser in a single flash' and they set out to apply 'Artificial Life techniques, in particular genetic co-evolution… … to the frequency domain using MPEG7 techniques, in order to create an artificial agent that mediates between an improviser and their unconscious mind, to probe and unblock improvisatory action'. (ibid) The resulting framework, *Frank*, consists of four interrelated elements 'which feed into each other in sequence as the live sound input comes into Puredata', these being:

> MPEG7 feature extraction;
> a database of 'Acoustic Lexemes' created from clustered MPEG7 frames;
> a co-evolution Genetic Algorithm, taking live sound and two other variables (breeding frequency and 'surprise');
> an audio repository, built from live sound input or existing soundfiles;

The system exhibits ecosystemic stability – it co-evolves 'output' and 'critics' – so that 'fitness' criteria evolve and bottlenecks are avoided, the two additional variables to the GA serving respectively to enhance continuities/contiguities, and to avoid tedium.

Frank emerged from a number of earlier experiments in which semi-autonomous agents were configured to behave as a generative system, algorithmically 'breeding' new binary strings, producing mutations or 'offspring' as a continuous process, these being mapped to rhythmic structures. 'Machine listening', using 'self-organising maps' effected judgements about the viability of the various offspring, killing off some processes and nurturing others, depending on how viable they were considered to be. The 'self-organising maps' (a species of neural network) were 'trained' by exposure to the improviser's playing, and the rhythmic models which survived the process of selection based on criteria partly derived from this 'compositional model' were mapped to the selection of samples from an archive ('sound fonts'), and to transposition (pitch alteration) of the samples. Casal's involvement as an assistant on Casey's (2001/2002/2005) MPEG7/Soundspotter project allowed the crucial breakthrough with respect to the framework's abilities to extract features rapidly from large amounts of audio data, and the current system has since been used in performance not only by Casal and Morelli[23], but also by Evan Parker and George Lewis, as well as providing for the current phase of develoment of my own VPFI flute project (below).

John Bowers and others: Virtual/Physical Feedback Instruments

Bowers's work on 'improvising machines' (Bowers, 2003) has been particularly influential in provoking a rethinking of the relationship between human and machinic agency. One relatively coherent design trend to emerge at UEA following the publication of this text has been the development of a family of hybrid Virtual/Physical Feedback instruments (VPFIs). The essential shared principle is that a physical instrument and a virtual counterpart are coupled in a manner in which feedback systems of some sort operate between the two. Typically the physical instrument excites its virtual counterpart which in turn drives the physical instrument, and so on… A dynamic coupling exists between the known system, be it

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[22] in conversation with the author, 2002

[23] at SARC, Belfast 02 Feb 2006, at UEA Norwich 20 Feb 2006, in the Interlace series May 2006, at IRCAM - NIME06 04 June 2006, and in Lisbon at the 9th European Congress on Artificial Life 12 Sept 2007.

vibrating string or air column, vocal tract, membrane, etc. and its physically modelled counterpart. Among the projects to date is a VPFI Long String devised by Bowers & Alex Sanders – essentially a monochord with various air microphones, pick-ups and electro-magnetic and physical drivers (including an e-Bow, 'reverse-driven' magnetic pick-ups and loudspeakers) – coupled at both signal and control levels with a variety of plucked string algorithms running in MaxMSP. Other devices include a VPFI drum, a VPFI electric guitar, and (inevitably) a VPFI Room. My own VPFI flute has featured in a variety of concerts with Nic Collins, Jonathan Impett, Cesar Villavicencio and others[24]. The VPFIs share the feature that they are assemblages consisting of heterogenous elements which afford both designed outcomes and, through their configuration and complex interpenetrative behaviours, emergent outcomes – unforeseen but desirable.

Simon Waters: VPFI flute

The VPFI flute system consists of a standard concert flute amplified by air microphone in which the signal is passed through DSP modelling of resonant tubes of varying lengths back into the instrument through a flexible tube inserted through the cork in the headjoint. The signal can be split and sent through 'external' room amplification, altering the system's behaviour by adding the room as an additional explicit variable into the various possible feedback paths. Under performance circumstances the flute can be induced to self-oscillate at frequencies relating to vibrating length of the flute body, as determined by the closing of keys 'as normal'. In a sense the flute 'plays itself' without the performer's breath. Paradoxically the introduction of conventional blowing techniques interferes with the 'pure' acoustic feedback system in a manner which markedly and controllably reduces its amplitude. With practice a graduated transition between the two states can be effected, or complex shifting or uneven oscillating states effected.

The original VPFI flute explicitly linked player/instrument/room and a hybrid physical modelling system in a relationship which, while productive, didn't ultimately address my feeling that modern flutes are 'from the waist up' in physical terms. Indeed in performance the most rewarding results often emerged when the headjoint – the most 'active' part of the system, was detached from the flute body and controlled with breath and/or both hands – particularly with regard to its proximity and angle with respect to the microphone diaphragm. The apparently 'reduced functionality' caused by the loss of keywork, equally-tempered intervals, and the tempting comfort of flute-playing rhetoric was more than compensated by the increased responsiveness of the system as a whole. Issues of body, instrument and environment momentarily ceased to exist in the supple pliability of 'hand-sculpted sound'. My interest in increasing the size and complexity of the performance ecosystem resulted partly from frustrations with the existing VPFI flute, and partly from my continuing interest in sonic proxemics (Waters, 2007). Any extension of the system had to be dynamic but potentially sonically intelligible, and the work of research supervisee David Casal led me to Michael Casey and his 'Soundspotter'[25] PureData framework. This uses (real-time) MPEG7 feature recognition of buffered sound material, providing correlations with pre-determined features of the performed input. Casal (and co-researcher Morelli) have over a series of projects, built an improvising system, *Frank*, which uses genetic co-evolutionary models in combination with Casey's work. The system's first public manifestations featured Casal's

[24] Notably at the Sonorities Festival, SARC Belfast 02 May 2005, and in the Aldeburgh Festival's 'Faster Than Sound' event at RAF Bentwaters 24 June 2006.

[25] http://www.merl.com/projects/soundspotter/

already extraordinary piano playing. Adding a modified version of *Frank* – notably with real-time control over the degree of feature similarity required to signify 'matching'– to the VFPI flute system has fulfilled my aim of extending the performance ecosystem more explicitly into the virtual realm. A further aim is to stream material into *Frank*'s buffers from internet audio search engines during performance, extending the ecosystem still further by correlating features with the vast body of audio material online. This will represent a significant point of contact between the 'ecosystemic' concerns which initiated the VPFI project and my exploration of the correlation between proxemics in physical and in sonic terms - with the online 'virtual'domain representing potentially the most physically and sonically 'distant' zone.

John Bowers: Simple interfaces/complex results

Much of John Bowers' work concerns itself with critically investigating the emerging principles of interaction design and human-machine interfacing. He has identified (e.g. Bowers & Hellström, 2000) four 'transgressive' principles of interaction design which diverge significantly (especially when taken together) from those which frequently inform 'good' design practice[26].

- 'Algorithmically mediated interaction' separates out a 'layer' of algorithmic mediation which is distinct from 'direct manipulation' - often by capturing or storing input data for use 'out-of-time' - so that 'different peripheral devices, transformation algorithms, and sound models can be freely exchanged'. (Of course at some level all digital input is 'algorithmically mediated' but here the point is that the algorithmic mediation stores muscular or tactile input in such a manner that its status and relationship with a particular temporal moment is malleable.
- Input devices with a small number of degrees of freedom are used to introduce 'expressive lassitude' - requiring careful algorithmic design to compensate for the small number of input data streams. Such 'divergent' or 'few-to-many' mappings can help in modelling systems with the richness and complexity interrelationship of touch and response characteristic of many acoustic instruments.
- 'Dynamic adaptive interfaces' which rescale or remap input over time (of performance) such that the interface's function changes dynamically under algorithmic control. In effect they work to produce interfaces which do not respond in an entirely consistent and predictable manner.
- 'Anisotropic interaction space' - where non-linear and discontinuous mappings are utilised such that gradual movement of a fader may operate predictably over some parts, but introduce radical discontinuities over others, requiring real-time evaluation and adjustment on the part of the performer.

Phil Archer: Re-purposing and reimagining

Taking his cue from Nic Collins, who espouses (Collins, 2006) human bodily intervention in the machine in the form of 'laying on of hands' in the bared circuitry of a transistor radio, and

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[26] Gaver (2005) reflects usefully on this: 'Ambiguity might seem anathema to good interaction design, but it can be a useful tool for designers. Ambiguity can encourage people to supplement incomplete or inaccurate system representations with their own understanding. It can be used to raise questions without dictating answers. And it can be used to present a situation to people without dictating how it should be approached. This creates an opportunity for 'interpretive appropriation', in which people make systems their own without having to construct, tailor or modify them physically. Interpretive appropriation allows people to determine the meaning of systems as well as how they are approached and used'.

who seems to have been among the first experimenters to successfully remove the 'mute' which functions on domestic CD players when they are switched to pause or search, resulting in compositions such as *Broken Light* [27] for string quartet and skipping CD player, Phil Archer has developed a long series of projects/performances/objects which are characterised by a reframing of their original function (Archer, 2006). Informed by Reed-Ghazala's 'circuit-bending', garage electronics and other forms of extended deliberate physical (mis)use of existing technologies, his family of performance devices includes a Yamaha keyboard, removed from its casing and inverted, and played by connecting semi-arbitrary points on its circuit board with hand-held wires. A bubblejet printer is more invasively refashioned such that its various mechanical processes – the paper drive, the print head shuttle etc -are harnessed to acoustic sound producing devices. By sending text files to the 'instrument' the composer can perform a sort of deviant version of the conventional notation/ composition/ interpretation/ performance chain. These 'instruments' are contiguous with his approach to the reframing of sound material through sampling, and of computer code through 'hacking' together elements from previous found objects. The language Archer chooses to describe his activity is instructive. He regards himself as 'rehabilitating neglected or overlooked technology' and of making use of that which has not yet been aestheticised, being 'too old to be new, but too new to be old.'[28] Bowers and Archer have coined the umbrella term 'infra-instruments' for projects which share qualities of reduced utility and eschewal of affordance of virtuosity, arguing that these refocus attention on the 'performance settings'- a term I take to be contiguous with *performance ecologies*. 'The whole performance setting becomes the unit of analysis, design and evaluation, not just the single 'new instrument for musical expression''. (Bowers & Archer, 2005)

Shigeto Wada: The *Sphere* improvising environment

Sphere is a computer improvising and performing environment for a number of participants in which collaboration and consensus are possible among the various 'actors' and in which there is also a machinic agency which may benignly aid such possibilities, but it may also 'choose' to intervene by impeding communication or otherwise altering the data exchanged between participants. The system - developed out of his early work for the European Meta-Orchestra (Harris, 2004) - is optimised for multi-user musical improvisation, and is flexible enough to cope with a wide variety of different types of input – commercial MIDI devices, data from sensors of numerous types, digitised audio streams, etc. – but could equally be adapted to utilise text or image. One of the initial impulses for the composer/programmer's work was his concern to explain to colleagues, metaphorically, some of the complexities of the Japanese language, which embraces not only the person/time distinctions of European declension, but codifies social position, age, employment, family relationship etc. in the use of distinct language subsets. The formalisation of certain types of context dependent exchange has substantially informed some aspects of the structure of *Sphere*.

Endnote

Complex dynamical systems do not result from the aggregation of all simple heterogenous elements. In aesthetic terms the law of 2+2 equalling 5 is a goal to aim for but not easily achieved, and rarely by conscious microscopic design and control of each and every element. And not all complex behaviours are desirable – the perceptual result of aggregated complex behaviours may be considerably less than the sum of its parts.

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[27] available on the CD *It Was A Dark and Stormy Night* (Trace Elements EL101)

[28] ARiADA Research seminar, University of East Anglia 10.02.02.

Shakespeare the man's success in contributing to the dynamic performance ecosystem we now know as 'Shakespeare' was in specifying *the right amount* of information in order to afford the maximum potential number of fruitful outcomes, many (perhaps most) of which he could not possibly have foreseen.

Musicking human beings have always explained and understood the relationship between body, instrument and environment as dynamic and mutable. Our digital present is no different. It is not fundamentally distinguished from other eras by the problems and opportunities presented by its ubiquitous technologies, because the biggest variable in the act of musicking has always been what we want to do/what we can imagine doing, and this in turn has always (as Humberto Maturana might have said) been afforded by our sense of ourselves as organisms with a history (even organisms inside a history).

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Performance Ecosystems: Ecological approaches to musical interaction.
Simon Waters: Photographic Appendix

Davros - Early versions of the project (International Conference on Music and Gesture, UEA Norwich, August 2003), and Stef Edwards performing at the Slade School of Art (February 2002)
photos:Simon Waters

Adam Green (left – trumpet and 'performance suit'), Jonathan Impett (metatrumpet) and Simon Waters (VPFI flute) at Aldeburgh Festival's 'Faster Than Sound' event, 2006. photo:Leo Impett

Waters (VPFI flute) and Cesar Villavicencio (custom MIDI/MaxMSP great bass recorder performance system) at the Sonorities Festival, SARC, Belfast in 2005 photo:Alex Sanders