ICMC 2011 Keynote Address, Music Imagination Technology

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Abstract

Our subject is much the richer in all its many forms for the vast contribution made by Max Mathews. He reflected and I discuss further the transition from technologies of information to those of the imagination. But how can we better externalise what we imagine, to use it more directly in the creation of sound and music? I discuss notation and evocation of sound, different modes of imagination and the intervention of memory. I suggest that interactivity is not exactly the same as 'response', and how meaningful response might be a better way of looking at 'liveness' in music making. I suggest the 'animate net-work' as one idea of mediatised performance ensemble. Do we hear cause or effect? – I suggest the latter is more important but that this can vary between listener and performer. Alan Turing gives us a view of the unexpected and the difficult within the apparently intelligent behaviour of systems. Finally a return to rendering the imagination in three dimensional space – a movie or sculpture perhaps might help, with a final reference to such a vision from playwright Denis Potter (which I had discussed with Max Mathews some years before).

Max Mathews, without whom...

I forget when I first met Max Mathews. My copy of his seminal text *The Technology of Computer Music* (Mathews, 1969) is dated May 1978 purchased in the MIT Press store itself on a trip to the USA while I was working on my PhD. I followed his work in the 1980s but only got to know him personally in the 1990s in Bourges where we were both members of the *Académie Internationale de Musique Electroacoustique*. What we talked about over breakfast was more likely to be British produced TV plays that he and his wife Marjorie made a point of watching, than anything about computer music. Indeed I clearly remember in one such conversation recommending a specific TV production to them which I shall return to later in this paper – not by chance, I described then some of the computer-generated visual effects in the context of the drama.

Not only was he the creator of the first true computer music programme but his contribution to live music making (Groove), new interfaces and instruments (the electric violin), culminating in the radio baton is fundamental. This, linked to score tracking of both traditional and newly composed music, was a major contribution to live and real-time computer music. There is not an area of our field to which Max did not contribute. I will always remember his imaginative and sometimes provocative contributions to debates in the aesthetics and research initiatives in our field at the *Académie* – always central to his views was the perceiving subject – that may seem surprising given that he spent so much time helping us create and perform sounds and processes through digital means – but to Max these were always at the service of the listening experience which had limits of physiological, psychological and learnt nature.

From 'information' to 'imagination'

This shift (from an emphasis on information to imagination) can be illustrated in Max Mathew's own words from near the start and end points of his career. Firstly from the seminal article 'Generation of Music by a Digital Computer', written with Newman Guttman in 1959, when computer music was all of one year old –

> Potentially, a digital computer may generate any sound [...] the digital computer may produce infinitely many sequences of numbers and hence an infinite number of sounds.

And then from Tae Hong Park's interview with Max in the (effectively 80th birthday) 'tribute' edition of Computer Music Journal (2009) –

> The question which is going to dominate the future is now understanding what kinds of sounds we want to produce rather than the means of usefully generating these sounds musically. This is going to revolve around experimental psychological studies of how the brain and ear react to sounds, [...].

At first the clear and logical definition (in the article) of the information structures necessary for the generation of *any* sound – from the sample to the waveform.[1] But secondly the increasing need to understand the actual *sound event* as a perception and how humans react to it. This is a rich insight – what do we want when we can do *anything*? What are the limits of our imagination?

The limits of imagination

Max Mathews intended his second point to be reversible as in all good scientific research – one of the aims of the study and understanding of human psychological reaction to sound would be to encourage the reverse – the ability to start with ideas of human reaction

and work out into the sound. In our imagination we might have only a very fuzzy idea of what we seek but we need better tools to externalise and test our potential.

To this end I would like to harness and extend an idea described and developed by Michael Casey in his idea for 'Automatic Foley Generation' – "The audio for an interactive game can be generated from a structured audio description of the materials and action parameters of a scene." (Casey, 1998, p.16). But he goes on –

> An extension of the automatic Foley application is the Producer's Assistant. [...]The most desirable control pathways for such an application are those that offer physical object properties as handles on the sounds such as materials, size and shape properties.

Casey in this instance assumes synchronisation to a film or video track but I think the principles could be set free and if we could work to an *imaginary* scenario. The basis of his imaginary assistant is ecologically sound instrument construction – while for Foley work this might demand 'realistic' sound output all the physically modelled synthesis and excitation types he describes may be used for the widest range of sound types. How do our imaginative ideas become realised? How would we drive this producer's assistant? With an imaginary movie or (better) a movie of the imagination?

Notation and evocation

Notation in the western tradition started off as a 'memory jog' – a simple aid based at first broadly on melodic shape which would remind the singer of the outline of the pitches of the already learnt chant of the offices of the church; rhythm and duration were decided by a complex interaction of word, syllable and breath. Pitch had emerged as a dominant carrier of musical meaning – oriental notations well established prior to those in the west show a wider range of concerns including playing techniques for different timbral and expressive results. Pitch as a single dimension parameter was well suited to the graphic representation of the page; at some point in the early part of the last millennium its notation evolved from the simply mnemonic to the definitive (the prescriptive).

Much electroacoustic music belongs to an aural tradition, one with little or no human readable notation.[2] The need to somehow 'fix' this ineffable flux comes from several quarters. This led to the 'evocative transcription'. From the earliest days of *musique concrète* and from all traditions of later acousmatic, electroacoustic, mixed and live electronic musics have emerged 'scores' – clearly having different functions than the traditional western score. This includes the human performer at the mixing console wanting to present the work on a large sound system (the art of sound diffusion or projection), the musicologist seeking an outside-time representation to allow analysis of the music's 'working', its material and form. Sometimes such a visual representation can aid concentrated listening – which can then become listening out for – and to give pointers and emphasise the 'something to hold onto' (in Leigh Landy's terms [9]).
But an interesting additional type of score is referred to only in passing in much literature – the composer's sketch score. Expressing the possibility of projecting the evocative notation into practice rather than the reverse.[3] In suitable form this might link to Michael Casey's notion above. I am dreaming of such an evocative notation 'driving' his production assistant – with of course real-time input from the user.

A universal and agreed notation for complex sound is extremely difficult to conceive of. FFT representation may be 'objective' but has inadequate correlation to and evocation of the actual sounding result. Thus the historical process which happened a thousand years ago for pitch notation will not happen in such a linear way for complex timbre events and processes (I try to avoid the term 'objects'). An interesting hybrid of 'machine assisted' and manual evocative transcription has been pioneered in the Acousmographe (from the GRM in Paris). This left the subject users to define for themselves particular shapes, forms, colours and textures visually to represent certain sound qualities.[4]

It may be that some degree of coherence and standardisation could be established through more thorough research into evocative notation.[5] With the development of such representation software packages some commonality of these visual attributions might emerge. Experience and a lot of use will tell us what works.
In addition the principle of driving the transcription system in reverse is there in its infancy – and of course there is software to translate a repertoire of shapes, attributes, colours and textures into sound.[6] And if generalisation and universal agreement on notation is not feasible in the short term, personalisation of choices and preferences should be simple.[7]

There may be those from some post-musique concrète traditions who are horrified at the prospect of such a notation used to create electroacoustic sound.

Pierre Schaeffer' s disenchantment

with western notation was on account of its distance from the sounding result. That is the degree to which composition had become manipulation of abstract symbols on the page completely separated from the concrete experience of music as perceived. Recorded sound and the listening experience, without recourse to notation, combined to give (he believed) tools for a renewal of compositional practice.

I am not arguing for a counter move against this position – many have done that already; the notation I have suggested above does not possess such a definitive (prescriptive) function – it cannot, as there is no firm mapping of symbol to interpretation as there is in traditional western notation. The proposal inevitably retains an experimental fuzziness, an empirical uncertainty. The aim in such an 'envisioning' of synthesis is to allow greater imaginative play ...

Different modes of imagination

The operation of sensory interfaces to computers has often focused on the physical aspects of our bodily space – muscle activity, limb movement, breath. Even when extended to include the monitoring of electrical activity – bio-interfaces – these have until recently been kept at the level of monitoring physical signals. But we have recently seen Marvin Minsky rotating a shape on screen through thought alone[8] – the computer programme tracking Minsky' s brain activity through non-invasive electrodes, learnt the electrical result of a set group of mental operations (such as rotation). This was a 'learnt procedure' – none the less powerful for that and an enormous step forward. This is rather like voice recognition of course – the system learns your idiosyncracies on a 1:1 mapping to a dictionary.[9]

Oliver Sacks, in his book Musicophilia [15], reports extensively on what he terms 'musical hallucinations' where music appears as apparently truly heard yet unbidden to the consciousness through no external stimulus. His examples appear to be triggered memories rather than creative acts and are sometimes frightening to read. Composers vary as to what exactly they say they do when they 'imagine sound' or 'imagine music'. There is also a tendency to bracket together 'imagery' and 'imagination'. While the two have the same origin in 'imago' we can make a distinction between them. And we may do a lot more than 'imagining sound' when we conceive of a piece. We may imagine a scenario, an instrument, a performance, a sense of space and place. We may also imagine a complex relationship expressed through mathematics – and many mathematicians claim to deal with symbols somehow 'out there' in space.

Then we have specifically musical functions, composers have often described the sense of form they have held in their imagination – and these are sometimes described as somehow 'outside time'. From Mozart to Stockhausen some have claimed to 'see' forms of works in an instant. This suggests somehow an 'outside time' representation. It also suggests a preoccupation with form as a kind of architecture not merely 'outside time' but 'in space'. Webern in his 'Path to the New Music' [18] confirms that he, Berg and Schoenberg worked from 'an intuitive vision of the work as a whole' - which came in a flash of inspiration – to the details. This is particularly strong in the Austro- German tradition. Goethe is often quoted by Webern but here by Xenakis – "Goethe said that 'architecture was music become stone'. From the composer's point of view the proposition could be reversed by saying that 'music is architecture in movement'." (Xenakis quoted by Le Corbusier ([10] p. 326)

Memory

It could be then that imagination is simply anticipatory behaviour - a tool for survival. But as one theory suggests it has expanded into the mental bandwidth previously occupied by the need to memorise – whether Homeric epics, routes for navigation on land and see – before maps, writing and other 'externalised memory'. I declare a frustration – throughout my life I have heard sounds while driving that I have wanted to capture. (Stockhausen ref.) Any attempt to do so has been fraught with impossible conditions. Sounds on the radio at but not beneath the ambient noise floor; the strange qualities of wind and water sounds; are some typical examples. All attempts to mimic them later in the studio have failed although the attempt has sometimes been worthwhile.[10] This has led to this request for more flexible, tactile and interactive ways to externalise imagination and effect its synthesis into sound.

From interactivity to response

Interactivity means a wide variety of things in computer assisted music. I want to look at some of them and extend the discussion to see how this relates to the notion of 'response'.
My dictionary tells me - Interaction - reciprocal action or influence: Response – a verbal or written answer to a question, possibly a reaction to something; - but this sounds like 'reply'. More relevant is the Latin origin my dictionary tells me means 'something given in return' which has a closer ring to how I understand it. Yet even this is not clear enough. I have written much over the years about the 'live' in 'live electronic' music. Only recently did I move beyond the crude physical world models around when I was a student: 'a human playing something,

making sound mechanically to be manipulated electronically'. Of course we need to overlay that with psychological worlds (of will, choice and intention) and social worlds (of being with others) – all three interpenetrate in 'living presence' [4].

I am increasingly of the view that liveness is about some notion of meaningful response. Let us step back a pace and arrive at that more slowly. Causality has been fraught with problems in the realm of physics, from the atomic to the cosmological. But we must tackle it to make sense of the world at the scale we encounter it.

In computer processes we often set up simple causal chains - In a world of agents called X, Y, Z etc. we might observe actions A, B, C, ...G etc. Thus if causal action is simply of the form: A (in X) causes B (in Y) -
then interaction adds the return path: A (in X) causes B (in Y) causes C (in X) etc. But we must be careful. As a musician if I 'call' and you 'respond' – I have not caused your response in the same deterministic sense. I might be said to have provoked your response through social and musical convention. We cannot easily avoid this 'transfer' problem but need to be acutely aware of it. Thus the perception of an appropriate and meaningful link in this interactive chain pertains to the nature of B with respect to A, C with respect to B etc. not simply to the nature of the causes. Where the nature of the result is appropriate and meaningful crude interaction becomes true response.

Our dictionary definition seems limited, also, to two entities. Networks do not act so simply. Where every element is potentially connected to any other causal chains are more likely: A (in X) causes B (in Y) causes C (in Z) etc. [... eventually] causes G (in X). Of course the chains themselves may also reconfigure dynamically. Furthermore in real performance systems a single action can have consequences in more than one element - A (in X) causes B (in Y) + C (in Z) + etc. There are here attendant multiplicative consequences – some possibly unstable and catastrophic.

Interactivity at micro and macro event levels

There are of course a range of possible aims and outcomes parallel to concerns in sound perception studies on the relationship of micro to macro events. In a David Tudor inspired system, or (for example) in the construction of a swarm driven piece,[11] micro-level causalities and interactions create large numbers of events which might possess emergent holistic properties. The agents are small entities which interact with immediate neighbours according to (often simple) rules. At a high level, simple actions input to the system might cause complex emergent results, and it is these that are the intended outcome of the action.
Matt Rogalsky has written recently about David Tudor's Rainforest - an open work, electronically as well as mechanically interactive.[12] Tudor's own descriptions of Rainforest over many years present an array of references to nature and the natural: it is variously "an environmental piece" (1974), "An Electronic Ecology", "an electroacoustic environment", "acoustically environmental" (1981). [...] In its 1973 version, [...] a complex environment is created where electronically generated sounds intermingle with field recordings and they frequently become confused. What seems to be an electronic sound might well be a recording of a frog pond; what sounds like chirping birds might be a feedback circuit assemblage of guitar effects pedals. [14]

An ecology is (as we are learning to our cost in our world today) a system in which all components are interactive and interdependent to a degree.
But if the agents X, Y, Z are complex high level entities quite perceivable by an audience (for example performing agents). Then causal chains are likely to be at the music event (macro) level directly available to the listener's perception – that is we are meant to follow the pattern of their individuality in sequence – and their interactive consequence.

Hearing cause and effect

There is a clear distinction between hearing an action or process and hearing the result of an action or process. It seems more obvious if I put this in the form – you do not always hear a cause,[13] you hear its effect. With this in mind I have always doubted the very limited debate about 'hearing algorithms' or indeed any generative procedure whatsoever. We must not fall into the trap of reducing music to a game of consequences – a guessing game of 'what caused that?' That may be fine for professional composers (and computer music conferences) because we really do want to know the answers! – but is not usually at the centre of the expressive musical experience.
Thus the aim of serial manipulations was not to 'hear the series and to work out its four forms and their transformations' in the mind of the listener. Xenakis did not intend us to 'hear Brownian motion' (gas molecules moving) in his work Pithoprakta;[14] and I do not believe composers normally intend us to 'decode' chaotic and fractal generators or neural networks (as such) as generators of musical material. Yet each of these has clear consequences in the sounding result even if we cannot consciously grasp what caused it. If that relationship is strong (that is with clear characteristics which

appear not arbitrary) then the processes has at least functioned 'effectively' (that is not the same as aesthetically or musically successful).[15]

If we as listeners cannot always consciously decode interactivity we can certainly perceive its result. In traditional music making of many genres we might say we sense interaction in an ensemble – where in fact we sense the results of interaction.[16] From a great jazz group, string quartet or live electroacoustic piece we lock into and follow 'something'. Here, too, (as above) interaction has both micro- and macro-level aspects, from the tightness of synchronicity to the fecundity of exchange at music material level, call and response.

Performer / listener distinction

But we have inadvertently separated the listener out as somehow privileged in this discussion. The perception of interaction may be substantially greater and more important for the performer. The statement we made earlier - A (in X) causes B (in Y) - seems to ignore who is doing the perceiving, and how that person got to know this. For the performer this may be entirely different than for the listener – and both different from the composer. We may have got locked in technical description here. We composers may know that 'A causes B' due to a particular relationship within our Max patch – that's simply 'how it works'. The listener may only have the sounding stream with inadequate visual confirmation (or none at all).

More importantly, a performer is quite used to sensing micro-level changes in timbre, pitch and loudness of their instrument and is in the privileged position to sense relatively small consequences in the live electronic system and interacting with them. The entire enterprise should perhaps focus more directly on the effect this has on the performer and performance. If this enhances the musical result then the interaction has clearly functioned positively and truly 'responded' not simply replied. The performer may know this well through rehearsal and practice – they may want to comprehend fully the exact cause of any response to what they do. Whether the interaction between performer and technology has as such been perceived and 'decoded' by the listener is however quite secondary. As listeners we should perceive its robust result (the effect) not necessarily it (the cause).[17]

Response to the unexpectd, the unknown, the unplanned, the disturbing

Alan Turing's famous test (actually a game) [17] is much mis-summarised in the literature. An interrogator addresses two separate entities believed to be people s/he cannot see. S/he is told that one is male, the other female – and that the female will be helpful but that the male will be unhelpful and may lie, in response to questions. The interrogator must decide which is which. The game is repeated many times. Unknown to the interrogator the real male human is occasionally replaced by a machine. An analysis of the results can tell us if the machine has succeeded in 'tricking' the interrogator into making a misattribution of its gender identity. If equal to or more successfully than the real human it might be said to be behaving intelligently.[18]

Do we make a distinction between behaving intelligently and behaving in a human way? Turing's insight that it takes intelligent behaviour to deceive successfully is easier to apply to language but not to music. I have discussed the possibilities and limitations of applying a kind of Turing test to live electronic music elsewhere [6]. But in summary I am led to conclude that in future we may simply not be able to ascertain if our fellow performers (if not present in the room with us) are human or not.[19] Let us return to Alan Turing and the possibility of deceiving the observer. I wrote in [6] – The role of the 'trickster' M[ale] is not easily modeled [in musical terms]. But there may be an equivalent somewhere: Creativity and the unexpected? The 'unwanted' musical event? Trying to put you off your stride, testing you? Being irritating? (The speck of grit that becomes a pearl.) These may be fundamental to our perception of 'the human'.

This is certainly beyond the simple throwing in of a chance occurrence. Whereas some 19th century philosophies of music came up with notions of artistic 'truth', it is sometimes unclear whether its opposite - 'falsity' or even 'lies' - is anything more than 'bad art' that simply fails to live up to such high ideals. Thus for all my attempts to move us from a crude interactivity to deeper response, there is always the need for the irrational, the unexpected, the accident, the glitch which function to challenge and potentially to change the ongoing cause-effect and response chains. In other words to innovate.[20] Our computer may need to be tired and irritable and do the musical equivalent of throwing something down onto the table.[21]

Response, expressivity, location, time

So why does interactivity remain so important to us? I want to tie this back to liveness. Interactivity like word processing may become a phrase we no longer use. It will simply be absorbed into 'the normal way we do things'. Systems which ignore mutual influence and meaningful response between elements will tend to be the

exception.

As an example, let us take the most traditional live electroacoustic performance in concert. There are three agents - performer and machine are taken for granted but let us restore an element so often ignored and remember its influence on the final result – the environment, the location - all aspects of it from acoustics, layout to sociology - the 'feel' of the place.[22] There has always been a tension between a 'white box/ black box' gallery style neutrality and the desire for 'character' in performance spaces. Whichever - any performer adapts to such a performance space in some way. But this generates a problem with fixed and absolutely timed 'instrument with electroacoustic sound' genres (called 'mixed music' in the French tradition). Until recently, in this kind of work expressive timing in performance (in part a response to the space surrounding) was severely constrained if not eliminated, the tape a ruthless conductor.[23] This combination will rapidly become the exception for just this reason.
Why be authentic? The technology already exists to perform a simple rewriting of this demand. We could add interactivity to pieces which were originally fixed in their relationships. Thus we could track the performer (whether against a traditionally written score or not) and compress or extend the fixed medium recording appropriately. The performer takes back responsibility for expressive timing. Or maybe the machine could change spatial diffusion options, reverberation and mixing, depending on the nature of the space.

The three elements thus enter into a tight interactive relationship. The human performer and the machine can both 'listen to' and respond to the space. The machine can track the performer and modify the passing of musical time. The performer responds likewise to this modification. The question of synchronisation – for example, a live instrumental attack simultaneously with an electroacoustic one – might be overcome by having a 'variable stopwatch' which clocks at a rate set by the interaction of file time and 'modified performance time' – or perhaps the sensing of an 'upbeat' gesture from the performer.[24] This interactivity is taken for granted in good traditional practice and needs to be restored to the relationship between human and machine – even for historical works that already exist. It is a 'normal' relationship in music making.

The animate network - interactive call and response

In a paper to the Australasian Computer Music Conference (Auckland, New Zealand) in July this year [5] I suggested that in future we may not strictly know whether 'other performers' are live or machine. I imagined an interconnecting web of agencies: human, environmental[25], computer-generated. I concluded that liveness may have more to do with the 'response' of such a network to an individual participant's actions – you perform something – what comes back at you? How do the other agents respond? This links that argument to our concerns here.

Such a network is impossible to draw (to visualize) – as is a map of any totally connected web - but somehow we can try to imagine it. I called it the 'animate net- work'. Now such an environment is clearly acousmatic in the sense of action at a distance without verifiable line of sight confirmation[26] of causes. So our task as creators[27] is to describe (and prescribe) 'response' between our three agencies: human <> machine, human <> environment, environment <> machine. Beyond that lie infinite possibilities combining installation, performance and network ecology. The scale of the animate net-work is of course completely variable from local to potentially world-size.

Space imagination

The fascination with the analogue world we have seen emerge in the last decade is surely in part due to its tactility - the physical positioning in space of knobs, dials and linear potentiometers was eclipsed by 'number boxes' rapidly on digitisation. Early Yamaha synthesisers pioneered the use of a single small digital display window to address maybe hundreds of parameters, a very small number at a time. We sense this loss of 'tactile location'.

But sound location is an increasingly important part of imagination technology in the increasing sophistication of the three dimensional presentation and an emerging compositional and aesthetic discussion [16]. Commercial applications (cinema 5.1 and its variants) remain limited – but I do not intend a technical summary here. Whether in the most recent BEASTmulch applications from Birmingham, the Zirkonium from ZKM Karlsruhe, the WFS system installed at the TU Berlin (and elsewhere). We need a much smaller composition studio scale version of this – I mean one the size of your desktop. Just as I see people watch videos now cut and mixed for mobile phone viewing, so I want this tactility in my hands in front of me.

It might be that the next stage of visualisation might be nearer sculpture than painting[28] to manipulate sound in space as a malleable (even fluid) substance – more accurately to place, dynamically move and smear sounds within that space which can then be projected out to performance. We have referred to sound

sculpture for many decades with respect to sound processing and synthesis. It is a metaphor that could be made 'real' through suitable haptic interfaces and three dimensional representation. How it would feel actually to 'sculpt' a sound is a non-trivial question. It shifts my imaginary metaphor for externalising imagination, too, from imagination as movie, to imagination as tactile activity.

The imaginative interface - how do we render the imagination?

Imagination - the faculty or action of forming new ideas, or images or concepts of external objects not present to the senses.

So finally – things might just be beginning. In that breakfast conversation with the Mathews in Bourges all those years ago I recommended a specific television production. In Denis Potter's final play created for British television, Cold Lazarus, the memories of a writer whose head has been cryogenically frozen for 400 years are extracted and projected in 3D into a relatively large space – we see memories of landscape and people, hear sounds and conversations which a small group of future scientists seek to make sense of.

This 'audio-vision' of the future (made in 1994 – the year Denis Potter died) was born of an intense nostalgia fuelled by a knowledge of the certainty of his impending death and loss of memory. It was clearly a wish fulfilment of something he knew he could never know.[29] The past is thus preserved and then projected into the present – memory becomes movie again.

What of the future – the act of imagination – what might be? - could this also not be projected in like manner to be rendered and synthesised at our behest? Of course this is not synthesising the future strictly but 'the imaginative present' – we might project what we hear (and see) in our imagination right now.

The separate parts of this paper have a kind of network quality – I am forced to present them to you in a fixed sequence but they interact across the page. In summary and conclusion the use of technology to harness more directly the power of our imagination – in all its technicolour glory – through the integration of analytical and synthesis media is occasionally but clearly glimpsed in contemporary developments. If fanciful and dreamlike it continues in a long tradition of speculation on the way we describe the imagination of sound - Shakespeare - The Tempest: ACT III scene ii: Caliban -

> Be not afeard. The isle is full of noises,
> Sounds and sweet airs, that give delight and hurt not. Sometimes a thousand twangling instruments Will hum about mine ears, and sometime voices That, if I then had waked after long sleep, Will make me sleep again: and then, in dreaming, The clouds methought would open and show riches Ready to drop upon me, that when I waked I cried to dream again.

And thank you Max, too, for your dreams and your realities!

NOTES

1. The identities of orchestra and score (in Music-N terms) emerged at this time and first made explicit in 1961 – see John Pierce's contribution to The historical CD of Digital Sound Synthesis (booklet).

2. Of course there may be a score in Music-N terms but that is not usually directly interpretable by the human reader.

3. I am grateful to David Gray (PhD student at de Montfort) whose thesis is on 'visualisation in electroacoustic music' for many conversations on this possibility.

4. A new software package EAnalysis is being developed by Pierre Couprie on an AHRC-funded project at De Montfort University ('New Multimedia Tools for Electroacoustic Music Analysis') as part of a more comprehensive 'toolbox'.

5. There is now over 60 years of examples.

6. Metasynth is one of the most important.

7. Judging by the emerging sales techniques on websites whose names I need not mention.

8. See http://www.emotiv.com/ - and their recent demo videos of mind controlling image on screen. Also Youtube movie.

9. The manufacturers in this case seem to promise games interactivity short-term.

10. These were at least real events and I leave aside a desire to synthesise the sounds of dreams which Hildegard Westerkamp alludes to directly in Kits Beach Soundwalk, a piece which I have always interpreted as a soundwalk within and around the imagination.

11. See the writings of Tim Blackwell and Michael Young (Goldsmiths, UK), e.g. [1]

12. While its realization was pre-digital I use it here as a paradigm case of a system which is a performance, a work, an environment, an installation without clear distinction.

13. I refer in Aristotelian terms to the

efficient cause of the sound, but the other causes are there for the 'decoding' from sound – the formal and material causes contribute to sound quality, of course.

14. Although he did refer to the more transcendental aspects of harnessing the world's (perhaps the cosmic) behaviours that lie behind the surface phenomena.

15. Of course there are examples of musics in which the overt process is intended to be perceptible, most famously Steve Reich in the first ca. ten years of his output.

16. This is a form of entrainment.

17. This is simply restoring where we were before electronic mediation – we do not need to devote too much bandwidth to decoding exactly what instruments are playing in an acoustic orchestra, eyes open or closed.

18. A strongly behaviourist argument. We should not infer anything much about human thought here – the response mechanisms of the machine may be very different to our own!

19. I shall argue in a later section that this need not be such a cause of anxiety or concern (see The animate net-work below).

20. John Bowers and Phil Archer [2] in their wonderfully thought provoking paper – 'Not Hyper, Not Meta, Not Cyber but Infra- Instruments' –sought to challenge the ever expanding world of controller power and to celebrate limited resources, simpler musical results – 'more from less'. A limit is not necessarily a limitation.

21. I suggest this area is vital for further research – see Andrew Hugill's *'Pataphysics: A Useless Guide* (MIT Press) [6] – 'pataphysics is the 'science of imaginary solutions'.

22. I have argued elsewhere that a full definition of genre cannot exclude the places and spaces of performance [4].

23. The pianist Philip Mead commissioned and championed a generation of works with fixed electroacoustic media but recently declared his 'distance' from such works – and the personal liberation of moving to freer, live electronic and improvised forms using Max/MSP (personal communication and MA thesis De Montfort University 2007).

24. This might be visual or physically tracked. It corresponds to Gary Kendall's Preparing > Starting section of 'Event Schema' ([7] Figure 3).

25. In that presentation (ACMA 2011 – [5]) I suggested the idea of the environment as a possible performative agent.

26. Schaeffer's idea of the acousmatic is difficult to maintain effectively in a network of telepresence, action at a distance, and latency. My present view abandons even trying to establish 'concrete evidence' as to who or what is where.

27. The composer and performer may be united in the term 'creator' even more than 'participant'.

28. The location of this talk in proximity to the Yorkshire sculpture park is particularly apposite. 29 Another theme in the work is that a group of terrorists with the motto 'Reality or Nothing' attempt to destroy all such virtual simulacra – immersive VR was just arriving at the time the programme was made.

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