

# Computer Musicking as Ethico-Onto-Epistemic Playground: On the Joy of Developing Complexity Literacy and Learning to Let Others Be

Keynote Address at the First Conference on AI Music Creativity

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**Abstract.** Theories across sciences and humanities posit a central role for musicking in the evolution of the social, biological and technical patterns that underpin modern humanity. In this article I would like to suggest that contemporary computer musicking can play a similarly critical role in supporting us through current existential, ecological, technological and social crises, by providing an embodied, generative space for exploring, recognising and refiguring our relationships with each other, the wider world and the technologies that we make. Framed by Gregory Bateson’s analysis of a fundamental “epistemological error” which leads to multiple interrelated existential, social and ecological crises, I draw upon a range of personal projects to illustrate the value of computer music practices in learning to think better – from cybernetic generative art, through ecosystemic evolutionary art and feedback musicianship, to the potential value of interactive music methods to support future acoustic conservation technology. These examples are used to illustrate ways in which computer music practices create a playground to explore ways out of crises through alternative ways of being, knowing and making. Firstly by developing *complexity literacy*, we learn to better understand the complex systems of our contemporary milieu; secondly by learning to play with self-determined feedback musical instruments we learn to *let others be* and develop more ethical modes of becoming in relation; and thirdly by recognising the value of embodied, performative modes of knowing in an increasingly experience-free science of our information age I point to ways that we may shape the emerging technosphere in such a way that ameliorates arrogance and operates in service of, and not against, the biosphere. As pre-historic musicking made us human, so I suggest that contemporary computer musicking can help us learn to think better and and try to become better humans tomorrow.

**Keywords:** Complexity, Enactivism, Artificial Life, Feedback Musicianship, Ecoacoustics, Ethics, Practice Research

## 1 Introduction

It is an honour and pleasure to have been invited to contribute to this new community of Artificial Intelligence and Musical Creativity. I hope you will forgive me in that I may have taken a liberty here: I am not addressing the core theme of computational creativity directly; instead, I'd like to shift the conversation sideways and use this space to think about the value of the some of the core practices of the computer music community for responding to the some of the wider problems of the world. We are at a critical point in human history, so I am sure I am not alone in finding myself reflecting at length on how I, how we, can do something constructive at this time of ecological, social, technological and existential crises. I would like therefore, to explore and illustrate the value of our ways of thinking, understanding, knowing and being with each other, through imagining, making, doing and becoming-with technology, to begin to correct what Gregory Bateson neatly identifies as “the epistemological error” that underpins our contemporary crises. So rather than computer *simulation* of musical creativity we are going to think about how computer musicking can *stimulate* human creativity, to learn to think better, to understand the world and ourselves better, to forge better relationships with and through technology, perhaps to *be* better humans. This is intentionally and unashamedly grandiose, so forgive me that and please question and critique with this speculate intent in mind.

Discussion will be grounded in a – for the moment – uncritical adoption of a central thesis of contemporary evolutionary music theorists such as Ian Cross (1999) and Gary Tomlinson (2015): that musicking made us human. If you are not fully convinced, then we can at the very least entertain the idea that musical behaviours were deeply tied up in the evolution of the biological, social and technical patterns that underpin modern humanity; that musicking played a key role in understanding, organising and creating the inner – and mutually constituted outer social – worlds of our progenitors.

My central proposition is that just as interpersonal techno-musical exchanges in our deep history cohered perceptual, cognitive, emotional, social and technological advances, so computer musicking today affords a rich, multi-faceted space to learn to *think* better, to tune our relationships with our instruments, each other, the world and with technology, to learn to *be* better, and through this perhaps to attune our future technologies such that they align with, rather than operate against, the wider biosphere. I will illustrate some ways in which computer musicking affords a rich playground in which we can imagine and even begin to create paths out of our current crises. Discussion will be framed with some intellectual heavy weights past and present, including Gregory Bateson, Hanne de Jaegher and Luciano Floridi, with a nod to Karen Barad and Donna Haraway, and illustrated with examples of three personal projects at the interstices of music, computing and ecology. I hope to convince you that computer musicking - which I use to refer to practices such as coding, soldering, imagining, reflecting, creating and performing music which involves computers - is a rich space to explore different ways of knowing and being, with ourselves, each

other and technology, a rich ethical ontological and epistemic (Barad, 2007) playground.

### 1.1 Global contexts: Ecological Crises, Occidental Hubris and the Runaway Technosphere

There are a few pressing global issues at the moment - ecological, social, technological and existential. Establishing a root cause of any is tricky, but I think Bateson came pretty close in the 1970s when he said that “*The major problems in the world are the result of the difference between how nature works and the way people think*” (Bateson, 2000). We will unpack this further below, but this boils down to a common human failure to recognise our intrinsic interdependence. Instead of recognising ourselves as a part of a larger complex system, we tend to misidentify as being separate from and attempt to exert autocratic control over other beings and processes, leading to what Bateson calls the “philosophy of control based on false knowledge”.

Bateson notoriously defies disciplinary categorisation. Raised in the natural sciences, he studied anthropology, contributed to psychiatry and cybernetics and cross-fertilised ideas from each to offer insightful, incisive (if at times impenetrable) analyses of humanity and the world, always pointing to, never quite elucidating, *the patterns that connect*. In an uncharacteristically direct speech to the Hawaii State Senate<sup>1</sup> he enumerated what he saw to be the “Roots of the Ecological Crises” (Bateson, 2000, pp. 496–501). Illustrated in Fig. (1), Bateson proposed that the environmental crisis and associated threats to human kind were traceable to three root causes: 1) population increase; 2) technological progress; and 3) hubris. Hubris here refers to arrogance toward nature: errors in the thinking, attitudes and values that perpetuate a purpose-driven mode of being, a mindset which aims to exert autocratic, linear control over systems for one’s own ends, rather than recognising our place within a larger system with humility. The idea that we are all fundamentally, intrinsically interdependent is nothing new of course: from buddhism and shamanism, to quantum physics, enactivism, neurophenomenology, ecofeminism and new materialism, if we consider ways knowing and being across all of human cultures through time and around the world, the individualistic delusion of dualism is arguably a minority ideology. And yet it is the dominant *modus operandi* today. So whilst Bateson is far from unique in calling out this error in thinking, I find his analysis particularly useful, because Bateson clearly articulates the relationship between this arrogance, and the technological and social factors that underpin contemporary crises, as shown in Fig. 1. These factors interact and each is also autocatalytic, creating runaway behaviour: the bigger the population, the faster it grows; the more technology we have the faster the rate of new invention; and “the more we believe in our

<sup>1</sup> This was a testimony on behalf of University of Hawaii Committee on Ecology and Man (March, 1970), in favour of a bill (S.B. 1132). The bill proposed an Office of Environmental Quality Control in Government and an Environmental Center in the University of Hawaii bill and was passed.

‘power’ over an enemy environment, the more ‘power’ we seem to have and the more spiteful the environment seems to be” (Bateson, 2000, p. 498).

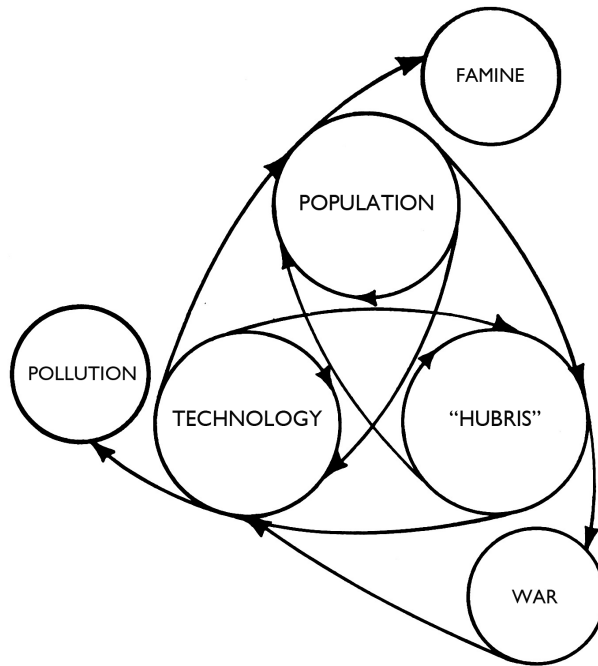


Fig. 1. The Dynamics of Ecological Crises, redrawn from Bateson (2000)

Elsewhere Bateson frames these errors in thinking in evolutionary terms and suggests that we have drawn the box in the wrong place: we mistakenly consider the organism as distinct from environment, where in fact “the unit of survival is organism plus environment” (Bateson, 2000, pp. 491).. We will not concern ourselves here with reconciling his position with contemporary evolutionary theory, but instead highlight the shift in perspective from organism in *opposition* to others, to understanding our deep interdependence as part of larger complex systems. This move has significant existential, ethical, ontological and ecological implications, which are of direct relevance to our current concerns.

Bateson saw technology as amplifying these problems, giving an illusion of greater control, when in fact it enabled greater damage. Again, his analysis is prophetic and in contemporary terms provides systemic insight into what we might now call ‘problems of the anthropocene’: world population has doubled, environmental devastation and inequality have accelerated, as has the ubiquity, impact and reach of technology. We have built a technosphere which is out of

control (Haff, 2014; Dyke, 2022) and numerous technosolutions are exemplify these errors in thinking.

More optimistically, Bateson suggests that all three of these fundamental factors are necessary conditions for the destruction of the world. The solution, he proposed, is to reverse any one of the arrows in Fig. 1. To the problem of overpopulation he offers no solution, but notes that the thinking and attitudes of western cultures obviate or complicate potential solutions. Whilst accepting that technological progress is inevitable, he proposes that seeking methods to “steer technology in more appropriate directions” (Bateson, 2000, p. 500) should be a top research priority. But the best entry point, he argues, is to overcome our *errors in thinking*. I find Bateson’s systemic analysis a useful complement to contemporary analyses such as Haraway’s ecofeminist plea to *make kin and stay with the trouble* (Haraway, 2016), Latour’s political ecological call to *become earthly* (Latour, 2010), or Seth’s neuroscientific recognition that *we are a part of, not apart from nature* (Seth, 2021). I find it useful, because Bateson also plots us a path out: we need to recognise (re-cognise) our intimate interdependence, to learn to understand how the complex systems that we are a part of behave, and to be more careful in our design and application of technology, in order that it operates in service of the biosphere, rather than accelerating along paths that overshoot planetary boundaries (Rockström et al., 2009).

The central proposition of this article is that attitudes and methods of contemporary computer musicking provide an invaluable space for imagining, implementing and interacting with and through technology in ways that may enable us to overcome these errors in thinking. I see computer musicking as a valuable playground for developing practices of knowing and being, through which we can learn to better understand our relationships with each other, the world, and technology and from where we can imagine, create and experience technologies which better align with humanity and the rest of the biosphere. I am not suggesting that we can instantly reverse global warming, or biodiversity loss, nor guarantee immediate world peace, but I do think computer musicking can help us learn to think better, to learn to better understand the complex systems within which we live, perhaps to explore ways of making and interacting with technology in new ways and to learn to enjoy all this. These processes are deeply intertwined. Building on Barad’s recognition of the inseparability of ethics, ontology and epistemology in scientific knowledge production (Barad, 2007, p.90), I would like to suggest that the creative, generative, systematic and intuitive practices of computer musicking create a playground where we have the opportunity to not only generate knowledge, but to create new worlds and ways of being in them. I would like to suggest that computer musicking as a valuable ethico-onto-epistemological playground in an era of crises and uncertainty.

## 1.2 Personal Context: Ecologically and Cybernetically-inspired Computer Music

I will shift momentarily from planetary to personal contexts to ground the examples that follow. I grew up playing the cello in chamber and orchestral set-

tings. These early musical experiences foregrounded collaboration and cooperation over solo musicianship - I made little impact on the world as a solo cellist, but playing with each other created new worlds which changed all of us, a little. Since then, musicking for me has predominantly been about co-creation, about group-composition and improvisation. A teenage interest in the mind led me to study psychology, where I was fortunate enough to have excellent lecturers in chaos theory and connectionism. I was drawn to dynamical systems theory as a framework for studying things like minds. This line of interest led me to the University of Sussex to study evolutionary and adaptive systems. This was an artificial life (Alife) bootcamp, combining neural networks, embodied (later enactivist) philosophy of mind and studies of animal cognition, with evolutionary theory, agent-based modelling, artificial evolution, cybernetics and evolutionary robotics thrown in.

I fell under the spell of founding cybernetician, Ross Ashby. In *Design for a Brain* (Ashby, 1952) Ashby addresses the origins of adaptive behaviour: How can a system (living or synthetic) which is fully deterministic also learn and adapt itself to a dynamic environment? In order to investigate this apparent conundrum, he built an electromechanical device called the *homeostat* which exhibited behaviours such as habituation, reinforcement and learning through trial and error. The device was built from four magnetically driven Royal Air Force bomb control units. Interconnected electronically. Each received feedback via water-filled potentiometers with the output of each unit trailing in a trough or more or less viscous liquid. These units of the homeostat model the organism in interaction with its environment. When the output of one unit hit the end of a trough (representing an organism's essential variables reaching threshold), the values of a commutator, which controlled the magnitude and polarity of the input voltage, were re-randomised, causing the connected units to swing to a new position. Thus by trial and error, the deterministic machine adapts to external perturbations and finds a stable state.

As a student, I made a simple model homeostat as a series of units interconnected by weights which are updated randomly every time the output of any unit exceeds its bounds, recreating the same homeostatic adaptation through trial and error of Ashby's electromechanical device. But my first grade coding skills left a lot to be desired. In the first implementation, the outputs of the homeostat did not behave as expected. Working with a Gnu compiler with no friendly debugging interface, I mapped the floating point outputs of the simulated homeostat to MIDI pitch bend values. Three things happened. Firstly, I realised the error in my code: the oscillations were unipolar with no negative part because I had inserted an erroneous floating point absolute value operator. Secondly, I gained a deeper appreciation of the adaptive behaviour of the homeostat by *hearing* the dynamics unfold (Eldridge, 2006). Thirdly, in spite of the General MIDI synth implementation, it sounded pretty cool.

This led me to a PhD (Eldridge, 2007) in which I explored cybernetic approaches to machine musicianship. Homeostasis and other adaptive, dynamical systems felt like rich compositional metaphors and processes. To my think-

ing these processes prioritised relational musical behaviours and dynamics over events, an approach to interactive and generative art that felt more true-to-life and also more *collaborative* than mainstream computer music was then. Such approaches were dubbed ‘extra-musical’ in academic analyses of the time (e.g. Miranda, 2001), but generating responsive, dynamical relations *between* parts felt more interesting to me than (static) statistical modelling of the surface structures of extant musical works, which was the dominant approach of the time – and arguably still reins today. If I am honest, I was never completely satisfied with the musical output. But I *was* compelled by the approach. I was intuitively drawn to the Paskian (Pask, 1971) conversational conception of machine interaction and wrote of the need to *dance* (metaphorically) with machines to get know them as musical partners (Eldridge, 2005) - a principally *performative* approach to knowing, which we will return to in section 2.3. This in turn led me to a post doctoral position with Jon McCormack and Alan Dorin in the computing department at Monash University, Melbourne, on a project called *Design After Nature*, in which we explored ecosystemic metaphors for bolstering generative creativity in digital media. It is from this project that my first example is drawn.

## 2 Overcoming Epistemological Errors in Thinking Through Musicking

### 2.1 Lesson One: Evolutionary Art as Speculative Fiction

In the *Design After Nature* project we were interested in creating the conditions for the emergence of aesthetic diversity. This is similar to Boden’s (Boden, 1996) transformational creativity (something new), Ashby’s idea of a system out-performing its inventor (Ashby, 1952), or the artificial life holy grail of open-ended evolution (Packard et al., 2019). We developed ecosystemic evolutionary methods, integrating ecological processes and principles of niche-construction, symbiosis and energy-recycling into standard evolutionary computation methods.

Evolutionary Computation (EC) mimics natural evolution in that it optimises fitness in a population through variation (mutation) and ‘survival’ of the fittest. In standard EC, the basis of this fitness selection is predefined, akin to selective breeding in livestock – where the cows with the meatiest rumps, or pigeons that fly the furthest are selected to parent the next generation. This is great for problem solving of the engineering flavour, minimising drag on airplane wings or optimising stock market portfolios, but arguably the main creative impulses in music and art are less happily framed as optimisation ‘problems’ (Gartland-Jones & Copley, 2003).

Similarly, evolution in the wild is not teleological: there is no predefined end goal of evolution, rather an ongoing co-evolution of organism and environment through processes such as niche-construction (Odling-Smee, Laland, & Feldman, 1996). We aimed to replicate this process by developing methods to implement *implicit fitness*. Theoretically this represents a shift from Darwinian adaptationist thinking to extended evolution (Day, Laland, & Odling-Smee, 2003) which

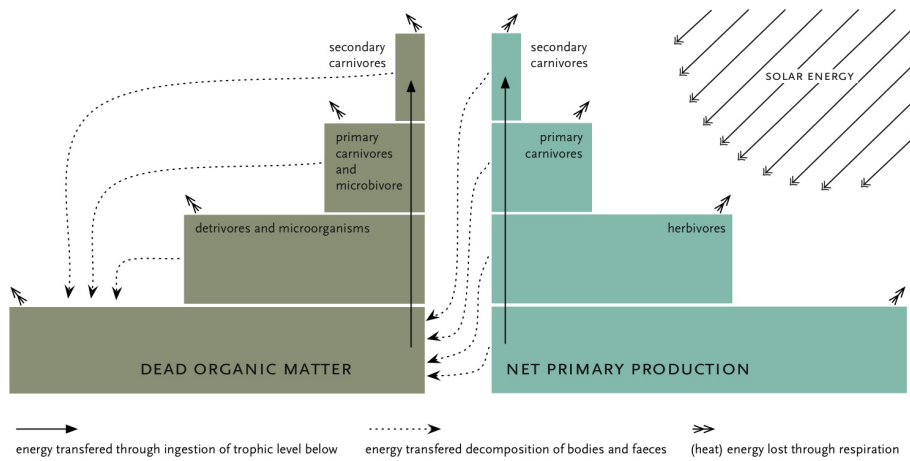
we intuitively felt was a more natural and rewarding approach. In standard EC the genotype is isolated in a data structure and evolved according to a pre-specified, explicit fitness function. Under an evolutionary ecosystemic approach the isolated genotype is embedded in an environment and an energy model introduced such that fitness selection is implicit: an agent's chances of survival and reproduction are implicitly determined by its environmental interactions. The design challenge shifts from that of designing a fitness function, to the design of organism-environment interactions. So the game is maximising and maintaining diversity, diachronic or synchronic, in emergent structure, dynamics or behaviour, whilst minimising interference with a minimal model.

The dominant interaction metaphor of evolution is competition. Energy models of early Alife agent-based simulations, as well as musical co-evolution models (e.g. Epstein, 1996; Werner & Todd, 1997) implement competitive co-evolution as a means to generate diachronic diversity. Organism interactions are not limited to direct competition however: the myriad of symbiotic relationships that are foundational to the diversity of life on earth (Maynard Smith, 1989; Margulis & Fester, 1991) provide rich inspiration for achieving synchronic diversity in creative system design. Colleague and collaborator Alan Dorin had previously highlighted the omission of death and decay in Alife models (Dorin, 2005). Building on this work, we took inspiration from the real world processes of *recycling*, as seen in the decomposer system that couples with the grazer system of real world ecosystems and supports mutualistic behaviours. Plants (autotrophs) convert sunlight into oxygen and simple sugars, grazers eat plants and carnivores eat herbivores (Fig. 2, right). But the story doesn't end here: Carnivores (and grazers, and plants) die. Their dead bodies rot down, and support similar trophic chain of detritivores and microorganisms to create a coupled system of grazers and decomposers (Fig. 2, left).

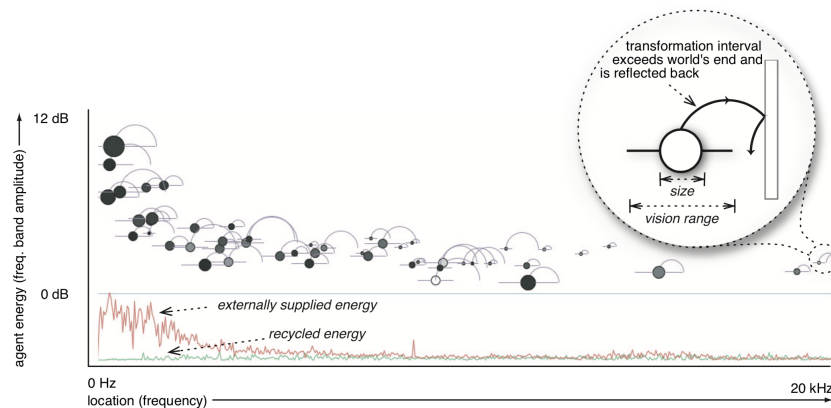
Earlier Alife models demonstrated that heterogeneity of resources in the environment can give rise to surprisingly complex agent behaviour at the population level (Epstein, 1996). Think of Simon's *Parable of the ant* (Simon, 2019): the apparently complex behaviour of an ant as it meanders across a beach can be understood as emerging from simple behavioural rules in interaction with a complex environment. Our intuition was that if interesting dynamics can emerge from agent-environment interactions with *fixed* environments, then modelling situations in which agents can *alter* their environment may have greater generative potential in creative contexts.

To provide a concrete example I will describe *Filterscape* (Eldridge & Dorin, 2009). Shown in Fig. 3 with link to video, *Filterscape* is a simple evolutionary sonic ecosystem in which agents traverse a spectral synth, extracting energy from one frequency band before re-depositing it in another. Agents, represented here as circles, have just two genes which specify their size and their *transformation interval*, in Hz. The bigger agents have wider arms which means that they can collect energy over a wider range of bins relative to their current position. The transformation interval – depicted as an arc – determines the location at which that agent excretes energy back into the world, relative to its current position.





**Fig. 2.** The standard energy model in agent based simulations focuses on the flow of energy from primary producers (green plants etc.) to herbivores (primary consumers), and sometimes secondary consumers such as carnivores or parasites (right hand side). This is known as the grazer system in ecology. At each trophic level in the real world there is an energy loss, creating a pyramidal form that reflects the relative proportions of bio-mass and energy stored at each successive level in the food web. In simulation, this form of energy model naturally supports competitive interactions between agents as they battle for resources. In the real world the grazer system is coupled with a decomposer system through which the bodies and faeces of all organisms in the food web are recycled. By expanding the basic energy model to include recycling, we were able to generate mutualistic as well as competitive interactions, so introducing novel survival strategies. Agents can not only compete for resources, but can cooperatively feed from each other's waste.



**Fig. 3.** Screen shot of Filterscape visualisation. Circle diameter denotes agent size and horizontal line through the body of each agents signifies its vision range, over which it can collect energy. The arc represents the *transformation interval*, the distance and direction that it excretes energy, relative to itself. This image depicts the population shortly after a population explosion. Inset shows how recycled energy is reflected at boundaries. <https://youtu.be/qY-dI1fkEIQ>.

Each ingests energy and excretes energy, and that energy is sound. So the 1D world can be conceived as a spectral synth driven by a population of sound-surfing artificial agents.

Ambient energy is supplied externally (à la solar) at a constant rate using either a uniform or random distribution. This is shown in red at the bottom; the green line denotes energy recycled by the agents. Agents survive by ingesting energy from a band in their immediate vicinity, and excrete a transformed waste product (the magnitude of which is reduced by metabolic cost of movement and reproduction) into another band according to their transformation interval. One agent's waste is another's food, creating a simple resource-recycling across the frequency spectra. As in the real world, there are trade offs: large agents can ingest across frequency across a wider bandwidth, but take more energy to move. As befits a spectral space, the world is bounded rather than toroidal: energy excreted at the edge of the world is reflected back.

The world is seeded with a randomly specified population. Haploid asexual reproduction occurs when an agent's energy exceeds its initial endowment by a fixed percentage. The offspring inherits half the parents energy, its genes are probabilistically creep-mutated, and it is inserted into the world in the nearest empty location. Death occurs when energy levels drop below zero.

What you hear represents the movement of agents through spectral space – i.e. the agent biomass specifies the magnitude of the corresponding frequency band. Sound is produced by convolving the array of energy values at each location with white noise and performing an inverse Fast Fourier Transform. Agents

therefore act to shift energy from the spectral bin where they are located either up or down the frequency spectrum according to their genetic makeup.

From these simple local rules a range of interesting behaviours emerge, at individual, community and population levels. As seen in the video linked in Fig. 3, the initial random population largely dies out, typically leaving a few smaller agents gliding around the world. In this example, resources are distributed heterogeneously: the total incoming resource is randomly partitioned and each partition allocated to a location in the world using a uniform random distribution. When the population is low, the red incoming energy builds up; as the population builds this incident energy is depleted and recycled, creating an increase in green energy. At the individual level we see at least three different “survival strategies” emerging. The default is to *glide* around, collecting resources from adjacent bins. This happens whether resources are distributed or homogeneously or heterogeneously. A heterogenous environment further supports two other strategies: firstly agents start to form temporary *mutualistic clusters*, where those agents with complementary transform intervals ingest each other’s excreted sound energy. Secondly, a *loitering* behaviour tends to emerge, as evolution serendipitously happens upon the trick of feeding on recycled, reflected energy at the edges of the world (organisms here can thrive on their own waste). Note that these behaviours are not explicitly designed or coded, but emerge from the interaction between the agent and the structure of the environment. At the population level, we see interesting population fluctuations like boom and bust cycles.

One of the aims of this experiment was to explore the impact of environmental structure on emergent diversity; the hypothesis was that heterogenous environments might support synchronic diversity. And this is what we see: phenomena at both levels are dependent on heterogenous energy distribution. Homogenous environments lead to low variation in population size and only simple gliding behaviours are observed (for details see Eldridge & Dorin, 2009).

More generally we were interested in understanding how complexity arises from organism-environment interactions. This is an incredibly simple system. The agents are specified only by their size and how they transform energy. But the combination of random environmental structure and simple recycling – which fosters relationships between agents via environment – we get these quite really quite diverse and dynamic emergent phenomena. We even start to feel some compassion towards them! At 2:08 of the video linked in Fig. 3 there is a tiny population of just three agents left and we find it hard to look away: are you going to survive? can you access the energy? And then BOOM, a population explosion. Our empathic joy is strongly felt.

**Evolutionary Art: Methods and Insights** This is very much a study. It wasn’t ever developed into a full scale artwork. But I would argue that these basic dynamics themselves are beguiling. These dynamics can’t be reduced to features of an agent, or of the environment; they emerge from particular qualities of the agent-environment interactions. I use this therefore as a first illustration

of the ways in which computer musicking – even before we get on stage – can help us to think better by providing a really rich space for learning to better understand the workings of the world. Somewhere between scientific simulation, thought experiment and speculative art-making, it’s a space for imagining and testing out different worlds, and so better understanding the complexities of our actual world. We play God here. We are making up a story, a little like theatre or science fiction. We have the freedom and imagination of the arts, to imagine other possible worlds, akin to speculative fiction. But we are not working with physical materials or words. We define generative worlds by creating energy models and laws of interaction – how these agents live, how they die, how they reproduce. We play with emergent *dynamics* through sculpting organism-environment *relations*.

Filterscape is also a simulation environment: we can run experiments. As mentioned above, we can explore hypotheses around the impact of environmental heterogeneity, of different energy models or forms of agent-environment interaction. Such Alife-style simulations have been described as opaque thought experiments (Di Paolo, Noble, & Bullock, 2000). Whilst the implications of a traditional philosophical arm chair thought experiments are self-evident, these simulated What If’s require some empirical unpacking, which itself can lead to greater insight. In a similar way, Manuel De Landa has talked about emergent simulations as a form of *synthetic reason* (DeLanda, 2011). As a tool for understanding the world, an instrument for thinking more carefully, I argue that this form of computer musicking is a pretty potent mix: we have the imaginative freedom of science fiction, the generative expressivity of the creative arts and the rigour and empirical investigation of simulation sciences.

Let’s think about what we have learned here. We immediately and intuitively understand the coupling of interconnected systems that Bateson discusses: it is plain to see that neither the organism itself, nor the environment alone is particularly interesting. It is the *organism-environment* interactions, that matter. Endless growth and bald competition make very little sense when you are designing an energy model: recycling and symbiosis are a better basis for a stable world.<sup>2</sup> Suddenly post-growth economics doesn’t seem like some fantastical fairy tale, but is revealed as the only sensible option. We start to gain an intuition that our technosphere must recapitulate the dynamics and logics of the biosphere in order for our planet to thrive. And finally, we see that this is not only a necessary logical, practical solution, but a rather beautiful one. We have started to develop a form of what we might call *Complexity Literacy*, through tinkering with evolutionary generative art.

## 2.2 Lesson Two: Feedback musicianship as speculative faction

For the next few years in Australia my interests became increasingly Zen. I made simpler and simpler models, focusing on the power of feedback to couple agents and environments, and create self-determined systems as a basis for generative

<sup>2</sup> See Barrett (2018) for further mathematical support of the stability of zero-growth economies.

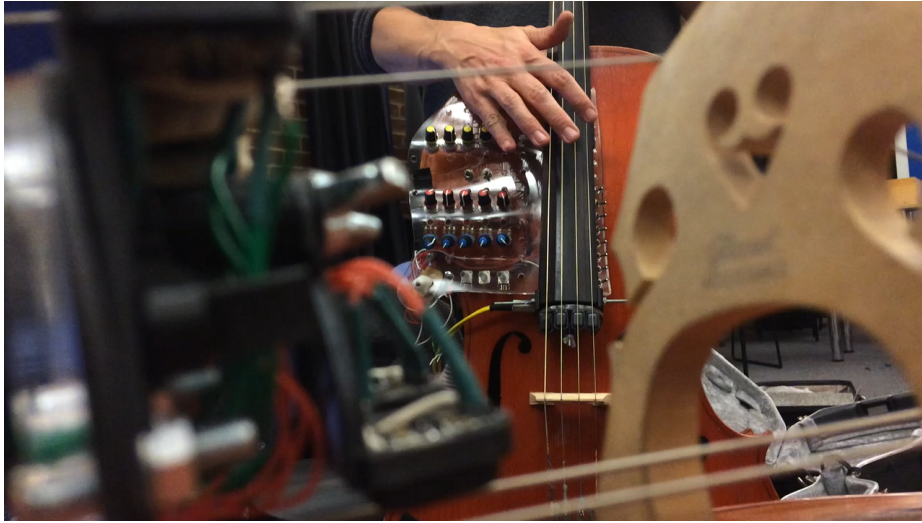
creativity. I had become thoroughly convinced by the coupling of media and materials through feedback as a means to create “synthetic agencies” and build more collaborative creative technology. Since doing my PhD I’d been hankering after more organic agency than I’d ever managed to achieve in the purely symbolic domain. In 2014 I saw a video of the wonderful Hilddur Gudnadóttir playing this awesome noisy, drone cello-like instrument called the *Halldorophone*. The creator was one Halldór Úllfarsson. So I propositioned him to show me how to retrofit a classical cello to create a similar style of feedback instrument. In 2016 we were hosting the International Conference of Live Interfaces, and we took the opportunity to invite Halldór over and hold a workshop for these instruments. Since then we have been working closely and iteratively with Halldor, another colleague Chris Kiefer and more recently a growing family (Polimeneas-Liontiris, Eldridge, Kiefer, & Magnusson, 2018; Melbye, 2021) to exploring the luthiary (hardware and software), performance and analysis of these feedback instruments (Eldridge & Kiefer, 2017; Kiefer, Overholt, & Eldridge, 2020; Eldridge, Kiefer, Overholt, & Ulfarsson, 2021), to develop a practice of what we describe as Feedback Musicianship.

In the Feedback Cello project we are interested in a particular species of feedback instrument that we have come to call Self-resonating Vibrotactile Feedback Instruments (Eldridge et al., 2021), or SRI’s. These instruments blend the materials and characteristics of acoustic and digital instruments, for example they can be both gesturally or procedurally controlled. Our feedback cellos are built from classical wooden cellos, but are thoroughly hybrid instruments. They have electromagnetic transducers fitted under the strings. The signals from these are mixed and passed to one or more resonators fitted into, or onto the body. They look like classical cellos, but in fact turn its operation on its head. In the classical instrument you inject energy into the instrument with your arm, the bow, through the strings and the bridge which makes the body vibrate. In the feedback cello, the on-body transducers vibrate the cello body causing the strings to vibrate; these vibrations are amplified by the pickups and sent back to the transducer, and so on and so forth, causing self-resonance. In some ways this is the same as a guitar feeding back against an amp, but a critical difference is that we can adjust each string gain individually. Also, the greater degrees of freedom in the physical body of the cello create opportunities for greater complexity in the resulting sound and behaviour. This becomes important as we find that the Good Shit Happens on the edge (Waldrop, 1993). Gains can be adjusted manually, by passing signals through a mixer, or programmatically, by passing signals through an analogue to digital converter for modulation in code.

As can be witnessed in the video linked in Fig. 4 we can adjust the gains individually to create dulcet drones. Here the string gains are balanced manually via an off-board mixer. I am playing a game to see if I can get all the strings, including a pair of drone strings fitted under the bridge, to all vibrate at once (hint, it depends on the relative tuning of the strings). In this setting the sound is quite ethereal, quite beautiful and calming for the nervous system.



**Fig. 4.** An analogue Feedback Cello with each string gain being adjusted manually on an off-board mixer. See <https://youtu.be/2UX6BwJMTHs>



**Fig. 5.** Chris Kiefer's feedback cello features a 3D assignable control interface, giving on-body control of parameters for programmatic modulation of individual string signals. [https://youtu.be/\\_qxBLjde39Y](https://youtu.be/_qxBLjde39Y)

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2 s.waitForBoot({
3   ~ctlbus= {Bus.control(s,1)}!128;
4   ~m = {|ctl, lo=0, hi=1| ~ctlbus[ctl].kr.linlin(0,1,lo,hi)};
5   ~ml = {|ctl, lo=0.000001, hi=1| ~ctlbus[ctl].kr.linuxp(0.000,1,lo+0.00001,hi)};
6 });
7 )
8
9 (
10 Ndef(\fbcellStringsIn, {
11   var w = SoundIn.ar(bus: [0,1,2,3]) * 30.2 * [~ml.(1,0,10),~ml.(2,0,10),~ml.(3,0,10),~ml.(4,0,10)];
12   w = w.mean;
13   w
14 });
15 )
16
17 (
18 Ndef(\fbcellPatch7, {
19   var amps,wi, w = Ndef(\fbcellStringsIn).ar(1);
20   amps = Amplitude.ar(
21     SoundIn.ar(bus: [0,1,2,3]) * 30.2 * [~ml.(10,0,1),~ml.(11,0,1),~ml.(12,0,1),~ml.(13,0,1)],
22     attackTime: ~m.(7,0,0.03), releaseTime: ~m.(6,0,0.03)
23   ).mean;
24   wi = w * (Integrator.ar(in: w.abs, coef: 0.99999 - ~m.(0,0,0.15)).reciprocal + 0.01);
25   w = XFade2.ar(inA: wi, inB: w,
26     pan: amps.linlin(inMin: 0, inMax: ~m.(5,0,0.005), outMin: -1, outMax:1));
27   Balance2.ar(w,w, SinOsc.ar(~m.(9, 0, 110)).cubed * ~m.(8));
28 });
29 )

```

**Fig. 6.** Supercollider code modifies the gains of each pick up in inverse proportion to their contribution to the overall sum.

Alternatively we can pass the string signals through further analogue or digital processes to create more complex sounds and dynamics. The video linked in Fig. 5 shows Chris Kiefer's cello in which the pick up signals are passed through Supercollider before being reintroduced to the cello. The patch shown in Fig. 6 is very simple: the inputs are summed and an amplitude follower is used to adjust gains reciprocally, i.e., the gain of each is adjusted in inverse proportion to its relative contribution to the total. As shown in the video, even this simple intervention has a quite profound effect. There are three things to note here: firstly, the strings act as an interface, they are sensitive controllers as well as the sound source and filter of the feedback; secondly, there is dramatic shift in the soundworld, note that there is no synthesis algorithm here, just adaptive modulation. Thirdly, the system becomes highly non-linear, deterministic but unpredictable.<sup>3</sup>



**Fig. 7.** Trio with Julie Kjaer and Stalle Slatvig at Fete Qua Qua, The Vortex, London. Video credit Jack Delmonte <https://vimeo.com/180304450>

Compared to an acoustic cello then, a feedback cello affords a new sound world, but it also demands a *qualitative* shift in the way we interact with it. This thoroughly lively beast renders obsolete the classical interaction metaphors of the classical musical instrument. The learned sensory motor contingencies which underly virtuosity in classical sense are out the window; control and mastery give way to a necessity to be open to an unfolding relationship with the instrument. In

<sup>3</sup> A vibrating string is a textbook non-linear system, but settles into periodic behaviour. In this system the non-linearities can be amplified, I think by virtue of the external power source and feedback.



systemic terms, feedback creates a system which has autonomy in the technical sense of being not “fully determined by its environment” [p.179](Seth, 2010). It is formally, experientially and aesthetically, *self*-determined.

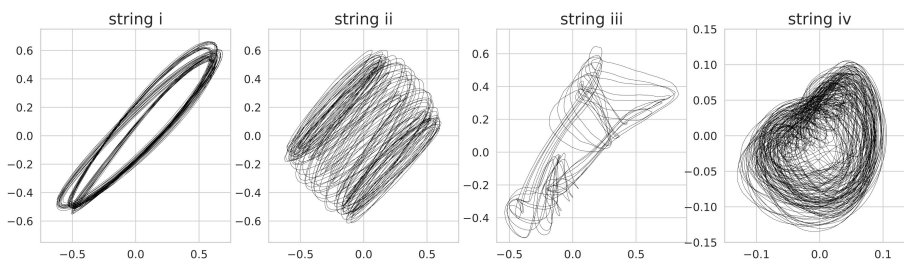
As illustrated in the video linked in Fig. 7 the job of the performer is in one sense to navigate and negotiate with this pre-existing, partially self-determined flow of energy. Yet in doing so I change the physical parameters of the system. We are in some sense each the other’s environment. So whilst I can certainly influence the sounds and dynamics of the cello, it is very different to deciding to put my third finger down on D string to play an F sharp. I can’t approach this with a plan, I can’t come to it with a predetermined idea. In Bateson’s language attempts to exert autocratic control undermine the nature of the instrument, it does not respond to a purpose full mind set. Instead, I have to explore it on its own terms.

In ongoing work we explore different couplings of these instruments, extending inputs across multiple instruments to form a multi-player musical interface. In the *Brain Dead Ensemble* (Polimeneas-Liontiris et al., 2018; BDE, 2019) the outputs from Thor Magnusson’s microtonal multichannel live-coding system, the *Threnoscope* are sent to three or more feedback instruments; in *Feedback-Feedforward* (Eldridge & Kiefer, 2021) the signals of the feedback cello pickups detour through a modular synthesiser, but also control it via a multi-layer perceptron, creating a shared instrument that neither performer is in control of. All these instruments and systems create a rich space to learn, musically, technically, philosophically and ethically.

**Feedback Musicianship: Methods and insights.** Let us reflect again on the methods used here and the insights gained. Our approach to instrument development is both intuitive and systematic. We proceed through iterative cycles of open-ended instrument design and fabrication, collaborative performance, reflection and analysis. We draw on a range of practices and methods from 3D design, Human Computer Interaction, string traditions, improvisation, computer science and engineering. We’ve started to think of this as a form of three-fold experimentation: experimenting as a musician, exploring musical paths of unknown outcomes á la Cage; experimenting as an engineer, tinkering, following hunches, testing things out in the real world, akin to the cybernetic approach; and experimenting as a scientist, forming hypotheses and testing through quantitative empirical analyses.

In talking about feedback musicianship we are naturally drawn to the language of dynamical and complex systems theory, following a tradition of improvisation as an emergent phenomena (e.g. Borgo, 2005). This language of chaos and complexity, of weak and strong attractors, hysteresis and instability are useful metaphors which scaffold our creative process as experimental musicians both in planning and performance. But what of our role as engineers? Can they also help us gain insights into the behaviours of the instruments and scaffold their future development? Does the maths of dynamical systems analyses align with the metaphor? It seems they do indeed converge. For example Fig. 8 shows

a short recording of each string plotted as a phase portrait. The visual forms reinforce the understandings that arise through lived experience of the sound and behaviours of the strings. In this example, the instrument is tuned with a perfect 4th, 5th and 5th between the strings (bottom to top), such that strings ii and iv are an octave apart, relatively tightly coupled and exhibit similar phase portraits. String i has the gain turned high and is a strong stable attractor, evident in the fairly straight ellipse. This gives a 9th between strings i and ii, the high gain of i creating a more complex phase portrait for string iii than might otherwise result from its couplings with neighbouring strings. In other work we have used information-theoretic measures of complexity as a means to modulate the gains (Kiefer et al., 2020). This three-fold experimentation provides a form of open ended, rigorous and robust methodological triangulation: a mix of creative, intuitive musical exploration, an engineering-style tinkering and scientific empiricism.<sup>4</sup> This feels like a productive way to move forward. We can approach working with no plan, following paths of unknown outcomes, and scaffold our development with both experiential and quantitative experimentation as we move forward.



**Fig. 8.** Phase space reconstructions using time-delay embeddings provide portraits for each of the four main strings on a feedback cello in action. Axes denote relative amplitude.

Beside their rewarding acoustic delights, I would like to suggest that these instruments provide further means to develop *Complexity Literacy* - in at least three dimensions. In building feedback instruments, we gain insight into the way relatively simple components can be coupled together through feedback to create non-linear, unpredictable, emergent behaviours. Once built, these instruments invite a delightfully and stimulatingly unruly encounter. As above, they are in a formal sense *self-determined* (Seth, 2010) - influenced, but not completely controlled, by their environment. As an improviser, this creates a dream space of instability. Learning to navigate the vagaries of a precarious, self-willed (wild) dynamical system nurtures humility. Playing with these instruments demands a kind of respect. The only way to make music with this instrument is to approach

<sup>4</sup> Perhaps we need to think more about the value of Musical, Engineering, Scientific, SensorY (MESSY) experimentation?

it with no strict plan and on its terms. This borders on the blissful as a musical experience, and I am coming to think that this bliss comes precisely *because* of this requisite attitudinal stance, precisely because the instrument defies wilful imposition: it can only be discovered by letting it be, and in doing so, becoming with it. This feels like the antithesis, and a valuable, experiential, anecdote to the mindset of purposeful control that Bateson warns against? This idea of *letting others be* feels an intuitively valuable ethical position in our current environmental and social crises, as a means to move from the delusional dualism that Bateson identifies as a root cause of our crises, a tool – an instrument! – to help us recognise (re-cognise) ourselves as part of a larger system. A shift from being in control to being in relation. It embodies a metaphor that Hanne de Jaegher uses to deepen her theory of participatory sense-making toward an engaged epistemology of knowing and loving.

Participatory-sense making (De Jaegher & Di Paolo, 2007) extends the enactive concept of *sense-making* (De Jaegher & Di Paolo, 2007) into the social domain. The interaction process itself takes on a form of autonomy, moving the onus of social understanding from the individual, to the interaction *between* individuals, and providing a more philosophically refined meaning of “interaction” in the process. More recently De Jaegher has been developing what she describes as an *Engaged Epistemology* (De Jaegher, 2019). She challenges the core assumptions of mainstream cognitive science, suggesting that the focus on language, planning, decision making and reason as the pinnacle of human intelligence is missing the crux of the matter. Instead, she suggests that our most sophisticated forms of knowing is Loving. To approach this, she deepens the enactive theory of participatory sense-making using Kim Maclaren’s (Maclaren, 2002) idea of *letting others be*. De Jaegher characterises knowing as a relationship of *letting be*, to provide a nuanced way to deal with “the tensions between the knower’s being and the being of the known, as they meet in the process of knowing-and-being-known” (De Jaegher, 2019, p.847) – a wordy, knotty philosophical proposition that we all know very well in our loving relationships, which to my mind includes our meaningful musical relationships.

To illustrate the idea of letting others be, Maclaren describes a horse trainer who is interested only in his horse as a means of making money. He trains and trains the horse, with no regard for its need to roam and play. The horse becomes more and more sullen. Eventually it breaks down. This horse has not been *seen* properly. Its trainer’s narrow perspective on it has informed the ways he interacts with it, has limited the horse in its very being, which may eventually lead to its death, rather than enjoying a life long relationship with the horse. This resonates with Bateson’s analysis that we need to learn to better understand the way nature works, to move from organism *versus* environment to understanding, appreciating and nurturing our interactions *with* our environment. I’d like to suggest that part of the beguiling character of the Feedback Cello as a musical instrument is it provides an onto-ethical instrument to practice this alternate form of being with the known, a place to play and experiment with letting others be in our process of becoming with them; it is an instrument to practice *intersubjec-*

*tive attunement.* The Alife simulation of *Filterscape* helped us “think better” by providing freedom to explore strange new ontologies in silico, providing a means to imagine other possible worlds, akin to generative science fiction; in scaffolding new modes of human-technology-human relations in the real world, the feedback cellos create what we might call *speculative faction*. This is a form of speculative world-making, but rather than an abstract space of words or code, it is a hybrid reworking of the material resonant world which we inhabit with our bodies. In Haraway’s terms, our ethico-onto-epistemic playground is a fecund terrain for *worlding* - a space for experimental and experiential co-operative patterning of possible other worlds through the lived interaction of humans, technologies and different forms of knowledge.

In this section I have introduced the Feedback cellos, thoroughly hybrid self-resonating instruments, that are created and explored using thoroughly hybrid methods. I have suggested that the process of making, playing and analysing them provides a valuable real-world playground for developing what we might call *complexity literacy*. This draws on three distinct, yet thoroughly complementary, modes of knowing through experimentation. These feedback musical instruments provide onto-ethical instruments for developing our relations with each other by *learning to let others be* as we practice intersubjective attunement. This is a physical, embodied, interactive epistemic, ontological and ethical playground for developing a more refined, sensitive, nuanced ability to get to know other beings, of exploring other possible worlds as we make this world, and as we learn to let other agencies in it be themselves and interact with them on their terms. This form of techno-musicking provides another rich onto-ethical-epistemic playground for worlding, for exploring other possible worlds, in the world. In doing so we live out an embodied experience different modes of being-in-the-world and set up some anticlockwise motion in Bateson’s dynamics of Fig.1. In building hybrid musical instruments that advance complexity literacy and nurture humility we take some tiny steps in countering hubris and steering technologies in “more appropriate directions”.

### **2.3 Lesson Three: Machine listening to the biosphere and the value of embodied musical interaction**

In the third and final lesson we take tools familiar to the computer musician – the algorithmic ears of machine listening – and apply them to the challenge of ecological monitoring. I will first outline a cunning “techno-solution” which is rapidly becoming mainstream in ecological monitoring in the form of computational ecoacoacoustics. I will then highlight a potential epistemological issue with this approach, related to the intrinsic a-sensoriality of big data science, before suggesting a possible way in which the embodied, interactive practices of computer music might bridge this epistemological rift between statistical power and ecological meaning. In doing, so I speculate on a possible path to reduce hubris in technosolutionism: embracing technological progress, but steering technology in a way such that it is used in service of the biosphere, recognising the need for

scientific tools that extend the human senses, whilst remaining interpretable to human mind and body.

We touched on the links between environmental heterogeneity and diversity in the *Filterscape* model in section 2.1: environmental heterogeneity was associated with synchronic diversity in the synthetic agents' soniverse. Somewhat more importantly, diversity is critical to life on actual earth and rates of global biodiversity loss are alarming. Numerous multilateral initiatives (e.g. EU 2030 Biodiversity Targets (Fetting, 2020), UN Decade of Restoration (Assembly, 2019)) make promises to halt or reverse biodiversity loss, but we are not doing well. Bateson's analysis is once more on point: this is in part due to political will, in part to over population through associated land use change, and in part because it's hard. It is hard, because in order to preserve biodiversity we need to be able to measure it.

Let us first take a quick biology lesson. What is biodiversity? Biodiversity refers in part to all the species encountered in a given area at a specified time and is taken as an indicator of the health of a habitat; it is associated with ecosystem resilience. The traditional method is to don rubber boots, go out into The Wild, count the birds and the bees, the moss and the trees, tally them and do some maths to boil this down to a single number which we take as a measure of biodiversity. But this traditional point count method doesn't scale. How can we monitor the Amazon Rainforest, or the Great Barrier Reef, or New York, for that matter? Remote monitoring is attractive and satellites and Lidar technologies can be applied, but they are expensive and hard to calibrate. Meanwhile, over the last decade robust, programmable audio recording equipment, memory and batteries have become more powerful and more affordable. Just as medics have listened to hearts and lungs and intestines, we are learning to auscultate the heartbeat of the planet.

This emerging acoustic monitoring method for conservation owes much to an observation made by musician and bioacoustician Bernie Krause. After hundreds, if not thousands, of hours of field recording in pristine habitats, Krause challenged the then popular conviction that the dawn chorus was a random melee and observed that it was in fact highly structured. In ancient, pristine habitats he noted that the chorus was more akin to a symphony than a cacophony; each voice having its own place in spectro-temporal space. Krause summarised his observations as the Acoustic Niche Hypothesis (Krause, 1993), and this can be understood in evolutionary terms, bringing an acoustic dimension to niche theory (Hutchinson, 1957). In order to survive, creatures need to be able to hear each other, this evolutionary pressure leads to partitioning of the soundscape. The prediction follows that in ancient, stable habitats there will be greater diversity of soniferous species and a wider range of frequencies present in the global soundscape. In the hunt for cost-effective environmental monitoring tools, the Acoustic Niche Hypothesis offers a neat prediction, which is not only measurable, but potentially operationalisable as a biodiversity monitoring tool. Nearly two decades later, these ideas have been taken up by mainstream ecology and it is to the emerging science of Ecoacoustics that we now turn.

Rather than focusing primarily on the vocalisations of individual organisms, as in Bioacoustics, Ecoacoustics (Sueur & Farina, 2015) investigates the ecological role of the emergent soundscape. The soundscape is comprised of all the vibrations made by the vocalisations of living creatures (biophonies), the wind, rain and other geophysical processes (geophonies), and those made by human-constructed machines and other processes of the built environment (anthrophonies, or technophonies). The soundscape is a literal meeting point of the technosphere and biosphere, and a global buffer that all sonically sensible organisms read from and write to. This global soundscape is a latent space for evolution, and each organism's personal, interpreted soundscape is a set of semiotic signals which guide their day to day business of staying alive - habitat selection, searching for food, mates and avoiding predators (Farina, Eldridge, & Li, 2021).

I became interested in Krause's ideas theoretically and creatively back in 2005 whilst I was engaged in creative ecosystem work. Later in 2012 I had a chance conversation over a coffee with a brilliant conservation biologist, Dr Mika Peck, who amongst other things works to develop rapid biodiversity assessment tools in support of community conservation projects in biodiversity hot spots globally. We decided that day in the café to investigate whether we could scientifically validate the idea. In 2014 we were lucky enough to gain grant funding to investigate the potential for some measure of environmental sound recordings to act as a proxy for biodiversity.

This work is a mix of very muddy field work and equally muddy multivariate statistics. The field work involved three months recording in UK temperate field sites and Ecuadorian tropical forests. Our aim was to test whether machine listening features derived from these recordings could predict bird richness<sup>5</sup>. This validation is best done by exploring change over gradients, so our field sites covered three different habitat types in each of these two ecozones: primary, ancient forest, secondary or regenerating landscapes, and agricultural monocultures. At each site we set up 15 programmable audio recorders covering around one square kilometre. We sampled one minute every 15 minutes around the clock for two weeks in three sites in each ecozone, giving 175,000 one minute files.

The work flow is familiar to computer musicians who work with large corpora programmatically (Schwarz, Beller, Verbrugghe, & Britton, 2006; Tremblay, Roma, & Green, 2021): start with a large repository of segmented digital audio files, calculate a collection of audio descriptors (acoustic indices in ecology), do some dimensionality reduction and some plots to sanity check the results, and then build a classification or regression model to compare them to human-labelled data. Here our human-labelling was carried out by expert ornithologists from each ecozone who listened to several thousand of the one minute recordings and annotated them with the numbers of each different species that could be identified. This is the ground truth for validating the audio features as ecological descriptors. Prediction of this species richness or abundance is one measure of validity of the descriptor; another comparison is the degree to which human-

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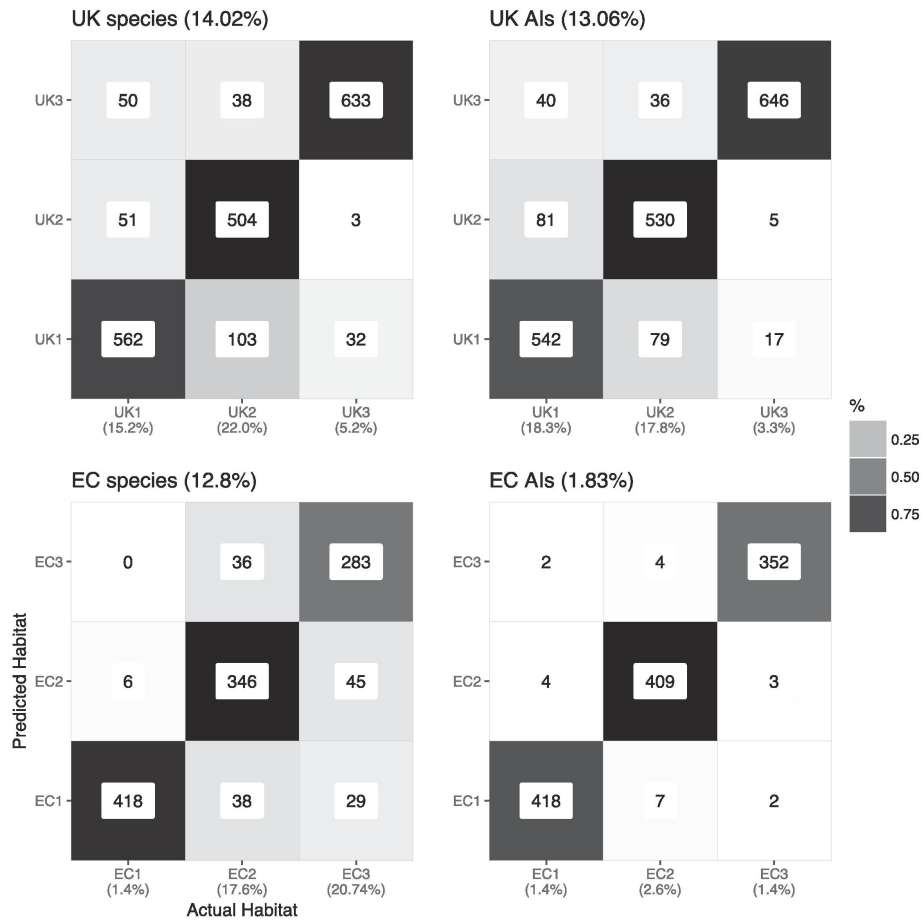
<sup>5</sup> It is well recognised that birds, both in temperate and tropical climes are strong indicators of wider biodiversity.

labelled species richness versus descriptor can accurately classify by habitat type of each of the nine study sites.

To cut a very long story short (see Eldridge et al., 2018), we showed that bird species richness (the number of species present at a particular place and time) is predicted by low level audio features, and unsurprisingly, better predicted by a weighted combination of several. Given the noisiness of data and simplicity of some of the features (zero-crossing rate, spectral centroid), this is quite impressive. More impressive was the habitat classification performance. As shown in Fig. 9, multivariate random forest clustering suggested that acoustic indices (AIs) cluster the gradient of sites more strongly than the actual species assemblage (range of bird species identified from the recordings). On the face of it this result is exciting, as it suggests that soundscape monitoring is a potentially *more* powerful predictor of habitat than the traditional species count method. But there are reasons to be sceptical. These results are hard to interpret. Are the differences due to subtle differences in the soundscapes across ecological gradients that evade human ears? were there other ecologically-relevant factors at play such as technophony of a flight path?, or geophony of a river? Or perhaps less relevant activity, such as a palm oil plantation worker's radio? a file-writing error on a recording device causing erroneous signals? or some other artefact of statistical analysis? We don't know. And it's hard to find out, because we necessarily need to collect and work with data which exceeds our listenable compass.

Issues of confounding variables crop up in Music Information Retrieval tasks too where analytical approaches have been developed to identify and resolve these confounds (Sturm, 2014). This analytic approach works in musical applications such as instrument classification, because invariably we know what we are looking for. Success in classification might be due to differences in the microphone used, or the specifics of the room acoustics, rather than the timbre of the instrument, for example. But we can ultimately resolve this, because for any particular task – such as differentiating wind versus brass instruments – we know what our targets are, and we likely have solid acoustic templates for each. But ecoacoustics is a such a young discipline that we are lacking theory, never mind spectral soundscape templates. We don't yet fully understand the ecological role of sound at these higher levels of ecological organisation, and are far from fully comprehending what the meaningful features or dynamics of global soundscapes are. Without theory it is hard to interpret these models. This is an issue more generally in contemporary -omics: we are drowning in data (e.g. Holzinger & Jurisica, 2014) but there is a paucity of theory to support interpretation of these notoriously opaque methods. And increasingly we are sensorially disconnected from the situations we seek to understand.

Think back to the Acoustic Niche Hypothesis, which is the core theory of ecoacoustics. This was dreamt up by Bernie Krause through sensory experience of being immersed in living soundscapes for thousands of hours. Longitudinal deep immersion in the rich multisensory web of life, is an experience from which all ecological theories to date have sprung, and is something that is changing rapidly in contemporary scientific practice. We are entering what we might call an age of



**Fig. 9.** Confusion matrices for multivariate classification of habitat by species (left) and acoustic indices (right). Actual habitats are shown in columns and predictions as rows for EC ( $N=1201$ : 424, 420, 357) and UK ( $N=1976$ : 663, 645, 668). Overall Out of Bag (OOB) classification errors are shown in each subplot title, and error rates per habitat type on the x-axes.



*experience-free* science. In some disciplines like astrophysics or neuroscience this is nothing new. But remote sensing is rapidly shifting the way we do ecology. By virtue of operating at spatio-temporal scales otherwise inaccessible to the human ear, remote sensing gives us access to large scale phenomena that were previously inaccessible, such as population level, seasonal shifts in response to climate change. The flip side is that ecologists are no longer *sensorially* engaged in their phenomena of study. This is an issue when it comes to interpreting statistical models, or attempting to fathom the basis of discrimination of deep learning models, which also hampers theory building.

How might we resolve this impasse? Reflecting back on the three-fold experimentation that engendered complexity literacy in the feedback cello project, what we are missing is the embodied, lived *experience* of these data. Could we somehow perceptualise these hundreds, thousands, hundreds of thousands of files such that we can *get to know* the soundscapes they represent through tacit, embodied knowing? We evolved to know things, to understand the world, through embodied, situated interaction with a fragrant, noisy, textured, sensory world, not by studying plots of error values. This feels like a nice open problem for the creative computer music community. Recent projects such as the *Fluid Corpus Manipulation* project (Tremblay et al., 2021) provide a ready-to-hand toolset. The project makes available the basic tools of data science inside the coding environments familiar to the computer musician. They are primarily intended for creative composition purposes, but also afford the possibility of rapid exploration and perceptualisation of large data sets. This basic interactive sonification is the bread and butter of computer musics, and potentially a missing piece in advancing ecoacoustic conservation technology. It provides a toy example of how our approaches may help us to create and use technology more carefully, in simple ways, which align better with the biologics of our own nature and in service of our wider biosphere. Could the embodied, tacit knowledge of the techno-fluent musician complement the data-rich sensory-deprived contemporary ecologist? Quite possibly, and in doing so we potentially build technologies that support a better understanding of our world, once more countering hubris and potentially steering technology in a direction that supports our biosphere.

### 3 Introduction

Through a whistle-stop tour of personal research projects at the intersections of music, computing and ecology, I have pointed to some of the ways in which a range of musicking activities might help reverse some of the arrows in Bateson's systemic analysis of ecological and social crises, to move from hubris to humility, from competition and control to collaboration and cooperation. Each project draws upon a range of approaches and methods that are born of contemporary computer musicking, a mix of simulation, storytelling and performance, a hands on, performative, exploratory empiricism, combined with the intuitive, open-ended, expressive and speculative story telling of the wider creative arts. This is

a knowing through doing and being, a thinking through making, a performative story telling and theory testing through which we triangulate ways of knowing and recreate and recalibrate our relationship with the world in such a way as to inevitably advance an ecological ethics. Through sharing these projects I aimed to illustrate some of the ways in which musicking can help us think better, to understand the world, our place in it and relationships with it better, and to perhaps to begin “steer technology in more appropriate directions” (Bateson, 2000, p.500), that it may operate in service of the biosphere.

I first introduced the homeostat and shared how in very simple terms, perceptualising the outputs brought me closer to its operation and rapidly revealed my technical errors. I detailed the strange ontology of the evolutionary artwork *Filterscape*, and suggested that this form of sonified simulation integrated a rich selection of ways of knowing: the imaginative freedom and narrative compulsion of speculative fiction and creative arts, the conceptual clout of (opaque) philosophical thought experiments and the empirical rigour of simulation. In this particular model we gained insight into the emergence of a rich diversity in agent behaviours and population dynamics through the interaction of simple agents in a heterogenous environment. This little experiment illustrates Bateson’s interest in shifting focus to the interactions *between* organisms and environment in interdependence, rather than thinking in terms of one in opposition to the other.

With the feedback cello project in lesson two, we considered the different ways of knowing that are embedded in our musicking practices. I outlined three forms of experimentation: musical, engineering and scientific and suggested that this methodological triangulation provided a valuable means to progress research within a practice that is at once open-ended and intuitive yet also robust and rigorous. I suggested that through these activities - making, playing and analysing - I had come to see the feedback cello project in particular, as a means to advance *complexity literacy* and to experience the joy of *learning to let others be*, a playground for tuning our understanding of and ways of being in relation to the wider world in which we are entangled.

In lesson three, I introduced some ways in which technology is explicitly being developed and deployed in service of the biosphere, but pointed to an epistemic gap in ecoacoustics as a nascent, big data-driven science due to an inherent lack of observation and lived sensory experience of the phenomena under study. I suggested that bringing some performative, interactive, embodied knowing into big data -omics disciplines, could offer a means to develop an experience which enables the perceptualisation and therefore richer interpretation of data which is necessarily beyond listenable compass, providing an empirical *experience* to inform new theory building.

My proposition then is that these myriad ways of knowing - in formal simulation, instrument building and performance - answer Bateson’s call to shift attitudes from us *against* the environment, to understanding ourselves in deep relation to the rest of the world, from hubris to humility, and that perhaps the joy of playing the self-determined, unruly instrument, is a joy in letting A.N.Other

be itself, to meet it on its own terms, to become with it, rather than master it, in the classical sense.

### 3.1 Unsolicited Curtain Call

Just as we can understand prehistoric musicking as a space within which early humans learned to develop core social, cognitive and technological competencies, so I have suggested that computer musicking today provides us with a playground to explore ways of being with and knowing each other and making technology at a time of multiple crises. As a closing thought, I'd like to ask whether computer-musicking has a special role in shaping the future of Artificial Intelligence (AI) in particular. Information philosopher Luciano Floridi popularised the term *infosphere* to describe the whole system of services and documents, encoded in any semiotic and physical media - all data, information and knowledge. Predictions of the rate of growth of data are bordering on absurd, and coupled with a booming AI industry have potential to fuel an already out of control technosphere. Floridi also recognises the contemporary hyperbole around AI and predicts an imminent AI winter. Winters he remind us, are cyclical. We had one in the 1970s, another at the turn of the 1980s and 1990s. AI is subject to these hype cycles, he suggests, because it is a hope or fear that we have entertained since we were thrown out of paradise. He exhorts us to learn some lessons, and to avoid what he calls a "yo-yo of unreasonable illusions and exaggerated disillusion" (Floridi, 2020, p.2.).

My final provocation, or perhaps rather invitation, is that the philosophical, experimental, empirical and performative thinking tools of computer music equip us well to debunk these exaggerated delusions and to ensure AI is steered in the "right direction" to ameliorate rather than bolster hubris. Computer musicians have the technical and creative knowledge to burst the bubbles of hype and to explore AI in ways that enhance both the needs of humanity and our planetary biosphere. Computer musicking enables us to foster new ontological dispositions towards worlds at large, to explore technical, aesthetic, emotional and ethical positions with a range of intelligences through imagining and creating other-possible infospheres, not just in speculative fiction, but here and now in contemporary society. At a time when we are told musicians are not viable, I'd go so far as to say the world is not viable without musicians! This article is based on a keynote talk which was given at a time when the UK government framed the arts as nonviable and ran a contentious cyber-first advertising campaign which exhorted the country's artists to retrain in cyber-security. The main protagonist was a ballerina called Fatima and the tag line ran "Fatima's next job is in cyber. She just doesn't know it yet. Rethink. Reskill. Reboot". Let us imagine Fatima has a sister who is a computer musician. I think her next job is worlding the infosphere. She just doesn't know it yet. Don't reskill. Do reboot. Keep making. Keep thinking. Keep becoming.

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