Fostering a Post-Digital Avant-Garde: Research-led teaching of music technology

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In this article we discuss how contemporary computational and electronic music-making practices might be characterised as a post-digital avant-garde. We also discuss how practitioners within the higher education sector can play a role in leading the development of these practices through their research and teaching. A brief overview of twentieth-century avant-garde practices is provided to set the scene before a case for defining a post-digital avant-garde is made. By way of illustration, the authors describe their own post-digital creative practices and then discuss how these integrate into their academic duties. We reflect on themes that run through avant-garde practices and continue into the post-digital. Finally, we describe how these themes inform an undergraduate music technology programme such that it might be shaped to reflect these developments and prepare students for a post-digital future.

1. INTRODUCTION

Building upon Andrew Hugill's (2012: 7) suggestion that digital musicians 'move perpetually from the known to the unknown', our overarching argument acknowledges a culture of constant change. We seek to embrace and celebrate the inherent instability of music technology, and suggest that appropriate methods for managing the dynamic nature of this condition might foster the development of a post-digital avant-garde. We are interested in the notion of 'post-digital' as an approach to creative work that embraces technologies, be they digital or analogue, software or hardware – including their faults. This practice is underpinned by a disposition of self-determination, yet simultaneously a community-oriented approach that values sharing. Amongst those practices that can be considered post-digital, we include our own live coding and instrument-building activities; we will describe these in more detail below. Interestingly, a connection between these two practices has recently been highlighted by Mooney (2015) who summarised the similarities in four points:

- They share a common historical trajectory of *live* (rather than studio-based) electronic music.
- In them the performer builds, modifies and/or combines the tools of music-making.

- They are improvised in nature, algorithmic in process and bounded by the constraints of the chosen system.
- Both are underpinned by a community-engagement ethos.

Importantly, we reject the notion that post-digital is a musical style or genre. To talk of a post-digital aesthetic, in the sense of a sound quality, seems to short change the potential of post-digital as a set of creative practices that might result in many sound worlds and musical outcomes.

We use the term 'avant-garde' because we think it useful to continue with accepted terms, even if this appropriation seems incongruous to some, to mean an embrace of the new as resonant with a research-led academic culture. We also use it to underline that we are talking about avant-garde practices, methods and ideologies and not comparing what has become known as 'avant-garde music' with our own (or contemporary) musical outputs.

2. TOWARDS A DEFINITION

There are a number of indications that the techno-cultural conditions that support a post-digital avant-garde are proliferating. Powered by developments in mobile computing, Internet connectivity, 3D printing and other technologies, there is an increase in affordable digital and analogue tools and 'maker' communities of practice around them (Buxmann and Hinz 2013). In recent years there has been a push for more coding education in schools and communities. Coding is seen as a contemporary form of literacy (Rushkoff 2010) and is encouraged by leaders such as US President Obama, and there has been an increase in code training sites such as codeacademy.com, which at the time of writing had over 25 million subscribers. This evidence of socio-cultural engagement with technology is at the heart of the post-digital avant-garde. A third indication is the re-emergence of 'live' music experiences (Mortimer et al. 2012). However, these current conditions build on a history of practices and understandings that it is important to acknowledge.

2.1. Post-digital music

Kim Cascone, who coined the term 'post-digital', characterises it as arising from the glitches of digital technologies, from the sounds of their 'failure' (Cascone 2004: 393). The accidental, the outcast, the 'noise' of machines and the 'idiosyncrasy' of software processes are brought to the centre of creative practice. Resonating with Martin Heidegger's (1977) notion that the essence of technology is revealed in its breakdown, the glitch reveals aspects of the technology, it draws attention to its structure, its opaque quality, and the fact that it is designed and has materiality. Often the glitch occurs, or is coerced, by interaction with the analogue or material world. More generally this disclosure of the digital and its limits points to a broader definition of the post-digital where the characteristics of technological interactions with the world are highlighted and leveraged for creative purposes. Cascone (2010) suggests: 'glitch was much more than a style, it was the glint in the eye of the artistically mischievous, a way of looking at and questioning our relationship with digital technology'. This definition moves beyond digital media as a McLuhan-like representation (digitisation) of what came before, to a post-ubiquity acknowledgement of technology's essential character and its situatedness, including its character flaws.

2.2. Avant-garde music

Within the flowing stream of changing media, creative practices and aesthetics, there have been historical moments of particular questioning and reinvention: times when there was a more deliberate assertion of newness and a distancing from past traditions. We take these periods to be 'high' points in an otherwise continuous wave of ongoing experimental practices. In this article, we make the case that current practices in experimental live electronic music, such as live coding and handmade electronic instrument performance, are one such moment: a post-digital avant-garde.

Later in the article we discuss themes that connect the avant-garde and our current post-digital practices, but for now we survey some previous avant-garde practices taking particular notice that, as Rosalind Krauss writes, 'One thing only seems to hold fairly constant in the vanguardist discourse and that is the theme of originality' (Krauss 1985: 157).

The term 'avant-garde' is applied across the arts but not always consistently. In musicology, the avant-garde refers to a network of musicians who share common cultural attitudes and practices (Cottington 2013). The label generally includes composers from around the middle of the twentieth century whose work departed abruptly from previous conventions of the instrumental music tradition; in particular, serialist composers, such as Webern, Boulez and Babbitt, who emphasised adherence to formal (serial) processes and the exploration of their sonic results which were intentionally unconventional in one or more ways, including atonal harmonies, abrupt dynamics, unpredictable structures and non-traditional timbres. Following these composers were those who, without following any unifying compositional approach, produced music that shared some of the same 'unconventional' characteristics. They include Xenakis, Ligeti, Penderecki and Berio.

Almost simultaneously another group of composers, typically lying outside the orchestral music tradition, explored unconventional approaches to music-making, generally labelled as *experimental* music (Nyman 1999). These approaches include the stochastic techniques of Cage, the musique concrète practices lead by Schaeffer, the electronic music of Stockhausen, the polyrhythmic works of Nancarrow, the minimalism of Reich, the soundscape compositions of Oliveros and more. Experimental musicians of this period shared the avant-garde tendency towards originality and nonconformity, but often were also responding to the creative possibilities of the rapid technological changes of their time.

New popular musics also arose in the mid- to late twentieth century, most notably rock and electronic dance music. In itself the emergence of rock music in the 1950s was somewhat controversial but it soon developed an orthodoxy, and has maintained a quite rapid evolution of styles and variants. Against the popular music mainstream there exist moments of disruption due to unconventionality and deliberate experimentation resulting in a series of avant-rock movements that opened new horizons. These include the extended guitar techniques of Jimi Hendrix, Sonic Youth and Merzbow; punk bands such as Sex Pistols and The Fall; the electronic music of Kraftwerk; the ambient music of Brian Eno; and the sampling frenzy of John Oswald's Plunderphonics.

2.3. Avant-garde unravelled

Having highlighted the chameleon-like quality of the term 'avant-garde', we now explore our interest in it:

> French, literally meaning 'advance guard' … Used in England 15c.–18c. in a literal, military sense; borrowed again 1910 as an artistic term for 'pioneers or innovators of a particular period'. (etymoline.com)

The metaphor of a small independent unit scouting ahead of the main group is compatible with our explorative approach to music technology. However, the terms 'pioneer' and 'innovator' are too culturally loaded; we prefer 'disruption' and are interested in what Fineberg (2000: 16) has termed the 'paradigm of the modern artist as a thinker of unexpected thoughts',

suggesting that avant-garde describes a situation in which an artist:

- thinks that his or her art expresses ideas;
- embraces ideas that not only differ from what the rest of society believes, but also come closer to 'the truth';
- makes art that has a bearing on understanding the present and perhaps even an influence on the future.

Although as musicians we are interested in sound, our methods, processes and materials are at least as important. The place of our ideas within society is an undercurrent of this text; we think it clear that there is tension between institutional/scholarly research and commercial agendas, and we see growing interest in direct encounters with technology beyond their commodification for consumption. Drawing from Attali's (1985) configuration of music as both a mirror and a prophecy, we see potential for predicting and influencing the future more broadly.

3. POST-DIGITAL AVANT-GARDE

The digital 'revolution' is characterised by a democratisation of creative production, where the ubiquity of computing devices and Internet connectivity combined with cheap and easy-to-use software enables everyone to make and share music and other media (Taylor 2001; Jenkins 2009). This is not without its problems:

> software manufacturers do the thinking for us, tell us which buttons to push, direct our attention. Anyone can be a music producer and publish their work on SoundCloud … are these people really being creative? (Cascone 2010)

In post-digital practices there is an emphasis on creativity, but this is different to the 'originality' described by Krauss of avant-garde visual art in the 1960s? The post-digital seeks to lift the veil of the technical, to find ways of being expressive using inherent structures, processes and other affordances. The development of personal tools and the value of starting from scratch are important characteristics, but intervention within and the interpretation of pre-existing materials, structures, sounds and ideologies is also celebrated. Not only does this manifest itself in the undertaking of music production and performance but also includes software and hardware hacking, algorithm and instrument building. In post-digital practices, exploration of the digital and electronic as media is prioritised and cyberphysical interactions (Sorensen and Gardner 2010) between people, digital systems and the material world set the stage for performative media projects.

These ideas are echoed in the authors' creative practices where we perform with systems built from basic electronic components, hacked from discarded toys, or live coded from blank text editors or chunks of code. This post-digital expression of originality is not so much an anti-referential statement or the seeking of a novel aesthetic as it might have been in the twentieth century – indeed, many of the musical outcomes of post-digital practice do echo the aesthetics of previous genres – but rather it involves a move towards a personalisation of established/pre-existing technological methods and processes. This reflects a search for individual authenticity, a coupling with materiality, and an anti-commodification statement; these trends are also reflected in contemporaneous movements such as the maker, DIY and cyber-punk communities.

Thinking from a perceiver's perspective about post-digital technologies and their decipherability, questions emerge around prior cultural understanding and the expectation of instrumental capability. Reflecting on the perceptual challenges of bridging the gap between performer and audience sonic expectation, Joanna Demers (2010: 15) argues that 'listening to electronic music constitutes an act that is fundamentally different from how listeners have been used to hearing Western art music for the previous five centuries'. The level of shared understanding about a traditional instrument, such as the piano, is far more significantly developed and uniform than that of any post-digital technology. Yet the opportunities for genuine creative development that are available to musicians/composers working with traditional acoustic/electronic instruments are often limited – limited that is by the expectations of a historical cultural cache. In comparison, the freedom to create and grapple with new opportunities that are available to post-digital practitioners is unprecedented. Rather than considering any inconsistency in shared understanding as a 'problem', we argue that an open-ended expectation of the relationship between a musician and their technology is, in fact, a benefit and an opportunity.

The evolving question of what music technology is or might become within a post-digital practice requires an acceptance of continual change and development. This offers exciting, radical and ever-evolving possibilities. We deploy the term 'post-digital avant-garde', in part, to query the integrity of the much touted 'democratisation' of technology and to suggest that for this so-called democratisation to be genuinely transformative it needs to draw more directly from independent and explorative activities underpinned by an ethos of research and technical understanding.

4. OUR (POST-DIGITAL) CREATIVE PRACTICES

The authors' creative practices revolve around live music performance and include software and hardware
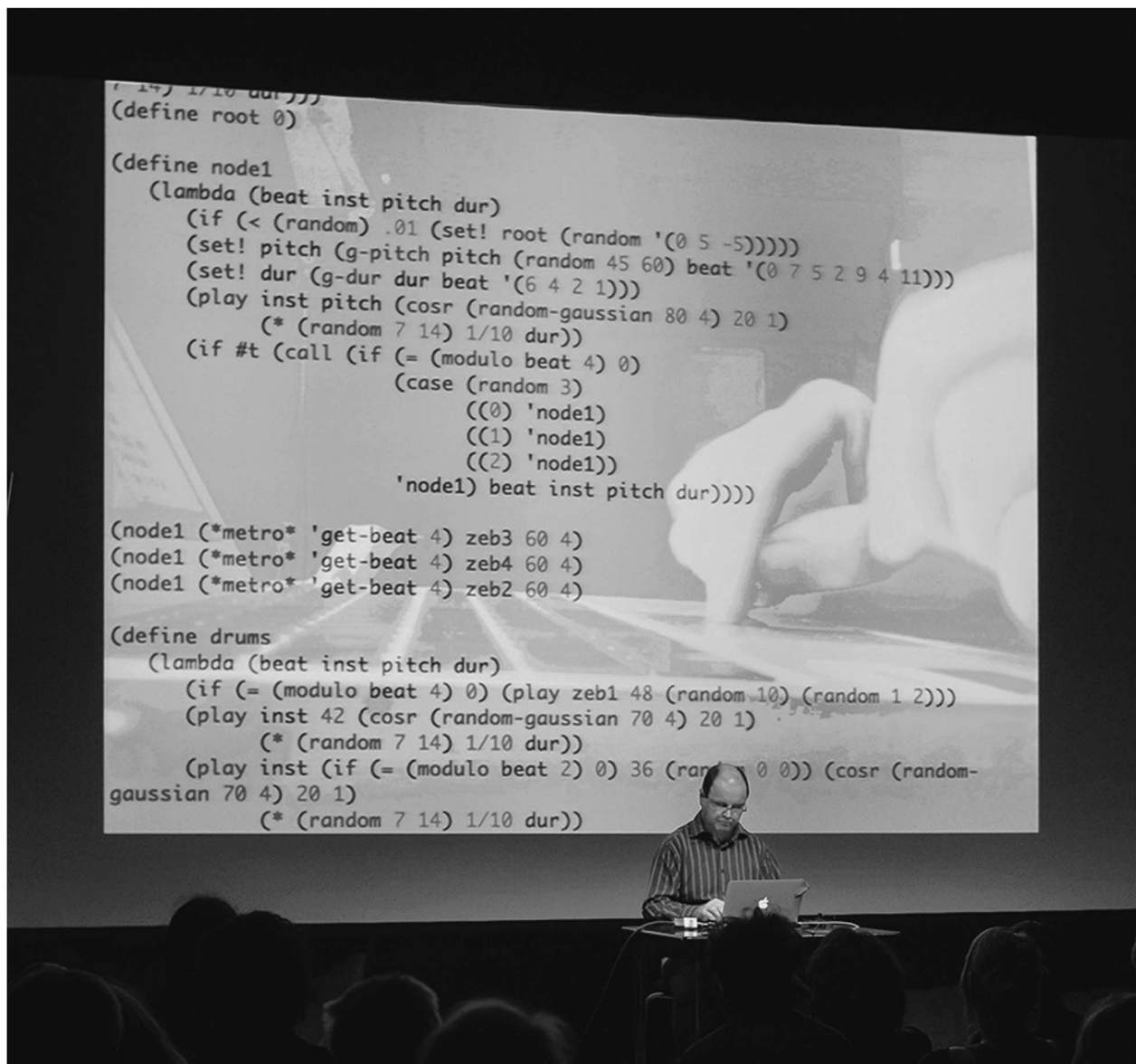
Figure 1. Andrew R. Brown (2013) live coding at the Live Code Festival, Karlsruhe. (Photo credit: Daniel Bollinger)

design and development. In particular our practices are in live coding and handmade electronic instrument performance. The similarities between our hardware-oriented and software-oriented practices were well described by Mooney's (2015) characterisations that we presented in the introduction. In the sections that follow, we describe our musical practices so that these points and other aspects of the post-digital may be illustrated.

4.1. Live coding: Andrew R. Brown

In the computer music community, software development (coding) has long been part of the production process, but typically it was a preparatory activity that built the tools or instruments with which music was made. Live coding is a practice that arose around the turn of the twenty-first century that disrupts this traditional role (Collins et al. 2003). Such disruption is characteristic of avant-garde practices, as we have described above. Its focus on directly exploiting foundational computing processes – usually hidden – as a creative practice, and positions it as a post-digital practice.

Live coding is the practice of public software development. Typically the coder's text editor is shown so the evolving program can be followed by the audience. As an artistic performance, the practice of live coding occurs 'on stage' and the audio and/or visual output is presented through a sound system and projection screen and code modifications effect real time changes in output (see Figure 1). An unusual technical requirement is that the running software not be

disrupted as it is updated; this is achieved through on-the-fly compilation of code.

The 'liveness' of this practice puts particular demands on the coder for accuracy to avoid 'bugs' that might crash the running application. Thus the practice supports the kinds of fluency, virtuosity and improvisational skills typical of musical genres, but previously foreign in the world of software development. There are aspects of the practice that challenge traditional musical concepts as well. Live coding is a hybrid of composition and performance; it is real-time like other performance practices but writing code equates to notating a musical score, a task traditionally associated with composition. In this case the coded 'score' may describe sonic and/or structural elements of the music (or other media) and is interpreted by the computer.

My live coding activities began in 2005 when I started performing in the live coding duet aa-cell with Andrew Sorensen (Sorensen and Brown 2007). We performed from-scratch live coding where the performer starts with an empty text editor and does not rely on prepared code fragments. This was made somewhat easier for us through the use of virtual software synthesisers as sound sources, thus our code at that time mainly described event-level processes and structures. Challenges in these performances included: designing processes that were interesting from the outset when only very minimal code had been typed; inventing succinct code patterns (of a manageable length) that described interesting musical output; finding methods of evolving the code that balanced appropriate musical changes whilst maintaining coherent code structures; and practising coding under the stress of a live performance requiring that syntax was memorised and errors were minimised. During these years, Andrew Sorensen developed the Impromptu live coding environment which we used for performance, so our tools co-evolved along with our developing knowledge and skills (Sorensen 2005). Over the years we expanded the practice from music only to live coding audio and visuals, increasingly controlled sound synthesis as well as event-level processes, explored live coding of multi-speaker sound arrays, and developed various methods of synchronising our computers to stay in time.

In 2010, I performed my first major solo live coding concert following some informal performances in the year or so prior. For me this was no small task and it had taken years of practice to achieve. What may not be so obvious to the observer of live coding is the cognitive load that can be required. For each part there are synthesised timbral processes, note-level generative processes, and large-scale structural considerations; then there are multiple parts. The computer, of course, has no problem managing the rendering of this complexity but for the musician instructing the computer through code there remain challenges. Around the same time my live coding practice began to spread across a wider range of musical genres. This was partly a challenge to devise succinct algorithmic processes that captured the essence of these different musical styles, and partly an aesthetic curiosity. Until that point my live coding music had been rhythmic, diatonic and followed a minimalist style that lent itself to computational repetition and stochastic variation. Over the next few years I explored and performed works in genres including electroacoustic soundscapes, studies in the style of various composers for solo piano (using a computer-controlled acoustic piano), and electronic dance music performed at Algoraves (nightclub dance parties featuring generative music systems).

Through this journey there has been a parallel investigation around the computational aspects of the practice; in particular, looking at the features of code and software structures. Considerations include choice of programming language, language design and features, data structures, software design patterns and efficiency for hardware optimisation. In general, I have been a passenger on this technical journal, while others in the live coding community have done the hard yards on developing and optimising live coding environments. Nevertheless it is important to point out that, even for me, this creative practice requires an integration of musical and computational understanding and skill. It is a hybrid, interdisciplinary, practice exploring the margins of disciplinary boundaries.

In summary: despite the inherently digital nature of programming, I characterise my live coding practice as post-digital mainly because of the context in which it occurs. By exploring the creative possibility of programming in a live, real-time, process-based scenario that is open to in-the-moment decisions and human error, live coding is an embodied and interactive practice that also explores the musical affordances of computing structures. It looks beyond simple digitisation and efficiency, towards the expressiveness with and of algorithmic processes, the machine's creative partnership with the performer, and its coupling with the material world (see Movie example 1).

4.2. Portfolio of post-digital practice: John R. Ferguson

My work approaches the topic of the post-digital avant-garde from a variety of perspectives:

1. During the last seven years I have developed Machine-assembled Dislocation (MAD). This is a hybrid computer instrument that extends an electric guitar via two Nintendo 'Wii' controllers and a Keith McMillen 'SoftStep' that are connected to Ableton software 'Live/Max4Live' via 'OSCulator'. One 'Wii' is attached to the headstock and a second (with associated 'Nunchuck') to the

Figure 2. John R. Ferguson (2015) performing Machine-assembled Dislocation at MuTech Underground, Queensland Conservatorium Griffith University. (Photo credit: Andrew R. Brown)

horn and rear of the guitar (see Figure 2). Performing is a whole-body experience, while there is some straightforward 'top-level' control of volume, mute and sample recording, parameters such as filtering, granulation, panning and pitch are controlled by relative motion in space and the angle at which the guitar hangs from my body. Some interrelated parameters are mapped across both the pressure sensitivity of the 'SoftStep' footpedals and the 'Wii' accelerometers. This makes the instrument feel more complex than it may logically appear. Although I have made an effort to learn its characteristics and to be able to repeat certain performance situations, stochastic processes are valued, accidental sounds are celebrated and musical form is often emergent. An identifiable repertoire for this instrument is possible to some degree, but MAD remains unstable and in-progress, there is no 'final object' in the sense of instrument or musical work.

2. Feral Technologies: this exploration of circuit bending, hardware hacking and DIY instrument building foregrounds disassembled electronic commodities. I find the visibility of quick/obvious modifications to be meaningful: in prying apart an apparently closed commodity system and exposing a plethora of creative potentials, appropriation and reuse becomes a form of artistic commentary. Integrating the human body with simple electronic audio circuitry – by directly touching components – or using light dependent resistors and small light sources can be highly expressive, and the level of sonic/visual variation

achievable with simple configurations is surprising (see Collins 2009). My aim with this project is to explore scenarios that emphasise the materiality and social resonance of post-digital music technology. The direct expressiveness of touch is also configured as a direct challenge to the supposed efficiencies and superior qualities of 'fast' digital technologies.

3. Robert Dominicus is a collaboration with Seth Dominicus Thorn. Working in an entirely improvised/live scenario, the goal is to explore techniques and timbres associated with a variety of vernacular electronic music practices, but to avoid the latent dynamics of genre-specific expectation. John relies on commercial Ableton software 'Live' and hardware controller 'Push'. Seth combines Ableton software 'Live' with bespoke 'Max' patches and standard controllers. Robert Dominicus believe that the repetitive rhythms, musical values and timbres of much contemporary vernacular music remain an awkward proposition for many supposedly forward-looking art institutions. This is a tension that they seek to highlight.

4. 'Circles' is a self-made instrument. The current version is a wooden box with knobs and switches arranged in a circle. This contains a single-board computer (Odroid C1) and two micro-controllers (Teensy LC and 3.1). Bespoke software is written in Pure Data and Arduino, running on Linux. Sampling is via an in-built microphone. The creative negotiation of imagined agency is the main agenda, the physical layout of the instrument and the idiosyncratic configuration of semi-random/quasi-intelligent sequencing is what marks the relationship between it and me as post-digital. The unique characteristics of this instrument are extended using a variety of effects processes based on standard sampling and studio-production practices (repitching, time-stretching, filtering, reverberation).

Although I often build bespoke software/hardware (Circles), or configure commercial devices in unusual ways (MAD), I have also used Ableton software 'Live' since 2003 and keep returning to this platform for three reasons: 1) I find it important to retain a rigorous practice outside of the more idiosyncratic instruments that I build/configure; 2) keeping in touch with commercial offerings is essential in evaluating the affordances of genuinely new technologies; 3) making music is a different kind of art to making instruments.

Thinking about narratives that run through these projects, my current work (Circles) is built using open-source software/hardware, this seems to resonate directly with the conceptual ideas behind Feral Technologies. However, the aesthetic output made

with Circles is a natural development of my work with Ableton software 'Live', though many of the performance strategies hark back to the live sampling and looping explored with MAD. In all these projects, the digital and analogue collide and physicality is often at the foreground. My approach can be described as postdigital for several reasons: it deliberately explores the features and quirks of digital systems, it pushes beyond the digital to digital-analogue hybrid systems and it seeks renewal through continuous engagement with varied and ever-evolving technologies.

Whether using commercial or bespoke tools, my approach is deliberately playful. Less about 'being in control of a situation than about ways to find lifelike resonances with which to interact', the relationship between 'imagination, expectation and material' is at the foreground (Ferguson 2013: 137). Focusing on real-time interaction and the multiple connotations of 'performing technologies', I aim for a situation where it is unclear whether I am performing the technology or it is performing me. This, to some extent, might seem to undermine what might be perceived as the autonomy of a musician. However, I am not attempting to remove my own agency from the creative process; this is not in any sense a 'chance'-based approach, but one which involves maximum attention and involvement (see Movie example 2).

5. EMERGING THEMES

In this section we identify and situate themes emerging from our practices and connect them with the conditions of the post-digital avant-garde. In finding connections with features of the post-digital, we hope to identify issues that might persist even as contextual conditions inevitably shift over time.

5.1. Instability

Continual change and renewal is a natural trait within music technology. Although partly due to technological development, the evolution of artistic methods are often independent of this: each iteration of an idea may demand a new technical competency; sometimes a new competency results in a new idea. Developing through practical exploration and theoretical querying, inspiration may be abstract or concrete, but our practices are always moving on and becoming something other. This idea is not without precedent:

> *unstable media* – reflects upon and takes into account the meaning, idiosyncrasies and boundaries of such media. In this process, instability is a creative force that is essential to the continuous re-ordering of the social/cultural, political and economic relations in society. Instead of providing us with an orderly, homogeneous worldview, unstable media present an image of a world that is inconsistent, heterogeneous, complex and variable. (V2_)

5.2. New skills and tools for new music-making

A feature of these practices is the mutual influence of instrument development and performance experience. The DIY design and development of software algorithms and hardware systems is an integral part of these practices. However, it is their behaviour in live performance that reveals their true identity. At times, thankfully, they glitch and provide happy accidents but more often than not they require refinement and development in reflexive circularity of post-digital practice. Post-digital practitioners are, like Cascone:

> not necessarily looking for a pre-packaged piece of software that's designed by marketing departments [where] you always are suffering from the median on the bell curve of average people wanting to do average things. … I'd much rather build my own software and work with the tools and have them get in the way, because that's what makes you think, this conflict is what's lacking, and the conflict is what creates, and allows you to be innovative. (Cascone 2010)

5.3. Appropriation and reuse

This vital characteristic of the post-digital avant-garde might be traced back to the Détournement of the Situationist International. However, the most famous post-digital appropriation is the Amen Break: a four bar drum solo which gave birth to the drum and bass genre (Harrison 2004). Examples include John Oswald's 'Pretender', DJ Shadow's 'Endtroducing', Danger Mouse's merging of The Beatles and Jay-Z, and the work of Mashup artist Girl Talk who is associated with 'RiP!: A Remix Manifesto' (Gaylor 2008). Beyond this audio/cultural sampling, appropriation and reuse is evident in the 'maker' community that often exists around open platforms such as the Arduino hardware and online collaborative software tools such as GitHub, all of which foreground the sharing of skill, code and experience.

5.4. Engaging with the mainstream

Despite an emphasis in our practices and the post-digital in general on being non-traditional and original, there continues to be a relationship between new and existing practices; not least the borrowing and appropriation mentioned above and the use of commercial technologies. Experimental practices are novel in relation to what has come before, and developments frequently move from the familiar to the original through incremental modifications. In turn, history has shown that novel practices are often absorbed by the mainstream as cultural developments.

Cross-pollination between academic and commercial worlds has always occurred – the FM synthesis that powers the legendary DX7 synthesiser is one

example – and we are starting to see new commercial instruments, such as the 'Zoom ARG', whose characteristics would be familiar to anyone who has attended conferences such as New Instruments for Musical Expression (NIME). In terms of a broader argument for a post-digital avant-garde, it is worth highlighting recent discussions around the move from STEM to STEAM:

> innovation remains tightly coupled with Science, Technology, Engineering and Math – the STEM subjects. Art + Design are poised to transform our economy in the twenty-first century just as science and technology did in the last century. We need to add Art + Design to the equation – to transform STEM into STEAM. (RISD 2015)

6. CREATIVE PRACTICES IN THE UNIVERSITY

An original condition of the post-digital was that it was not academically based (Cascone 2000). This was seen as significant because so much of previous avant-garde and experimental music practices emerged from or found refuge in the academy. However, we do not take this to imply that this prohibits an active interaction between the academic and secular music communities in moving practices forward.

We see our creative relations with the world as being less about the production of an aesthetic product than a need to negotiate with the affordances and possibilities of the contemporary cultural situation, this is configured as a form of practice as research. This approach adheres broadly to Borgdorff's (2006) definitions, and additional discussion can be found in Brown and Sorensen (2009) and Ferguson (2015). Despite a strong belief in the validity of artistic practice as research, there are tensions between academic research and commercial interest, academia and the art world, students and their teachers, and musicians and their environments. Croft's (2015) 'Composition is not research' and Wheeler's (2005) 'Performance art and its institutionalization' usefully highlight some of these issues. The text below scrutinises practice as research and offers a reflexive overview of some of the relevant issues.

While experimental musical activities with technologies abound, the academy respects their conceptual frameworks; we are interested in the ecological connotations of David Tudor's 'Rainforest', the social values of the Ubiquitous Music movement, Christian Marclay's reuse of recorded media, and the hardware hacking/circuit bending practices of Nicholas Collins and Reed Ghazala. All of which highlight the fact that music is so much more than the sound that it makes. Our point here is not to suggest that post-digital avant-garde be considered akin to conceptual art but, rather, in highlighting methods and musical material as valuable sites for meaning, broader considerations

are foreground. For example, there is a cultural expectation that a musician authors sound, but – thinking about music technology – there is ambiguity and indeterminacy to take account of, as well as the design role of the instrument maker and the interpretative role of the perceiver.

One undercurrent in these contemporary practices is a broad environmental consciousness. This pertains to design and use of technologies. It suggests an awareness of our situated materiality and that media be designed in such a way that they can be reused, deconstructed, or otherwise (re)deployed beyond their initially intended function. This has best been argued in Braungart and McDonough's (2009) 'Cradle to Cradle: Remaking the Way We Make Things'. We hope that the notion of a post-digital avant-garde can offer a metaphor through which to resist the perpetual acceleration of industrial civilisation (Jensen 2006). Or to put it another way, we ask: how might music technology embrace a practice sensitive to the materiality of media and culture, of making and reuse, and push beyond the latent dictations of a throwaway commodity culture? We believe that the promotion of do-it-yourself practices such as instrument building prioritise personal and deep engagement with technologies, and thus the world. In celebrating the formation of intimate relationships between a musician and their tools, passive commodity consumption is resisted, and innovative/potentially lightweight workflows emerge. One example of such thinking is the fairphone.com movement, which promotes a re-education around the costs of our technologies, offering modular, long-life, and easily repairable devices.

The process-oriented and socially open aspects of our creative practices give them a particular character, which aligns well with work in a creative arts academic context. Framed as a research endeavour, both the technical and the artistic aspects meet the objectives of discovery and innovation. This has attracted postgraduate students and the skills gained have fed into undergraduate courses in music technology and interactive media. Even as these practices become increasingly popular, they remain a niche activity. The orientation of academic research towards new knowledge allows individuals and small groups in universities to make meaningful contributions to post-digital avant-garde practices that help shape the development of the practice. This seems to have been a feature of the role that the academy has played in avant-garde practices in the past also; the modest pace and scale of university research seems a good match to developing and emerging practices.

There is also a strong vocational orientation in higher education these days. Creative Arts schools in universities are often focused on helping students master well-established skills and repertoire. Students themselves are also keen to improve vocational

competencies that might make them competitive when seeking limited professional opportunities. Thus far there are no live coding jobs nor a big market for bespoke electronic musical instruments. The very nature of experimental work in this field means that the quality of artistic output is unpredictable and, as history shows, new styles of music often meet resistance (or worse). Arguments can be made for the practical benefits of skills such as coding, electronics, digital media and audio production expertise, especially their role in an innovation economy. However, it would seem better if traditional academic values of enquiry and personal development could be sufficient to advocate for the place of these practices in the academy.

7. RESEARCH-LED TEACHING

We champion a teaching programme that engages with the evolution of musical culture. This needs to be more than, say, through updating to the latest equipment or using contemporary music exemplars. A programme should grapple with fundamental shifts in practices and artistic motivations. This position aligns with that articulated by Thomas in his reflections on popular music education in higher education, when he claims that the effect of the digital revolution:

> on what pop music is and can be seems to have had little influence on how it's taught anywhere, at any level. Sure, all institutions are happy to embrace the technologies of contemporary production and dissemination (everyone uses SoundCloud), but the overwhelming tendency is to emulate the rock industry's use of them to maintain archaic musical forms and frameworks. (Thomas 2015)

Moving forward, to highlight how we see the current situation and foreground the need for a post-digital educational agenda, we return to Cascone (2010):

> We are still pre-post. It is unfortunate that the post-digital has never gotten past the post-part of its name. Like a car stuck in a snowbank unable to move out of its rut … Disposable cultural artefacts of fractal-like similarity are easily created, downloaded, and then tossed under the compost of popular culture … Derailed by a technology which has democratised the physical apparatus [and] has only resulted in replacing musical practice with gadget consumerism.

What then can be said of the prospects of music technology education? Why might research-led teaching be important to informing these prospects in a higher education environment? Again, we briefly share our current experiences as educators to illustrate one possible engagement with these questions.

7.1. Implementing a post-digital educational agenda that foregrounds the avant-garde

Recent rejuvenation of Music Technology studies at Queensland Conservatorium Griffith University (QCGU) – where the authors work – has resulted in a distinct live component. Starting from the perspective that music technology is an unstable field that offers ever-evolving questions, teaching highlights the fact that researches are still grappling with the impact of recorded sound and the instability of music technology. Ableton software 'Live' is the performance tool initially encountered by first-year students. The main agenda is to explore creative approaches to technology beyond those offered by the 'arrange' page of a digital audio workstation. The clip-launching paradigm of the session view and creative use/misuse of software instruments/audio effects is at the foreground. A variety of commercial hardware controllers are utilised; joysticks, 'Wii' controllers and mobile phones are explored. This orientation emphasises the creative possibilities of liveness, foregrounds performance practice, and empowers students to fully engage with ensemble dynamics and real-time interactivity.

Next, we introduce Pure Data software. Although the agenda in terms of performance and liveness is similar to previous, the switch to an open source graphical programming environment is ambitious and challenging. However, the introduction of programming concepts presents an opportunity to explore the relevant creative process in much more depth. Following this, we gravitate towards programmable microcontrollers, basic hardware electronics, text-based coding and performance with interactive sensors. Taking Cook's (2009) 'Re-designing principles for computer music controllers' as a point of departure, students become increasingly familiar with approaches to harnessing the intelligence of the human body through movement and touch. Their projects are expected to offer some response to questions such as: what makes a good/expressive digital/electronic instrument? Should the design of these instruments follow the established blueprint of their acoustic and electromechanical counterparts, or should new technologies equate to new musics and new forms of musical expression? Some experiment with single board computers, others use software such as Mobile Music Platform to run bespoke Pure Data patches on mobile devices. In short, things become increasingly open-ended, creative interpretation is at the foreground, as is the ability to apply/reimagine previously introduced technical competencies.

These courses are not about making products, they are about fostering and articulating aesthetic intention, innovative design, avant-garde thinking, and about the development of intimate relationships with post-digital materials (see Movie example 3).

8. CONCLUSION

Cultural and technological change is constant, however, there are periods of greater stability and moments of disruption. It seems that in this second decade of the

twenty-first century the combination of a renewed interest in making with technology – rather than simply using and consuming it – is reflected in a rise of post-digital avant-garde music practices that exploit these trends; in particular, novel live performance practices with bespoke interactive music systems.

Inspired by Mooney (2015), we suggest that post-digital avant-garde music practices have four particular characteristics:

- live electronic music-making;
- engage with technical materiality and tool building;
- celebrate uncertainty through improvisation and algorithmic processes;
- are openly shared and community oriented.

The non-mainstream emphasis in these practices provides a particular opportunity for those in higher education to show leadership in these practices without being overtaken by more well-resourced commercial forces. However, it does not foreclose on practices that are popular and may become commercially successful.

In this article, we have described how we integrate artistic practice, research and teaching activities in this field, and we provide a vision for structuring a programme of learning for higher education students that takes account of the post-digital avant-garde context.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1355771816000054

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