All the Noises: Hijacking Listening Machines for Performative Research

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ABSTRACT

Research into machine listening has intensified in recent years creating a variety of techniques for recognising musical features suitable, for example, in musicological analysis or commercial application in song recognition. Within NIME, several projects exist seeking to make these techniques useful in real-time music making. However, we debate whether the functionally-oriented approaches inherited from engineering domains that much machine listening research manifests is fully suited to the exploratory, divergent, boundary-stretching, uncertainty-seeking, playful and irreverent orientations of many artists. To explore this, we engaged in a concerted collaborative design exercise in which many different listening algorithms were implemented and presented with input which challenged their customary range of application and the implicit norms of musicality which research can take for granted. An immersive 3D spatialised multichannel environment was created in which the algorithms could be explored in a hybrid installation/performance/lecture form of research presentation. The paper closes with reflections on the creative value of 'hijacking' formal approaches into deviant contexts, the typically undocumented practical know-how required to make algorithms work, the productivity of a playfully irreverent relationship between engineering and artistic approaches to NIME, and a sketch of a sonocybernetic aesthetics for our work.

Author Keywords

Machine listening, music, immersive environments, design research, sonocybernetics.

CCS Concepts

• Applied computing → Sound and music computing; **Human-centered computing → Interaction design theory, concepts and paradigms; • Information systems → Music retrieval**;

1. INTRODUCTION

A large body of work exists exploring machine listening processes to analyse music and other sonic material to extract features of interest. Such processes have found application in musicology where computer-based analysis might reveal stylistic tendencies in a composer's work [9], in music information retrieval where identified features may be used to index a corpus of recordings and facilitate retrieval [7], or in building real-time performance systems where a player's input might be analysed to parameterise algorithms which generate a machine accompaniment [18]. Extensive bodies of research also exist analysing melodies to extract musical features of relevance to foundational issues in ethnomusicology [1] or to identify the features which contribute to the emotional character of a piece of music [14]. For some writers, machine listening techniques have the potential to unlock just what it is human minds find so compelling about music [16].

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Within NIME, Schwarz, Tremblay and Harker [19] offer a sophisticated example of how various contributions to these research concerns can be combined in an expressive musical instrument. A corpus of music material is pre-analysed for various descriptors (e.g., in the example shown in the paper, spectral centroid, periodicity and note number) and a navigable map of grains of sound extracted from the corpus is presented to the player. Selected grains are convolved with the signal from a contact microphone. In this way, the contents of the corpus can be played by contact gestures such as hitting, scratching or strumming and new sounds can be resynthesised from its microstructure.

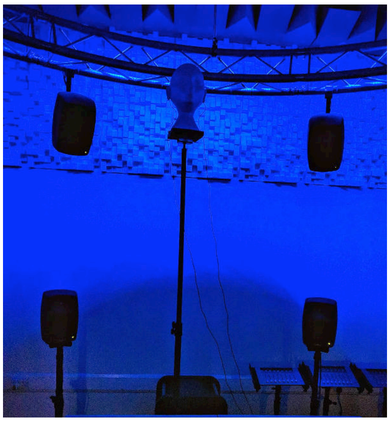

Figure1. Stookie Helen listens to many machine listening algorithms (see Section 4 for explanation).

Impressive though such contributions are, research into machine listening processes tends to be marked by certain biases or priorities which constrain the forms of musical creativity that the work engages with. Corpora of sound, whether they are used for experimental judgment purposes such as in [12] or in gesture-propelled concatenative synthesis prototypes such as [19] tend to be dominated by Western tonal music or at least music which can be segmented into note-events. Sound input is typically sanitised or idealised in its preparation for analysis or corpus-membership. One would tend not to conduct computational musicological analyses of Mozart on a corpus of very bad performances or ineptly engineered off-mic recordings. At an extreme, score-derived MIDI-style representations and playback are sometimes preferred as idealised materials with controllable variables and so better suited to psychological experimentation than actual recordings. Machine listening research also has a tendency to be organised along functional-engineering research paradigms. Design proposals are derived from theoretical considerations or variations on prior work. They are then implemented and tested and perhaps incrementally improved. Applications are discussed where the techniques which are designed, implemented and tested are considered as means to perform some musical end. Musical interfaces are literally conceived 'instrumentally', as tools to realise expressive intent.

We have no argument with such approaches except if they insist that theirs is the only rational way to proceed. Research on machine listening is now adequately advanced to address some of its biases and prioritise other creative concerns. For example, like us, Collins [8] notes the dominance of tonal-note oriented music in studies of music information retrieval and presents an approach to the analysis of the noise music of artists such as Merzbow, Nurse With Wound and Einstürzende Neubauten. Improvised music problematises any concept of a normative score against which performances might be judged or in terms of which the essential features of a work might be identified and analysed. Contemporary 'non-idiomatic' [2] improvisation with its concern for extended instrumental technique further problematises ideas of the ideal rendering of a work or of known instrumental identities to search for in analysis. Furthermore, improvising guitarist Derek Bailey questioned the 'instrumental' character of instruments: "The instrument is not a tool but an ally. It is not only a means to an end, it is a source of material, and technique for the improvisor is often an exploitation of the natural resources of the instrument" [2, page 99]. On Bailey's view, it could be argued that methods in addition to tool-oriented, functional, engineering-influenced research are needed: ones that address head-on the potential for interfaces of interest to NIME being sources of material with a lively agential character. So, while examples like Collins [8] and other playful orientations to NIME research certainly exist, we wish to intensify this tendency in a concerted examination of machine listening.

2. CURATED RESEARCH

As musicians, our acquaintance with noise music and the character of improvisation give us an initial motivation to offer alternative approaches to researching machine listening. As noted by Bowers et al. [5], there is considerable potential in NIME for drawing on the methods of 'Research through Design' (RtD) which have already made an impact in research on Human Computer Interaction at large. RtD prioritises creative design work as a means for exploring research issues and new possibilities at the intersection between research fields or disciplines. [5] introduces the idea of 'curated research' whereby researchers proliferate a number of responses to a provocatively formulated research theme. In [5] a collective of 11 researcher-artists made work in response to the provocation 'one knob to rule them all' to explore a variety of issues in interaction design of relevance to NIME. On similar grounds, [4] names their approach 'many makings', again emphasising the exploration of a number of 'makes' rapidly and in parallel. In both [4] and [5], the collection of makes is assembled into exhibitable and/or performable work and reflected on as an 'annotated portfolio' to speak to research issues. This represents a rather different style to the engineering orientations most common in machine listening research - one which puts expansive creative work and public presentation to the fore but without cost to its research relevance.

3. MANY MAKINGS

We decided to approach the domain of machine listening with a similar orientation. We sought to explore how 'noise' (in all the varied senses of that word, see [20]) might provide challenging input to algorithmic listening techniques or make for a desirable, divergent output. Following the artistic strategy of détournement [10], which is often approximately translated as 'hijacking', we sought to misappropriate known techniques to uncover their limitations or the implicit assumptions built into them. Independently, we each brainstormed proposals for makes. Combined we had a long list of 48, some expressed compactly, some at greater length, some in a standard 'scientific' language, some deliberately written humorously or facetiously, some with a degree of overlap and convergence with other proposals, some unique, some based on our existing preoccupations, some creating new challenges for us, some making reference to existing artworks but bending them to our context of interest, and so forth. Following in the spirit of [4] and [5], we made work in two concerted sessions of two days duration each, one at each of our host institutions. We worked with a light touch doing just enough to prove the principle of our design ideas before moving on to the next. We were drawn to prioritise proposals that we both shared but we ensured that our individual idiosyncrasies were also represented to maximise the coverage of our work. We conducted a third two day session to combine our makes in a performable installation environment which could also serve as an occasion for discussing the wider implications of our approach with researchers and the public. In total, 18 of our proposals were made to some degree with 14 having a role in the final presentation of the work. In the rest of this section, we set out our makes individually before describing in the next section how they were composed into a performable environment. (Further documentation can also be found at: http://www.algorithmiclistening.org/seeds/oiA/)

3.1 AntiGate: Amplitude Version

The input signal is amplitude envelope-followed. When the signal drops below a given threshold, it is let through the gate, thereby performing the opposite to a classic noise gate. When the signal drops below threshold, it is subject to single frame FFT analysis which is used to create a freeze effect that is held until the next time the gate opens. The sound through the open gate and the frozen spectral texture can be cross-faded. The cross-fade and the threshold are both variable in performance.

3.2 AntiGate: Spectral Version

In the Spectral AntiGate (SAG), a carefully engineered multi-resolution spectral gate, made by Harker to showcase his new FrameLib signal processing framework [13], is hijacked by simply reversing the inequality at its core. Being multi-resolution means that the chirping redolent of crude spectral processing is mitigated somewhat, particularly in higher frequencies that retain a degree of texture. If a feedback loop is set up with an air microphone picking up SAG's output, a steady cycle is settled into that alternates between more chirpy mid-frequencies and bursts of higher frequency noise, although the inner textures of these components do vary. This behaviour is oddly reminiscent of the change ringing of bells. The rhythmic behaviour changes if a player manipulates the microphone, for instance by shielding it.

3.3 Room Tone Shift Register

Bursts of filtered room-tone are fired back into the space with an attack-release energy profile. The timing of these bursts is dictated by a maximum-length pseudo-random sequence (see our discussion of LFSRs below) with four 'voices' each with different length sequences and occupying different spectral bands. The room tone is read from a 10-second delay line, so depending on the delay time, there is the possibility of sampling previous output. The overall effect depends to a large degree on how fast the sequencers are driven. High speeds and short bursts produce an impulsive texture, moderate speeds a more rhythmic feel, and low speeds with long bursts can punctuate whatever else is in the space with dramatic impact sounds.

3.4 Electrical Field Re-synthesiser

An inductive coil (sometimes known as a phone tap coil) is used to transduce electromagnetic fluctuation into a signal that is presented to the EFR which tries to model its input as coloured noise. This is done using a conventional source-filter technique where noise is filtered in the Fourier domain by a spectral envelope derived by cepstral liftering of the input. This is supplemented with a very simple, single-voice sinusoidal model driven by the sigmund~ external to the Max language. The character of the resynthesis is largely determined by the degree of liftering and, of course, how much sense it makes to model the input with filtered noise in the first place. In variants of the EFR, a microphone has substituted the inductive coil.

3.5 Disagreeing Pitch Trackers One

A signal is 'resynthesised' by sine oscillators driven by three different pitch trackers in Max (sigmund~, zsa.fund and the built-in Fzero~). One can also mix in another signal of oscillators driven by the difference in frequency between each of the three trackers, ring-modulated with each other. Driven with a pitched signal and a sensible gain structure, the effect is rather like six excited slide whistles. However, introducing feedback and nonlinearity opens up a much wider range of territory. If left in a feedback loop with a suitably large delay (we use 12 seconds here), DPT1 can settle into a diverse range of states, especially if there is clipping or distortion in the loop. Smoothing and delaying the frequency inputs of the oscillators by different amounts can also enrich the emerging dynamics.

3.6 Disagreeing Pitch Trackers Two

A similar approach to pitch tracking and making the disagreement in results between algorithms palpable was made using the Pd-vanilla language, The sigmund~ and fiddle~ objects are used to identify pitches in the input and to set the frequencies and amplitude envelopes of two sine waves. These signals are also ring modulated to enhance the perceptibility of their disagreement. The performer can cross-fade between the sine waves and their ring modulation. The identified pitches and their absolute difference as a disagreement measure are made available from DPT2 to other patches (e.g. to parameterise the LFSR, see below).

3.7 Eternal Resonance Machine

The ERM is a means for converting any input into a sustained noise texture. On receipt of a button press style event, the momentary spectrum of the sound is subject to an 4096-band FFT and used to synthesise a sustained frozen noise. Successive button presses will add partials to the sustained sound if their FFT bands are louder than in the last analysis. Button presses will also momentarily open a gate to pass the input sound to Pd's freeverb~ set to a large room size with little damping. When the gate closes, the reverb is frozen to give an infinite reverb effect. This gives an alternative way to synthesise a spectral noise from input sound. The performer can cross-fade between the two methods and reset the analysis (which fades both kinds of noise to silence).

3.8 LFSR Sequencer-Synthesizer

An 8-bit linear feedback shift register (LFSR) was implemented in Pd-vanilla. A flexible design was adopted where the last bit could feedback to any of the 8 positions in the register for exclusive-OR combination with the position's contents. This creates an algorithmic system which can generate a variety of behaviour from the digital pseudo-noises of maximal length sequences to varied periodic behaviour. The values in the register were interpreted both as a 8-bit sample values to be read into a wavetable and as 8-bit specifications of frequency with which the wavetable (or a sine or a square wave) would be played. The rate at which the LFSR is clocked and the centre and range values of frequency could be determined manually or received from other processes (e.g. the Disagreeing Pitch Trackers). In this way, pseudo-noises or pitched sequences could be generated which followed identified profiles.

3.9 Emotion Recognizer-Generators

We reversed-engineered a music-psychological study that aims to demonstrate a mapping between given musical 'features' (timbre, tempo, mode, register, articulation, dynamics) and 'emotions' [12] on the basis of rating judgments given by listeners to various transformations of simple melodies. Working in parallel, we each independently came up with ways of trying to estimate these six features from an audio stream. Then, using the paper's experimentally derived table of correlations between features and emotions, we constructed a mapping function between 'features' and the four 'emotions' examined in the paper (happy, sad, scary, peaceful). We then set about using this mapping for generative purposes. One of us made a noise/drone generator, which constructed a spectrum based on a shifting histogram of detected pitch classes that was modulated using the detected emotions and features. The other of us made a melody generator which, on the basis of the emotions recognised in the input audio stream, estimated values for the six musical features analysed by [12] and played back notes synthesised with enveloped, filtered sawtooth waves.

3.10 Random Sample and Holding

The instantaneous digitised value of an input audio stream is sampled at random intervals and read into a wavetable, the insertion point wrapping round when the table is full. Following the fractal expansion technique outlined in [5], the wavetable is read to generate long patterns of nested amplitude modulated sound. The reference rate for reading the wavetable can be set as a linear function of the currently sampled value or from other pitch tracking processes. The range of the random sampling intervals can be set in performance. The output can vary from a noisy reconstruction of the input through a slow pattern which can variably follow the pitch content of the input to a distorted granular-sounding stream.

3.11 Arduino Nano Circuit Noise

The analog-in values from an Arduino Nano are read into wavetables and used for direct digital synthesis via nested amplitude modulation as described above. The terminals are left floating so they are respond in unpredictably interactive ways to touch and circuit noise. This creates a five oscillator digital synthesizer capable of a range of distorted, bit-reduced and granular-sounding textures which can be steered by touch but not precisely played. Two improvisations were recorded and used by us in performance as a fixed media element.

3.12 Schlechtmusik

In recognition of the prominence that Mozart's music has in the history of algorithmic composition and machine listening [18], we took a recording his *Eine kleine Nachtsmusik* and extracted its tonal component using Izotope RX. We followed this with a sinusoidal analysis using Spear and made various resyntheses. For example, we made a version which was reconstructed out of banks of sine waves, another which retained only the transients and yet another in which the tonal analysis was read at a slow rate to generate a 45 minute texture. To explore how machine listening techniques might react to suboptimal renderings, we also degraded the original recording by playing it back in a reverberant space, freely talking over it and recording the result using a gain structure with a tendency to distort. We selected five versions plus the original and mixed them using a good to bad (Nacht- to Schlecht-musik) crossfader. We informally calibrated the crossfader so that at extreme good/Nacht the online music recognition service Shazam (www.shazam.com) accurately recognises *Eine kleine Nachtsmusik* while at extreme bad/Schlecht no results were returned, with an approximately 50% hit rate in the middle.

3.13 Sincere Resynthesis, Violated

Using sigmund~ feeding an oscillator bank with a generous number of partials (100), we found that a reasonable facsimile of even a noisy environment could be rendered, but that it was a simple matter to reduce this to a sludge of artefacts by over-smoothing frequency and / or amplitude tracks. The degree of over-smoothing was made a function of the distribution of averaged spectral centroid in the space by building a histogram (periodically cleared), that was occasionally sampled as if it were a PDF and used to set the amount of smoothing.

3.14 I Am Sitting in Skype

Following the same principle as Alvin Lucier's *I am Sitting in a Room*, a prepared text was read by one of us and recirculated through Skype until its original identity had completely dissipated. This was roughly 30 iterations. In contrast to the shifting resonances of Lucier's acoustic version, the accumulating artefacts included bursts of noise and clicks, and the appearance of a distinctive crescendo of bass-drum-like impact sounds partway through, as well as the chirpy filtering we had expected. Our text was from a review of Abraham Moles' *Information Theory and Esthetic Perception* [15], and formed a fixed-media component of the final presentation.

3.15 Re-De-Reverberation

Using a de-reverberation plugin (www.zynaptiq.com/unveil/) and a reverberation pedal (shift-line.com's A+ Astronaut), we constructed a controllable feedback loop, stimulated with chirps, noise bursts and crackles programmed in Pd-vanilla, and recorded a short improvisation that was used as a source of fixed material in our presentation. The plugin enables reverberant components to be boosted as well as suppressed, using a 'focus' parameter, and it is easy to mistune the settings to generate artefacts. The resulting material had a drone-like character but did not tend to collapse into indistinct mush.

3.16 Miscellaneous Makes

We made a number of other explorations which we will only briefly relate here. Many of these concern processing fixed media material using offline processes or involve recordings that for reasons of practicality could only be appear in our work as fixed media. For example, one of us created a piece entitled *Maximum Zero* which takes a recording of David Tudor performing John Cage's 4' 33" and subjects it to brickwall limiting to bring out the environmental sounds around the performance at maximum intensity. One of us also made recordings using the aerial array and amplifier designed by NASA's Radio Jove to bring recordings of the radio transmissions of Jupiter to our project. We also made experiments to see whether we could transmit the results of our machine listening analyses via non-standard means. This included an encoding of identified pitches as audible Morse messages, which we decoded and played back in a feedback loop. In this way, we sought to corrupt conventional understandings of the relationship between representation and the represented and between signal and noise.

4. PERFORMING OUR WORK

4.1 An Immersive Environment

Our first presentation of this work was in the Spatialisation and Interactive Research Lab (SPIRAL) at the University of Huddersfield which offers 25.4 channels, in the form of three vertically stacked rings of eight, plus a ceiling mounted speaker directly above the monitoring position. All the makes that had real-time listening processes took their input from two channels from a DIY binaural dummy head. We approached these spatial resources by assigning particular makes to a single speaker or to a pair (not necessarily adjacent), rather than on the idea of moving sources through space. Our reasoning for this was that, first, this allowed more or less scrutable relationships to emerge between processes as they interfered with each other, and second, that it also encouraged visitors to explore the space, and discover different points of focus. We had some control over each process, in the form of individual gain faders, 'nudge' buttons which would push an individual process into a new (possibly random) state, and a combined overall control on a boundless rotary encoder that would affect all processes. This combined control yielded 24 separate control signals internally, based on a set of transfer functions. Processes were free to use whichever of these we fancied, however we wished, the object being to generate variety with coherence. For example, processes like the crossfades on the Anti-Gates or the ERM could set by the values from the transfer functions.

(Note: The dummy head was named *Stookie Helen* continuing a theme of dummy heads in the work of one of us. *Stookie* is Scots for a rigid cast or effigy. *Helen* was for Helen Duncan, the last woman to be convicted of witchcraft in the UK, 1944).

4.2 An Improvised Durational Work

Under the provisional title of *All The Noises,* our work was first presented on 18th January 2018, and occupied territory between a performance, an installation and a research presentation. We started with a brief, 15 minute, performance whilst an audience of colleagues and members of the public arrived and explored the space. We then set the system into a lower-key state whilst we explained our project to the room at large. Thereafter, we had a steady trickle of guests passing through and we would alternate between talking, nudging the system, and demonstrating brief performative moves. Finally, we concluded the session with a 10 minute performance crescendo.

5. REFLECTION

5.1 Audience and Performer Reflections

Audience feedback from our presentation was very positive. Attendees indicated that they understood the impetus for the project, were sympathetic to our aims and saw the value of our approach. They also expressed their enjoyment and interest in the artwork as such, remarking on how engaging and varied the sound world was. A recurring comment, especially from audience members with some experience of live electronics and machine listening, was to note how controlled the overall environment seemed, with no blow-ups or collapses. This may be due in part to the heavily controlled environment of SPIRAL which enjoys copious acoustic treatment across the whole audio spectrum. More than one person noted that it would be interesting to try the piece in a less controlled, more reverberant environment, which we are keen to try in future work.

Some attendees also noted a cybernetic character in the assembled piece, with multiple processes all in feedback loops with each other and human action being part of the mix. This corroborates our experience of performing the system, in that the most dramatic changes in sound world and medium-term behaviour came from changes to the relative gain structure of the processes, rather than alterations to individual parameters. Our shared feeling, emerging from this period of intensive work, is that we have laid the foundations for a fruitful research tactic, as well as a collaborative piece worth continuing to refine and perform in more public settings.

5.2 An Annotated Portfolio

To develop some unified insights into our collection of makes, we developw them into an *annotated portfolio* following the approach of [4,5,6]. This allows us to draw out themes between the pieces, and in the assembled performed work, and show how these connect to issues within the NIME community.

5.2.1 Creating Noise
In one way or another, many of our makes are concerned with bringing to the attention of performers or audience *something noisy*. This can be in a straightforward sense, as with the Arduino's circuit noise, or reconstructing the soundfield using a noise model. However, a concern in this project has been to explore noise's polysemy as a kind of allegory for the gap between people's situated, embodied practice and the sorts of selective reductions we make with machines and interfaces. For example, our emotion recognizers-generators or the disagreeing pitch trackers bring forth a kind of noisiness by weaving in and out of scrutable, sensible responses to the auditory field.

5.2.2 Negating Noise Control
Algorithms can be viewed as mechanisms for extracting order from disorder or for identifying an 'essence' of musical input and discarding surface variation (as noise). A number of our makes destabilize this principle. This is quite blatant in a couple of examples, such as driving Skype's echo cancellation, double-talk detection and so on to becoming their own source of material, or in letting a de-reverberator do battle with a reverb pedal. In other instances, it is more implicit: noise control is neglected as a consequence of getting things done swiftly (e.g. oscillators' control signals aren't smoothed), and perhaps added in later *after listening* as a mechanism for producing a range of material, rather than a fixed constraint.

5.2.3 Opaque Practice
We contend that there is no *a priori* reason for treating either states of flow or complete gestural scrutability as ends in themselves for musical interfaces. Rather, degrees of instrumental *resistance* [17] or causal mystery are vectors than can be explored productively. Many of our makes exploit this by dint of their semi-autonomy and, in some cases, nonlinearity. For instance, in both the random sample/holding and the variations on shift-registers, what we hear can be more or less remote from the environment being 'reconstructed', which is a function of the internal logic of the devices themselves, and their precise settings (in relation to their input). Meanwhile, the anti-gates are intrinsically hard to control: there is always a thin zone between explosion and collapse. Moreover, the opportunities for dislocation and confusion multiply when the whole assemblage of makes is in action. We regard this by no means as a shortcoming, but as a idiomatic feature of the work that signals the kinds of aesthetic labour that performers and audience are engaged in. Very commonly in computer science, we speak of 'transparent' processes in which inputs regularly, predictably and non-problematically yield outputs without distracting the user into having to ponder a process' inner workings. Desirable though this might be in many applications, in creative settings such as those we engage with, there is a least as much value in the opposite: practices which have a noisy uncertainty to them in which the contingent work of performers and the audience is highlighted and which, if the former are 'transparent', must be named 'opaque'.

5.2.4 Letting The Environment In
A key concern here is that neither sounds nor performative gestures are something that we are especially interesting in purifying in relation to some putative ideal. Our 'live' makes have in common that they do not seek to insulate themselves from their environment, or aspire to any degree of invariability in different performance settings. Our expectation would be that different circumstances can and should give rise to palpably different behaviours, and that part of our task as performers is to cope with, or even profit from, this. Our approach to performance is to allow our makes to cohabit with each other and produce patterns and textures apparently independently of our performance gestures. A number of these makes, such as Disagreeing Pitch Trackers One and Electric Field Resynthesis, feature quite substantial but variable delays at their inputs, in order to try and accentuate the range of different patternings that can emerge, much as can be found in some of Agostino Di Scipio's work [11].

5.2.5 Sincere/Insincere
Our makes walk a narrow line between, on the one hand, being sincere attempts to work with established research in machine listening and genuine attempts to construct processes which embody well-engineered principles, and, on the other, somewhat tongue-in-cheek responses which willfully push techniques in a direction they were not intended to take and which have an eye for absurdity and a little humour. For example, having sincerely made an effective resynthesis technique, we then show our insincerity by violating it with over-smoothing and emphasising artefacts. Similarly, having painstakingly engineered an emotion recognizer loyally following published research, we make a synthesiser which generates patterns found to show the same emotions (but only an algorithm could possibly think so). In these makes, we are not mocking existing research so much as to explore the field's boundaries and limitations. Similarly, we are exploring the utility of available machine listening techniques never mind their limitations, provided a rich enough experimental context is given for them, perhaps one like our *All The Noises* where many processes can chatter to each other.

6. DISCUSSION
We characterise our approach as a creative response to and appropriation of research in machine listening. Our orientation to the work we reviewed in the introduction to this paper is respectful yet also irreverent. We are not just *using* prior research as *hijacking* it to a new destination. In this way, we can explore the boundaries of existing research and, we hope, uncover new possibilities for research and creative work - a familiar theme in endeavours which draw on 'Research through Design' traditions. Let us discuss three upshots from our work.

6.1 A Noisy Design Space
We gave a brief documentation above of some 18 makes and presented them as a portfolio which could be analysed in relationship to five annotations [cf. 6]: creating noise, negating noise control, opaque practice, letting the environment in, and sincere/insincere. The activity of analysing a collection of makes into an annotated portfolio is one where we bring out the relationships of similarity and difference between the makes. It also enables us to describe a potential design space for new work. We intend our annotations not merely to retrospectively characterise what we have made but also to prospectively outline possibilities for the future. We believe that a design space, in which we create many different varieties of noise, do not attempt to eliminate it, recognise our own and our audiences work in sense-making, allow our processes to be permeable to each other and the environments they find themselves in and do all this with a mix of rigour and playfulness, sounds like a rather exciting addition to NIME.

6.2 A Sonocybernetic Aesthetic
In *All The Noises,* we creating an environment in which many of the processes we had investigated interacted with each other. It was designed as an immersive yet perambulatory space where audience members could experience sounds all around them but also explore and 'lean in' to streams of particular interest. Participants to the environment can also influence its

behaviour by shaping the relationship between what the speakers give out and what Stookie Helen takes in through interpolating their bodies and making sounds of their own. What we have here, then, is a piece of work that can be understood as embodying a number of sonocybernetic aesthetic principles, as recognised also by some members of our audience. *All The Noises* is bound up with its environment. It takes its character through complex feedback relationships. It uses noise as an agent of change. It features heterogeneous materials, human and non-human, and includes repeated loops from digital to analogue to physical and back again. In these ways, many of the concerns of *All The Noises* reflect those of Gregory Bateson, Gordon Pask, Anthony Wilden, amongst others. However, it is worth making a contrast between our rather unruly sonocybernetics and the work of Agostino Di Scipio who, through *Audible Ecosystems* [11], sought to develop an alternative discourse around interactivity with a divergent approach to machine listening, also embedded in second-order cybernetic thinking. Whilst Di Scipio's pieces are elegant, paired down affairs that explore a particular 'noisy' phenomenon, our rather more inclusive style has enabled us to sketch a research approach for producing speculative, playful and environmentally embedded pieces that adopt an exploratory attitude towards what machine listening might 'tell' us.

6.3 Performative Research

We chose to make our durational presentation of *All The Noises* occupy a hinterland between installation, improvised performance and research presentation. This has led us to reflect more generally on the performative character or our work. We identify a three-fold.

- Straightforwardly, we research to create performable techniques and technologies (research *for* performance).
- We also present our research performatively (research *as* performance), both in the sense of occupying a stage of sorts and in the philosophical sense of trying to make something so by uttering it [3].
- Importantly, we also fold performance into the research process, performing to and with each other (performance *in* research). We test out and establish new channels to explore and try to avoid over-engineering our work by returning to performance as quickly and often as needed. Simultaneously, we may perform *at* each other, adopting contrasting roles in order to maintain the dialogical energy needed.

Performative research is, for us, a thorough-going artistic practice which valuably complements an equally valuable and well-represented functional approach. It allows us to approach prior work with respect, yet irreverence, whilst, in machine listening, investigating a domain with very many unknowns which can be misleadingly over-simplified when researchers try to specify a tractable engineering research question. In the creative domains we inhabit, there is a notable (and desirable) absence of established normative listening practices, instruments and fixed aesthetic criteria. But this need not deter the performative researcher willing to hijack existing work to expose new possibilities where listening machines are rerouted to find themselves in the ontologically noisy, and hence creative, territory between people and algorithms.

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8. REFERENCES

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