'A Hapless But Entertaining Roar': Developing a Room Feedback System through Artistic Research and Aesthetic Reflection

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ABSTRACT

This paper presents a room feedback system which the author has been developing and performing with for nearly three years. The design emerged from an artistic research process which emphasises multiple explorations coexisting around a research topic while having a sensitivity to the practicalities of a customary gig (short set-up time, unpredictable acoustics). Typically enabled by a stereo room-mic and a pair of speakers, many algorithms have been explored in the loop with some being tributes to historical feedback works. An overall design is offered where all feedback pathways are simultaneously available and mutually interfere via the room. Each algorithm is designed to have one significant performable parameter but how this is mapped to sensors or widgets is itself performable with various behaviours available, including some explorations of self-programming and 'intra-active' ideas. Concert experience in solo and small ensemble formats is discussed and a number of contributions are identified in how the work: extends room feedback research to explore multiple parallel processes of varied spectro-morphological character, offers connections to historical work in a pedagogically interesting fashion, demonstrates several novel algorithms, while exemplifying a characteristic artistic research method. The paper closes with a speculative 'feedback aesthetics' to help configure future work.

Author Keywords
NIME, feedback, room feedback, interaction, intra-action, artistic research, performance ecology

CCS Concepts
- **H.5.5 [Information Interfaces and Presentation] Sound and Music Computing.**

"…the hapless but nevertheless entertaining roar of feedback…"
Roy Brassier

1. INTRODUCTION
This paper reports on nearly three years of artistic research, technical development, and performance with a room feedback system. Feedback has a long musical history with often-cited contributions including the electronic circuits of Bebe and Louis Barron stimulated into unpredictable self-oscillation [2], the electric guitar of Jimi Hendrix heavily overdriven and amplified, and the matrix mixing and related techniques that can be found throughout David Tudor's music [3, 4]. Feedback is ubiquitously employed in modular synthesizer patches and many current commercial synthesizers build in feedback paths to, for example, overdrive an analogue filter. Many artists have found feedback to be a valuable aid in extending or repurposing the capabilities of commercial devices as in, for example, Toshimaru Nakamura's no-input mixing boards.

In NIME and allied research worlds, we have seen a number of instruments and interfaces built around interactive feedback. This includes: the feedback cellos and self-resonating vibrotactile instruments of Eldridge, Kiefer and colleagues [15, 16], the hybrid resonant assemblages of Bowers and Haas [5], Paul Stapleton's VOLA [9], Halldór Úlfarsson's augmented cello [6], Adam Pultz Melbye's feedback actuated augmented double bass (FAAB) [13, 14], Ward Slager's Pandora's Box [7], amongst others.

Several writers have begun to reflect on the overall character of feedback music categorising the different ways in which feedback is implemented [8], analysing interviews with feedback musicians [12], and speculating on the philosophical and aesthetic issues that feedback connects with, including an examination of contemporary cybernetic and posthuman thinking [14].

2. DESIGN METHOD
The research reported here was initiated in the early days of the COVID-19 pandemic as a personal response to lockdown conditions in the UK. Housebound, I reflected on the character of enclosed spaces [17] and the experiences of those confined to them, from prisoners [19] to mystics [18]. In this setting, it seemed appropriate to develop a room feedback system but one which was capable of many different ways of creating room sound to, as it were, enliven the room rather than accept its fixed modes, thereby creating an interesting aesthetic contrast to, say, Alvin Lucier's *I Am Sitting In A Room*. While the gently modulating, contemplative work using microphone feedback and long tape delays of Éliane Radigue in *Vice-Versa* and *Feedback Works 1969-1970* was part of my lockdown soundtrack, I also sought more dynamic ways of creating and intervening in the room's sonic confinement, perhaps to please restless prisoner Jean Genet as much as contemplative mystic Julian of Norwich. For this reason, Di Scipio's [21] insistence that the "sound is the interface" and the ever changing feedback roomscapes of Collins' *Pea Soup* [23] were valuable influences.

Within this aesthetic framing, I adapted the artistic research methods I and colleagues have previously worked with [24, 25, 26] and engaged in a proliferation of different ways of creating and working with room feedback, with the intention not so much of finding 'the best' or 'the most innovative' but of exploring the design space of room feedback through many different 'samplings'. This included novel approaches to be sure but also incorporated my own attempts at replicating techniques from room feedback's history.

In common with [25, 26, 5, 9], I worked with an assemblage idea whereby the different algorithms I explored could all be brought into contact with each other in an open, incrementally developing system. In this, the room came to have an extra status as a kind of design

NIME' 23, May 31–June 2, 2023, Mexico City, Mexico.

metaphor. I saw the system I began to develop as a kind of room, one which could accommodate many different participants (algorithms and guest instruments) and their encounters, and be tolerant of their comings and goings.

I worked with computationally frugal algorithms so that the system could run on one processor of a contemporary laptop or, in a cut-down but still recognisable version, on a microcontroller-based environment such as Bela [10]. These were the resources available to me, locked down. I did not explore methods for pre-processing or detailed analysis of, say, room acoustics. I preferred that the behaviour of the system should emerge in performance and through how its behaviour is configured by the room, the algorithms which process room sound, and how the performer works with/in the system.

There was also an early commitment to develop with a conventional MIDI controller in mind and to support the gestures of a player at such a device. While it is easy to imagine alternative controllers finding a use and, say, hybrid devices which combine movable microphones or speakers and sensors, this is deferred to a later stage of exploration. I discuss the controllers I had available to me later in this paper. They all had the format of a series of channels, each with a fader and a small number of knobs on buttons. Their build gave a number of hard design constraints which I was happy to work with from the start. As we will see, I explored algorithms for sound processing with only a few controllable parameters (knobs) or modes (buttons) in an overall design which mixed their amplitude (faders).

3. THE FEEDBACK SYSTEM

The system has been in continuous development for nearly three years with many different algorithms explored, several in many different versions. Throughout this time the system has been performed with, starting during lockdown with online streamed solo and collaborative performances with Paul Stapleton and Adam Pultz Melbye (as the trio 3BP), and more lately in traditional gigs. My performance experience is discussed later in the paper. Here, I described the state of the system as of 7th April 2023, the publication deadline for NIME 2023, but also the day of a solo gig in which it will be played.

Overall Organisation. Figures 1 and 2 depict the overall organisation of the system by way of a screenshot and a functional block diagram. Twelve different algorithms are present, all implemented in Pure Data (PD, http://puredata.info/). A software gain control acts globally on the input, post [adc~]. All twelve algorithms send their output to two summing busses. After passing through a gain adjustment stage, these busses are output to [dac~] which communicates with the audio interface, ultimately sending the sound to the room. Eleven of the algorithms receive the same two channel input. The twelfth is an internal feedback loop containing a variable long delay and an optional convolution reverb. This internal loop receives input from the summing busses.

Input Saturation and Output Limiting. While the confines of COVID-19 lockdown shaped the work, I wanted to develop something that was readily gigable when such opportunities returned. Many feedback musicians [e.g. Alice Eldridge, personal communication] have stories to tell about the fragility of systems, the sensitivity of their gain structures, and how beautiful effects at soundcheck get absorbed by the bodies of an audience when they arrive. By contrast I wanted something that was quick and easy to set up, was not overly sensitive to microphone and loudspeaker placement, and would not be liable to unwanted distortions, explosions or flatlinings to unbreakable silence. After much experimentation, I use a saturation function on the input to each algorithm:

[expr~ (if ($v1!=0, $v1/abs($v1), 0))*(1 - exp(-1*abs($v1*$f2)))]

a PD implementation of the equation specified in Reiss and McPherson [27]. The parameter ($f2) is set with a default for each algorithm individually to manage the saturation character appropriately. The defaults have emerged after years of

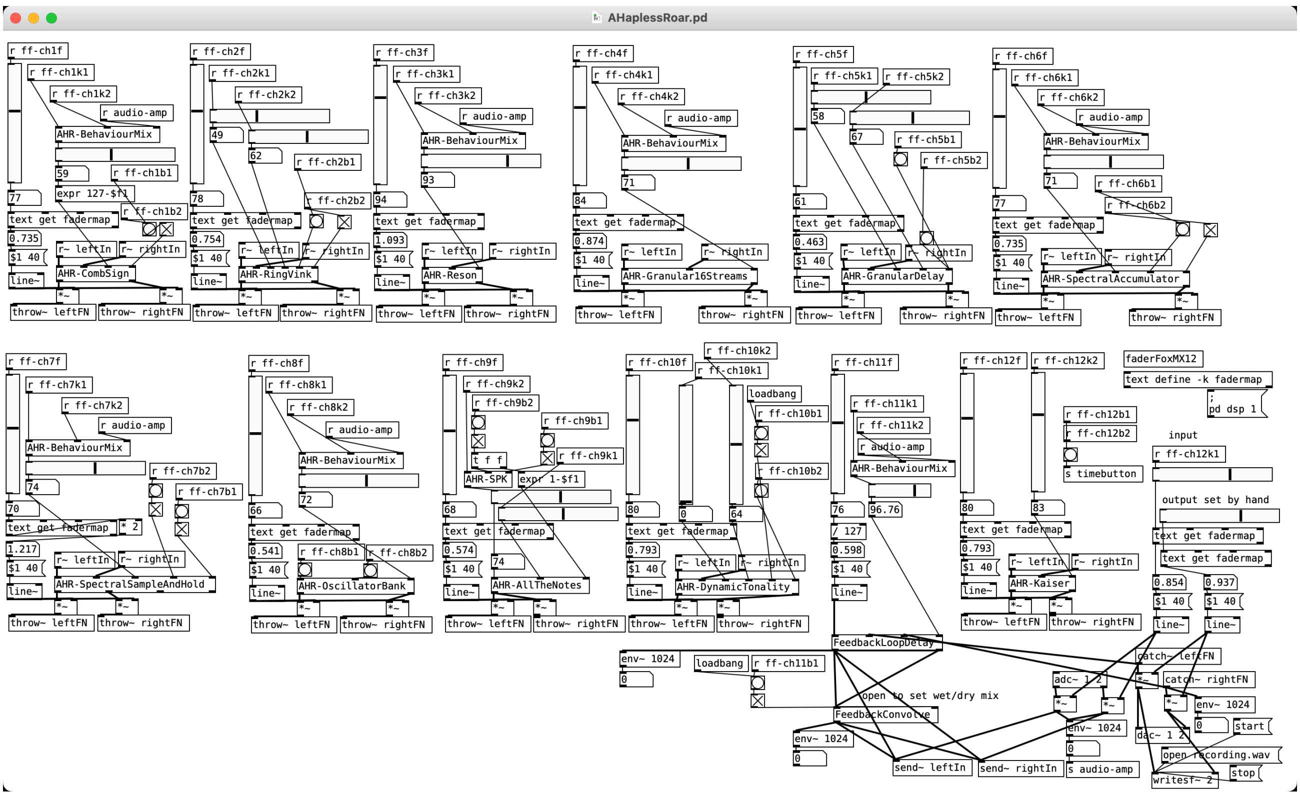

Figure 1. Screenshot of the Pure Data implementation of the feedback system described in this paper.

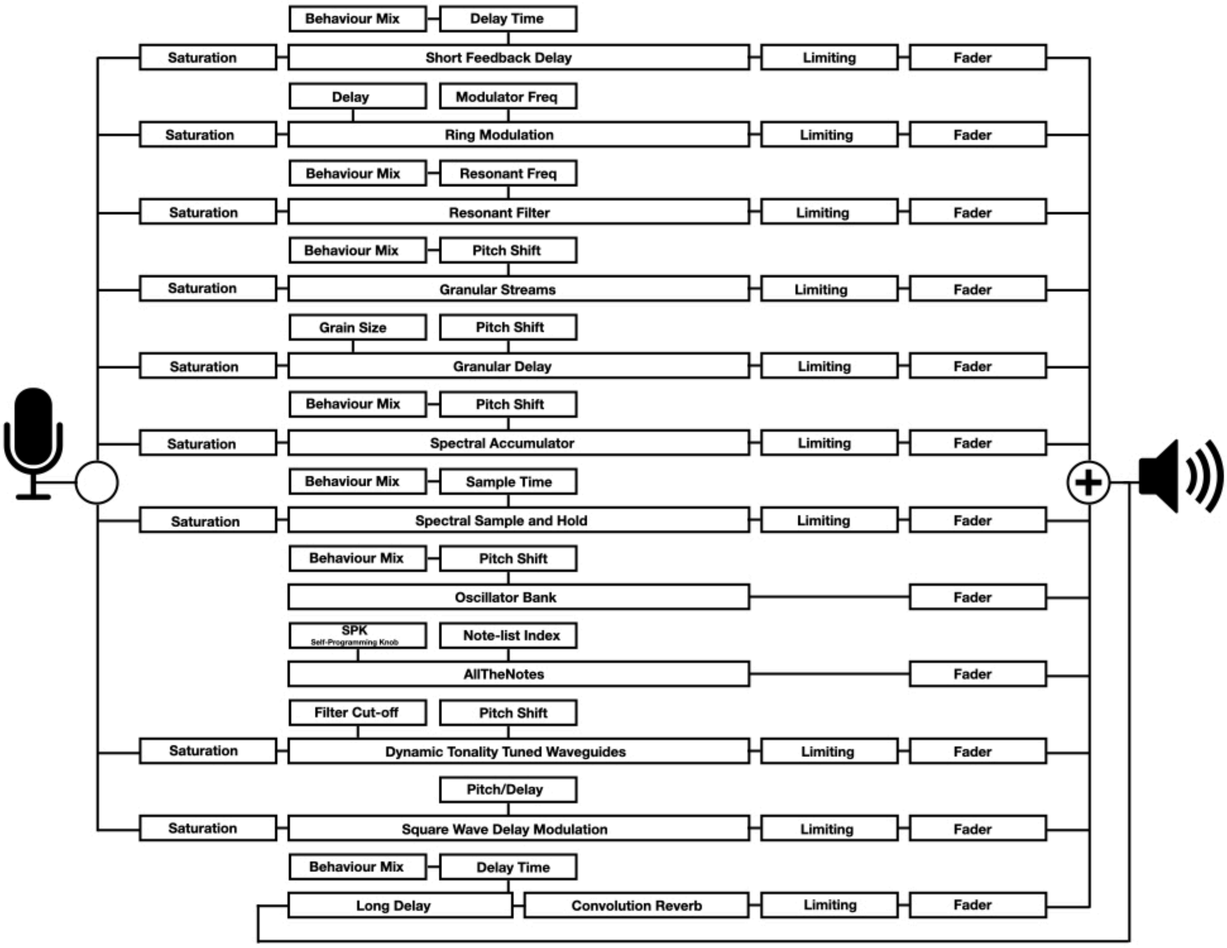

Figure 2. Functional diagram of the feedback system described in this paper, showing the sound processing algorithms and their routings.

experimentation and vary across the algorithms. For those algorithms whose output levels are unpredictable, a Hilbert transform-based limiter is placed on the output to give delay artefact-free amplitude limiting by default to 83dB (where, by PD convention, digital full-scale is 100dB). For this, I developed a two channel version of Katja Vetter's vcompander~ [28] set to perform signal limiting.

3.1.Algorithms

In this section, I describe each algorithm in the depicted version of the system and give some sketches of others which have been experimented with.

Short Feedback Delay. A variable delay is available of up to 12.7ms. Interpolation of delay times takes place if values are changed. There is an internal feedback loop to give comb filter effects with a coefficient of +/-0.91 determined by judgement. The sign on the feedback can be changed so as to obtain octave shifts.

Ring Modulation (Vink). This algorithm draws on the work of Jaap Vink [29]. Vink designed a very flexible analogue feedback system where the feedback signal was, in order, tape delayed, ring modulated with an oscillator, put through a voltage controlled amplifier (VCA), an artificial reverberator, and then a third octave filter bank before being looped back to the tape delay. The signal's amplitude was measured post-filter bank and inverted to control the VCA to avoid distortion by giving more amplification to quiet signals and less to loud ones. My version contains a digital feedback routing inspired by Vink's design. It can be fed by a mix of room signal and internal feedback, passing this to, in order, an interpolating digital delay, a digital approximation of a ring modulator by means of signal multiplication with a sine wave, a Schroeder reverberator [30], and a 10-band resonant filter bank. The coefficients of the filter bank randomly walk. The output of the filter bank is fed to both the overall output mixer and the feedback loop internal to the algorithm. The delay time (up to 2000ms) and the modulating frequency (8Hz to 6000Hz) can be set. A button press randomises the room size, damping, and wet component of the reverberator. Another button press switches the reverberator in or out. In this way, reverberation can be obtained from the room or artificially or both.

Resonant Filter. This is a simple resonant filter (PD's reson~) with a fixed Q of 80 and a centre frequency up to 12.5k.

Granular Streams. The room sound is sampled into a 20s buffer. Sixteen streams of grains are extracted from this buffer with random length between 0.1ms and 5000ms. Grains can be pitched up or down 2 octaves, and are randomly panned.

Granular Delay. An adaptation of Johannes Kreidler's patch [31] is used with delay times variable between 100ms and 30s, and +/- 3 octaves of transposition. On a button press, a delay/transposition pair can be randomly selected.

Spectral Accumulator and Pitch Shift. The room sound is analysed by an FFT into 1024 bins. The signal representing these results is passed through an infinite impulse response (IIR) filter with the previous frame being weighted W and the current frame weighted 1-W. W can be thought of as the 'weight of the accumulated past' or a control of spectral 'smear' over time.

The spectrum emerging from this calculation is combined with an FFT of white noise. The resynthesised signal is effectively a noise with a spectral profile that is an accumulation of the past with, at the extremes, W=1 freezing the analysed spectrum and W=0 updating it every frame, with values in between giving various flavours of pseudo-reverb. This synthesised spectral noise can then be pitch shifted +/- 2 octaves using an algorithm which simulates the tape-head rotation technique.

Spectral Sample and Hold. The room sound is analysed by FFT into 256 bins. This spectrum is then sampled and held driven by two metronomes. One of these beats quickly - varying between one trigger every 1ms and every 20ms. Sixteen of the bins are selected at random on a trigger. The amplitude of these bins is normalised and the other 240 bins are set to have zero gain. This spectrum is then cross-synthesised with pink noise, the roll-off of which gave less uncomfortable results in this algorithm than using white noise. The other metronome beats more slowly - between one trigger every 50ms and every 7620ms. All 256 bins are sampled on this trigger, normalised and cross-synthesised with pink noise. In this way, two noises are created, derived from different rates of sampling from and holding the room spectrum. Two buttons turn the samplings on or off - when off, the associated spectrum is frozen to a static noise texture.

Oscillator Bank. PD's sigmund~ algorithm is set to identify 'notes' in the room sound. Large analysis windows (up to 16384 samples) and analysis reporting (8192) intervals are selected to maximise frequency domain accuracy and make the rate of reporting manageable. The most recent 16 different note values are stored in a FIFO (first in, first out) stack. On a button-press, these values are sent to a bank of 16 sine wave oscillators. A control can transpose this bank +/- 3 octaves. A press on another button resets the transposition to 0.

AllTheNotes. While *Oscillator Bank* keeps a record of the last 16 different note values detected in the room sound, *AllTheNotes* keeps a time-ordered record of all values since the system was launched or the algorithm was last initialised. A control navigates through these data to select the note value to play. In this way, the pitch history of a performance can be played by sweeping the control. A wavetable oscillator is used with frequency and table values derived from another control. This technique is described in greater detail below (see *SPK: The Self-Programming Knob*).

Dynamic Tonality. This algorithm is inspired by suggestions of Sethares and colleagues for scales which can dynamically vary in response to ongoing sound [32]. In addition to finding notes, [sigmund~] is set to look for three frequencies which correspond to the three strongest partials in a sinusoidal model of the sound. Call these, in ascending order of amplitude, f1, f2, f3. The ratios f2/f1 and f3/f1 are used to generate a scale by repeatedly iterating each ratio up and down, taking modulus 2 of results to preserve a sense of octaves. Accordingly, each iteration adds 4 scale degrees. Up to 5 iterations of this calculation are repeated every time sigmund~ detects a new note. On a button-press, the most recently detected note is taken as a root and the derived degrees (plus root) are used to tune a bank of 21 waveguides made of tuned delay lines with high gain feedback. The whole tuning can be shifted +/- 3 octaves. The output from the waveguides is passed through a one pole low pass filter with adjustable frequency. In this way, partials present in the room sound can be reinforced or pitch-shifted and/or other spectrally related partials can be given the chance to emerge if they resonate with one of the tuned waveguides.

Square Wave Delay Modulation. This algorithm is a PD implementation of the signature technique developed by guitarist Henry Kaiser [33] initially for the Lexicon PCM-42 digital delay whose clock time can be modulated by a square wave. Kaiser sets the frequency and depth of the square wave modulation of a long delay line so that repeats occur time (pitch) shifted up and down (down and up) by the same ratio. In the early 1980s, Kaiser proposed this as an alternative to the long fixed delays employed by Terry Riley and in Robert Fripp's Frippertronics. The algorithm here uses a simulation of the tape-head rotation technique in PD (rather than forcing PD's clock speed to change!) with a nominal delay set to 4800ms (i.e. 2400ms an octave up, 9600ms an octave down), the maximum in the original Lexicon device. A control makes available a 5-limit pentatonic just intoned scale (plus octave) with ratios selected so that (with the exception of the octave) inversions do not also appear in the scale: 1/1, 5/4, 4/3, 3/2, 5/3, 2/1. This is used to determine time/pitch shifts. For example, selecting 2/1 will give pitch-shifts an octave up and down (half and double delay) while 3/2 will give pitch-shifts a just fifth up and down (2/3 and 3/2 times the nominal delay, 3200ms and 7200ms respectively). There is no feedback internal to the algorithm. Any further repeats will be via the room.

Internal Feedback Loop and Convolution Reverb. As shown in Figure 2, receiving its input from the bus which sums the output of all algorithms is an internal feedback loop containing, first, a variable delay with a maximum value of 20 seconds, this being selected in tribute to Di Scipio's *Background Noise Study* [22]. A control is available to set or modulate the delay time. Following the delay is a convolution reverb which made use of William Brent's [convolve~] object [38] which can be wet/dry mixed. While the system's primary use is to explore room feedback in the very room in which the system is located, the possibility to load Impulse Responses (IRs) from different rooms or imagined spaces was conceptually relevant to some performances. For example, in one networked performance of the trio 3BP, IRs from the locked down home studios of my collaborators were loaded into the system's internal feedback loop.

Others. Many other algorithms have been experimented with and several of the above have gone through different versions. For example, a simpler *Ring Modulator* in the loop was tried but it did not produce the variety of the Vink-inspired design. Other algorithms are, as-it-were, in the repertoire and could be favoured for particular performances. *Crusher* is an aggressive reduction of the room signal to a square wave with a switchable Schmitt-trigger with variable thresholds. Switching in the Schmitt-trigger reduces noise and setting a large separation between thresholds can turn the room sound into bursts of clicks. *Anti-Signal* puts an inverted and variably delayed room sound back into the room. *Quaternion Oscillator* uses an oscillator design of Miller Puckette where the room sound, rather than a synthesised impulse, drives the oscillator [34]. *Frequency Shift* uses an implementation of the single side band (SSB) technique. *Amplitude Modulation* amplitude modulates the room sound with a sine wave whose frequency can be adjusted over a wide range.

3.2. Inter- and Intra-Action

As was remarked earlier, development was done with conventional MIDI controllers (with a selection of sliders, knobs, and buttons) in mind and a variety have been explored including inexpensive ones such as the Korg Nanokontrol (8 channels each with a fader, a knob, and 3 buttons) and the Akai MidiMix (8 channels with a fader, 3 knobs, and 2 buttons, together with a master channel fader and 4 more buttons). These have both been experimented with and are small enough to fit in a gig bag. Preference though is given to a Faderfox MX12 which offers 12 channels each with a fader, 2 knobs, and 2 buttons with high quality components and lightweight long-throw faders, comfortably spaced, enabling dexterous movement, fast if needs be. The constraints of this device, and indeed of the 'MIDI universe', create design challenges which have been interesting to pursue.

[25], [36] and [49] report on a number of strategies for extracting much playability out of simple control surfaces by, for example, layering different mappings in few-to-many designs. In contrast, here, I have preferred a design strategy where the algorithms are typically implemented to pick out one or at most two key controls which have a clear performative consequence (together with a fader to control the amplitude of the algorithm's output). However,

exactly how these key performance controls work is itself performable.

This approach builds upon a philosophical perspective associated with Karen Barad [37] and introduced into NIME by Nyström [11]. Developing Niels Bohr's writings on quantum physics, Barad argues that objects and their properties, and phenomena and their character, emerge in encounters rather than pre-exist them. In her terms, objects intra-act rather than inter-act. Developing this, [11] presents some experiments where gestures, control devices, parameter-mappings, and sound synthesis all mutually configure each other. For example, a fast sweep of a fader might be interpreted differently from a slow sweep and sound synthesis may vary on the basis of the accumulated history of gesture rather than predicted on the basis of a single controller position.

Behaviour Mixer

For several of the algorithms, one knob is devoted to being a 'behaviour mixer'. This affects how the second knob (call it the controller) will be mapped to the algorithm. Seven behaviours were identified.

- Direct: the controller value, given by its position, is passed without change.
- Gray: the controller is transformed by a Gray code. In a Gray code successive values, when expressed in binary, differ only in one bit. However, as the significance of that bit varies, the jumps between successive values are distributed as a power law with small jumps most frequent and larger jumps being progressively rarer. This gives an interesting texture to a sweep of the controller knob.
- Collins: a random mapping function is computed at launch time - with all available output numbers selected without replacement, 'urn'-style. This technique is used to map the valve positions in Nic Collins' !trumpet [41]. It provokes the exploration of the mapping in performance, the playing of local 'sequences', alongside larger 'sample and hold'-style gestures.
- Triangle: a triangle LFO sweeps through all the values with the period of oscillation, P, set by three successive presses of a designated button. The controller serves to set the LFO's phase.
- Envelope: the amplitude of the room sound is measured with the same period, P. This is normalised in overlapping windows, scaled and output. In this way, the amplitude of the room sound can affect sound transformation, as amplitude affects phase-delay in Collins' *Pea Soup* [23]. The controller is ignored.
- Smooth: random values are selected and smoothly interpolated, ramping with period P. The controller knob value, given by its position, is passed instantly when it is moved but new smooth random values appear when the controller hasn't changed in P.
- Stepped: random values are selected with period P but without interpolation. The controller knob behaves as with smooth. These last two methods of obtaining random values echo the classic design decisions in Buchla's Source of Uncertainty synthesizer module.

Sweeping the behaviour mixer knob moves from one behaviour to another through a zone where the output of two is mixed. In this way, for example, the triangle LFO behaviour can fade to the envelope behaviour or smooth random can become stepped. This overall design allows a number of behaviours and mappings to be selected from and performed. Slow moving modulations in the manner of Radigue, amplitude driven delay times in the manner of *Pea Soup*, random sample and holds in the style of early electronic music, amongst different mappings of manual gesture are all available.

SPK: The Self-Programming Knob

The idea of a method of intra-action where how significant performance controls work is itself performable is carried to an extreme with the *SPK*, named in partial tribute to the Australian industrial noise band. This takes the 7-bit [0,127] value from a knob and writes it to a table (of size 128) at a given index. The index is then incremented by 1 and wrapped around to lie in the range [0,127] if needed, ready for the next value. Accordingly, the table fills with 7-bit values, holding the last 128 received. This table is construed as the mapping function from which the output value is derived. Just before the new input is written to the table, its value is taken as the index from which the stored value is to be read. This is then output. In this way, the *SPK* writes its own mapping function.

A switchable modification to this inserts the output, rather than the input value, at the current index in the table. This creates a variety of bifurcations and discontinuities in the table, adding to the range of behaviours that can emerge from the *SPK*. Finally, the mapping function can be iteratively sampled without taking new knob input. The output is used as the index to the table, the value stored there is output. This is then used as the next index. And so on. In this way, the *SPK* can be used as a kind of arpeggiator-sequencer, sometimes with short repeating patterns, sometimes with long periods, seemingly random. This behaviour can be modified further if the output is also switched to be stored in the table at the current index. This tends to cause the table, and hence the output, to settle to a small number of values, often just one constant. In the current design, to keep with the *SPK* philosophy, the timing for the metronome that governs the iterations is given by intervals between direction changes in the knob. In this way, the knob determines not only its own mapping function but also the timing of any process which iteratively uses the function. In *AllTheNotes*, one of the knobs is used as an *SPK* to generate output which, scaled, gives sample values for a wavetable. Its output combines with the output of the other knob to retrieve note values from the performance history. These note values play the wavetable oscillator with timing data taken from the *SPK*. In this way, *AllTheNotes* creates sounds which are an intra-active emergent of room analysis, gestural data, self-programmed mappings, timings, and sample data.

Direct Interaction

Where possible I have tried to implement intra-active concepts in how the control knobs and buttons engage with the algorithms. However, sometimes the algorithm cannot be happily reduced to just one essential control, now matter how ingeniously multiple parameters might be derived from this. On these occasions, the algorithm's playability is typically promoted by keeping two parameters independent and directly manipulable in a traditional inter-active fashion. The Vink-inspired *Ring Modulator* and the *Granular Delay* both seem more playable with a direct manipulation of two significant parameters each.

4. PERFORMANCE EXPERIENCE

I have performed with this feedback system on over 20 occasions in the last three years. This included live streamed performances during COVID-19 lockdown in solo, duo, and trio formats [e.g. 50, 51] and a number of performances at international arts festivals both solo and in small ensembles (e.g. with 3BP at NIME 2021 and the IF 2021 improvisation festival, Guelph, Canada, and at Piksel 2022, Bergen, Norway in the trio HPB with Kerry Hagan and Miller Puckette). In the early stages of development, I added the system to a performance setup which included many other elements (e.g. modular synthesizer, field recordings, effects units, a zither). Over the last year, however, I have done a series of performances where the system is effectively my only musical resource - one as part of a curated feedback music concert [52] a live recording of which has subsequently been released [53]. The system has also been used in studio recording contexts. Most recent to the time of writing, I performed a 4 hour long durational improvisation to mark the 2023 Northern Hemisphere Vernal Equinox using exclusively room feedback sounds [54]. The reader may wish to check citations [50-54] to gain an impression of how the system has been

Figure 3. John Bowers and Owen Green performing *The Brazen Head* at Sonorities 2022, Belfast, UK. A DIY binaural head picks up the room sound. Photo courtesy of Sonorities Festival.

Figure 4. John Bowers performing *Khôra For Slapstick And Room Feedback* at the Feedback Musicianship Network Concert, The Meeting House, University of Sussex, Brighton, UK, 2022. A slapstick interacts with room feedback. A Røde NT4 stereo condenser microphone is on the boom stand above the shot. Photo by Dimitris Kyriakoudis.

used and as a background to the discussion I now give.

The system is easy to set up. The inclusion of saturation and limiting components make gain structure a less critical issue than with many feedback systems. It is easy to adjust to the difference an audience makes when I have sound checked to an empty room. It behaves differently in different environments, and with different microphones and different placements (including in a DIY binaural head in *The Brazen Head,* a performance with Owen Green at the Sonorities 2022 Festival, Belfast, see Figure 3), but the algorithms are rarely mute, do not explode, and it is uncommon that interesting effects are unobtainable.

I tend to select a different set of algorithms per performance. I prepare them so that their left-to-right organisation on the Faderfox M12, for example, suggests 'trajectories' and supports 'adjacencies' that might be explored. In *Khôra For Slapstick And Room Feedback* [52, 53], the feedback was first processed with the algorithms I had placed to the left of the device (e.g. *Short Feedback Delay*), spreading to the right as the performance unfolded to halfway, but then with much to-ing and fro-in when interesting interactions had been discovered. In this way, the system is primed to help find interesting 'modulations' with the layout of the controller itself helping shape performance. However, my performances are strongly improvised, both by preference and in recognition that the emergent effects of feedback cannot be properly explored otherwise. I typically search out 'sensitive zones' where one feedback mode or behaviour slips into another in critical regions of some control or where the feedback flickers autonomously. I also search out combinations of algorithms which entangle with each other in interesting ways. The loss of human control that many feedback musicians celebrate [12] can be actively sought - a paradox I will return to at the end of this paper.

The algorithms have great spectro-morphological [42] variability between them, in part by design, but also through their responsiveness to room conditions and behaviour mixing. This makes it possible to organise performances by spectro-morphological contrast and similarity, to find layers and transitions, to vary intensities. I feel that the system is capable of supporting performances of an unusually dynamic character for work exploring feedback. This also helps responsivity to others in group improvisation formats. While I can generate drones and textures which form a 'base' or a 'canopy' to other musicians, it is also possible to swiftly react. For example, in the trio 3BP I commonly 'duel' the *Short Feedback Delay* algorithm with Adam Pultz Melbye's double bass played arco.

For me, perhaps the most satisfying feature of the system is its flexibility in terms of the contexts and ensembles it can fit in with, whether these work with a sparse responsive improvisation ethic or a full on noise assault, are acoustic or electronic in character, prefer scruffy pub-gigs or concerts in cathedrals, while also providing ample resources for solo work. This open character is discussed further below.

5. CONTRIBUTION AND FUTURE WORK

In this paper, I have presented a room feedback system which has been developed out of a process which combines artistic research, technical development, and performance practice. In terms of research in NIME, I think this work makes a number of contributions.

- It describes a system where many algorithms are made available simultaneously and can be mixed in performance and explored in how they entangle via the room. Di Scipio's systems often explore several feedback routes and processes [43]. For example, in *Background Noise Study* [22, Figure 4], there are four (delay, filter, resample, granularise). The current work develops that interest to offer a multitude of paths (here as many as 12).

- The work extends the spectro-morphological variation that is typical in a feedback system by offering multiple algorithms and varied behaviours and mixes of them to map (or disrupt or ignore) performer gesture.

- Some of the algorithms are novel in their application in feedback scenarios (for example, tuning waveguides through an application of dynamic tonality). The paper also describes some further experiments in 'intra-action' where how aspects of the system respond emerges in performance [11].

- The system incorporates tributes to several historically important feedback works. This gives the system a kind of pedagogical potential, as well as building a sense of historical development into the artefact in a literal sense. This, together with the long-term performance practice associated with it, engages with Marquez-Borbon and Martinez-Avila's [44] call for an alternative performance pedagogy in NIME that is concerned with longevity as much as innovation, see also [55].

- The work has been carried out within a tradition of artistic research that emphasises the proliferation of design alternatives which are then assembled performatively [26, 25, 24, 55]. These projects typically involve collective exploration. The current system is an example of how this approach can be applied to creating an 'assemblage' system within the practice of an individual artist-researcher.

- The system has an open character and can accommodate other performers and their sound-makers. It can help 'fold in' the contributions of multiple performers into a shared acoustic environment, giving a kind of augmentation to what a room does anyway. As such it helps create 'performance ecologies' [45, 46] where different musical resources are gathered and interplay.

In future work, I anticipate adding more algorithms to the system's repertoire and exploring more complex routings between them. Currently, the algorithms get to feed each other via the room. While this has a certain coherence and elegance to it, there is much scope for creating networks of algorithms [35] and, perhaps, making their topology 'intra-actively' configurable in performance. I have also begun explorations feeding back the room sound to modulate synthesis rather than, as in most of the algorithms discussed here, for the room sound to be processed. This works well in combination with the approach described here [54]. Most of my work to date has used quite simple set-ups with a pair of microphones and a pair of loudspeakers. Clearly there is much scope for the exploration of multi-speaker, multi-microphone arrays in more carefully considered physical architectures [cf. 39]. I have done some preliminary experiments with hand-held microphones and mobile loudspeakers, together with sensors or tracking technologies to capture movement data. Clearly, this offers a different kind of 'instrumentality' from a MIDI control box and suggests a different performance aesthetic, perhaps one more staged and focussed on the performer than the more modest presence that the wok currently manifests.

6. CONCLUSION: A FEEDBACK AESTHETICS

Magnusson and colleagues [12] write: "Rather than being a style or a genre, feedback is a technique". However, it is a technique that lends itself to certain kinds of musics and is in play with a bundle of related values and commitments, in what I would call, in short, a kind of aesthetic. Indeed, on the basis of a number of interviews with practitioners, [12] document some of these values and commitments under the headings of:

- *agency* - e.g. how feedback creates circumstances where performers can lose control and devices can exhibit autonomy

- *complexity* - how multiple factors can impinge on the feedback instrument or system and affect its behaviour

- *coupling* - how feedback couples performer and system in mutually transformative ways

• *design* - e.g. the exploration of design strategies to promote the emergence of autonomous systems

• *play* - the different forms of interactivity that performers can explore with feedback

• *post-humanism* - how some practitioners linked feedback music to forms of thought in which human/non-human relationships are rearticulated.

For many respondents, their position on these themes was developed in opposition to ideas of traditional musical and instrumental practice. While it should be clear that the new work I have presented can speak to all of these themes, I want to develop an aesthetic which does not set feedback music in opposition to other forms nor sees it emerging as a new genre [1]. Rather my experience in developing and performing the room feedback system is that it creates *an exploratory arena in which different framings of agency, complexity, and the rest can be put in contact with each other.* It is not so much that feedback music expresses, represents or materialises prior commitments but that room is (literally) given for their formation and juxtaposition in the duration of the performance.

Sometimes I just let the system be. Sometimes I search out for interesting phenomena. Sometimes I engage in vigorous fader-flipping, knob-yanking and button-pressing, which has a direct effect and sometimes a bizarrely mapped one. Sometimes the system can approximately return to a prior state, sometimes it has reprogrammed itself to make that effectively unfindable. My situation in this as a performer is profoundly variable. Sometimes it seems as if my (fader, knob, button) gestures are transduced and exert control over algorithms. Sometimes it seems that I am implicated in a kind of correspondence as multiple streams of sound and action become entangled. (On this contrast between transduction and correspondence, see Ingold [40]). To use Karen Barad's phrase, *there are many and varied 'agential cuts'*. And all this can change on a moment by moment basis, worked up improvised from within the performance, that is, *immanently*.

In his writings on the history of cybernetics, Pickering [47] argues that its various projects stand as 'ontological theatre' - that is, as means to help us reimagine what the world consists of. When writers in cybernetics tamed their fascination with complexity and saw ways to simplify and manage the world, 'control' sometimes worryingly approximated 'domination' [48]. In contrast, for Pickering, it is a 'cybernetics of uncontrol' that keeps an 'ontology of unknowability', without a desire for domination, alive.

I intend these room feedback experiments as a kind of *ontological theatre*, a musical one, where what music, action, and space consist in can be reimagined. I do not wish to tame their complexity and so I see *'control' as one instance in a sea of multiple possibilities*. Accordingly, the system I have described I treat, not as an instrument, but as *a playable design space* where designs can be introduced and juxtaposed with each other and with other goings-on in the room.

And all this to create a hapless but nevertheless entertaining roar.

7. ACKNOWLEDGMENTS

I wish to thank Queen's University, Belfast, UK for a visiting position at SARC during which I have deepened my musical engagement with feedback.

My friends, colleagues and bandmates in 3BP, Paul Stapleton and Adam Pultz Melbye, have been especially supportive in the development of this work theoretically, technically, and artistically.

I am also grateful to The Feedback Musicianship Network which was funded by the UK Arts and Humanities Research Council, and organised by Chris Kiefer (Experimental Music Technologies Lab, University of Sussex, UK) and Dan Overholt (Augmented Performance Lab, Aalborg University Copenhagen, Denmark) to whom I presented an early version of this work.

8. ETHICAL STANDARDS

The work reported here was self-funded by the author. It did not involve the participation of any human subjects. I have no conflicts of interest to report.

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