Exploring the music making and performance affordances of *ams,* a new acoustic modular musical machine, featuring a human agent.

Sam Underwood



Image credit: Jorge Sebastião Soares

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Abstract

What would an acoustic modular synth look and sound like?

Through the design, creation and use of a new and unique acoustic modular musical instrument system, entitled *ams* [æmz], this research makes the case for developing new musical instruments as a means of generating fresh opportunities for creative expression and novel repertoire, in a way that is less burdened by established habits and working practices. *ams* adheres to modular synth standards but with all sounds expressed and shaped physically and acoustically. The outcomes herein consist of the system itself—sixteen MU/5U modules across four module cases—presented module by module, along with compositions and performances used to identify the system's music making affordances in both studio and live settings.

Through the development and use of *ams*, a wholly new way of engaging in music making and live performance was established. Though modular acoustic and electro-acoustic multi-instrument systems are not unheard of, such an explicitly 'acoustic modular synth' is novel in its form and uses.

When considered alongside the work presented by pioneers in the field at the event series *Soundings*, which I organised and curated as part of this research, the inexorable link between an instrument's design and its affordances was clearly demonstrated.

The experimental and feedbacky methodology I employ is explored through both text and work-in-progress videos and can be seen to underpin my processes across design, prototyping, testing, recording and live performance; through continual revision. This is a relentlessly inquisitive whole system practice-research approach where everything is

intertwined and self-referential. Mine is a reflective practice where process and outcome enjoy parity. Where findings remain fluid rather than solid. More adjective than noun.

Presented in a media-rich hybrid form, including text, video and audio recordings, I expose the processes and outcomes of my research in a way that befits its sonic and visual immediacy, with the aim of inspiring the adoption of similar approaches; seeding new creative practices and sound works.

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Introduction

"Adaptations and importations are not the only engines of change. More radical innovations come through instruments that artists and composers invent, not to improve on what's already there but, variously – to start again; to explore musical ideas that are unsupported by existing resources; to test new materials; to force new thinking – even, on occasion, just for the hell of it."[1]

This research builds on and further interrogates my long-standing commitment to the design and development of new musical instruments as a path to novel musical outcomes. I approach this first as an experimental musician, with my work as a self-taught designer and maker necessary to achieve my vision and aims. Similar in this sense to Harry Partch who stated, "I am a philosophic music man, who long ago was seduced into musical carpentry."[2]. Though unlike Partch, I rarely build instruments towards a specific musical aim, preferring to encounter them experimentally once built. A commitment to such investigation and an openness to wide-ranging outcomes underpins my work.

1 Chris Cutler, host. "PROBES #31" *PROBES* (Podcast). 22nd October, 2021, accessed 16th October, 2024. https://rwm.macba.cat/en/podcasts/probes-31

2 Robert Hasegawa. "Harry Partch". IRCAM. 24th June, 2015, accessed 16th October, 2024. https://brahms.ircam.fr/en/harry-partch#parcours

My instruments are predominantly modular, mechanical-acoustic and electro-acoustic, and are created in part as a response to electronic music performances I witnessed from around the mid-1990s. This was a period in which it was often unclear to me what the invitation to be at such a live event was, with the act of music making often obfuscated, impenetrable, or simply absent. I have been turning my instruments and live performances inside out ever since, by which I mean I have been creating musical machines that are exposed to real-time human intervention. Placing a human performer/disruptor at the heart of my musical machines in this way, creates a form of human-machine music that is open, easily interpreted and reflexive, whilst maintaining many of the strengths of a machine, such as multitasking and hyper-virtuosity.

Nonetheless, many of my instruments stand on the shoulders of electronic music cultures I cherish, often featuring methods of playing, sequencing and performing that draw directly from them, alongside my wider fascination with the creation of 'electronic music sounds' through acoustic means.

This research was carried out through the design, development and use of my acoustic modular system, *ams,* which represents the most explicit rendering of this relationship in my work to date. It draws directly from electronic modular synths for its structure and control standards. The system to date consists of sixteen modules, in four cases, all operated using control voltage, with sounds generated acoustically and shaped physically.

This is a lively and burgeoning field. Figure 1 below, shows “the explosion in the number of artists making use of musical robots to create electroacoustic music that occurred in the 2000s and 2010s”[3]. Aside from the fact that this inevitably omits many practitioners, it seems to me that the growth demonstrated has continued to this day, due in part to an availability of new materials and technologies, including hardware such as microcontrollers, access to digital fabrication and a wealth of online shared findings.

3 Long, Jason, Jim Murphy, Dale Carnegie, and Ajay Kapur. 2017. *Loudspeakers Optional: A History of Non-Loudspeaker-Based Electroacoustic Music.* Organised Sound 22 (2): 195–205. https://doi.org/DOI:10.1017/S1355771817000103

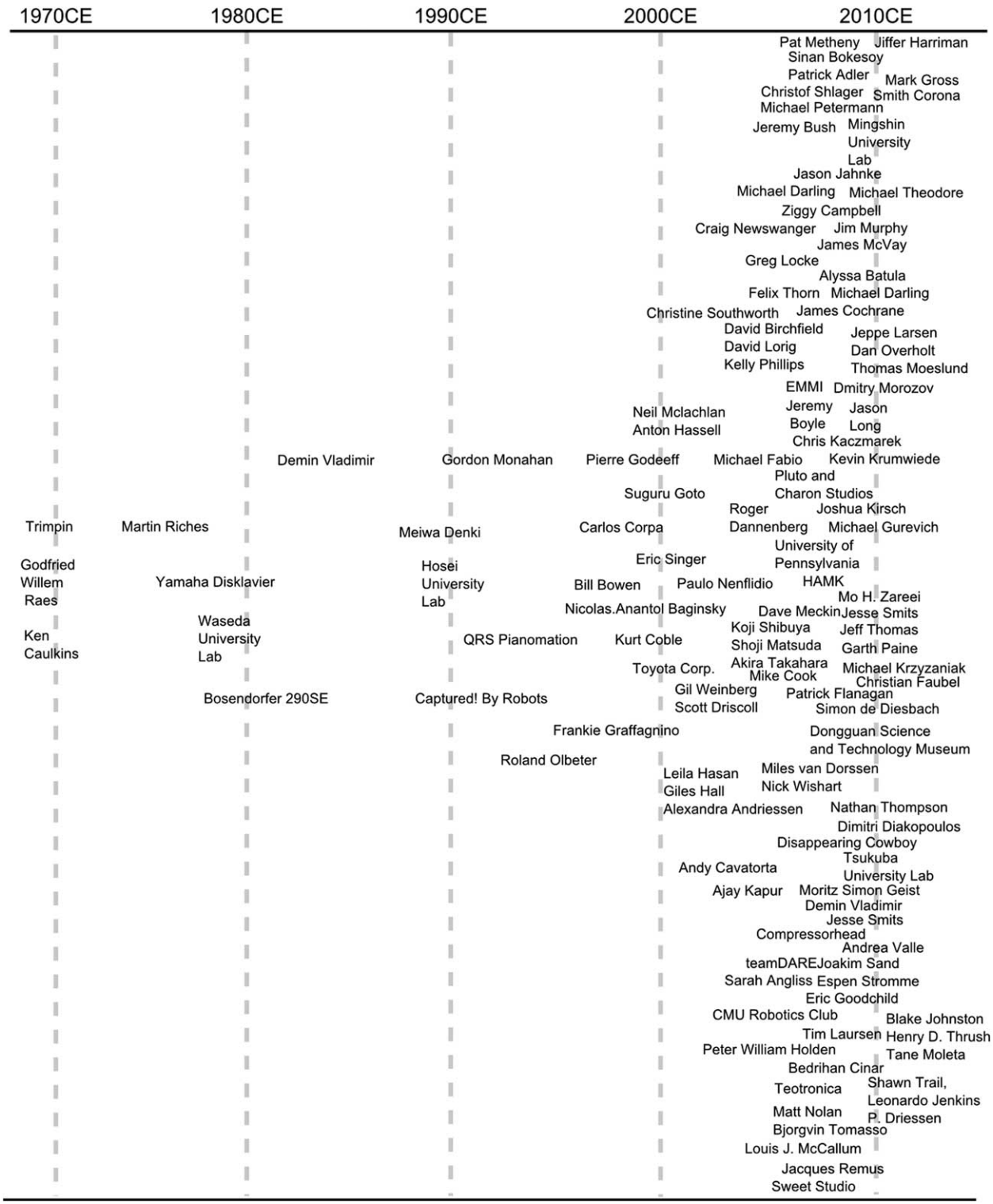


Figure 1 - Approximate dates of entry of musical roboticists[3]

The aesthetic goals in this field are inevitably diverse, with some practitioners more focussed on replicating human playing of existing instruments, such as Metheny's Orchestrion[4], to those for whom mechanisation is a route to more experimental musical ends, such as Pierre Bastien's self-built Mecanium[5]. My work, as demonstrated herein through the creation and use of *ams*, seeks to foster new and novel encounters with sound and music making, through a resolutely experimental instrument design and performance practice.

This also applies to my research methodology and the way in which I develop, or encounter, outputs, be they physical modules, novel objects and findings, recordings or live performances. In many senses, these outputs are the byproducts of an experimental and open-ended process. One that is considered holistically. Development is use and use is development. Crucially, this process *is* the work.

4 Copyright © 2013 Pat Metheny. "Pat Metheny : Pat Metheny Orchestrion", accessed 16th October, 2024. www.patmetheny.com/orchestrioninfo/index.cfm

5 Pierre Bastien. "MECANIUM – Home", accessed 16th October, 2024. www.pierrebastien.com/mecanium

This field is replete with pioneering work, presented on and offline, with a generosity of spirit. As a practice-researcher my work is influenced and shaped by instrument systems and trends that exist today, spanning a broad variety of creative and commercial aims, providing me with boundless inspiration. Examples of these include Korg's phase8 acoustic synth module[6] at Superbooth (their entry into this realm indicates a growing scene / zeitgeist); Koka Nikoladze's Beat Machines[7] or Gijs Gieskes' physical modular gear[8] (inspirational work that is adjacent to my own); Physical, live examples of work such as Sarah Nicolls' Inside-Out Piano[9] or Kathy Hinde's pieces Chirp & Drift[10] or Piano Migrations[11] (featuring the physical acoustic sound coupling I relish); Bart Hopkin's latest addition to his vast Instrumentarium[12] or Bear Kenchinton's extension to their pedal-powered orchestra[13] (endlessly probing methods of acoustic sound making); work-in-progress videos received from Graham Dunning showing his latest extended turntable[14] innovations (providing forward motion to our collaborations); and Wintergatan's latest Marble Machine[15] update (always inspiring if towards different musical ends).

6 Iaria, Tata, Lukas, Rachel, Tom. "Phase8", accessed 16th October, 2024. https://korg.berlin/products/phase_8

7 Koka Nikoladze. "Koka'S Beat Machine No. 5", Vimeo, accessed 16th October, 2024. https://vimeo.com/312694108

8 Gijs Gieskes. "Klok Eurorack Module", YouTube, 12th September, 2023, accessed 16th October, 2024. www.youtube.com/watch?v=lipytDM2010

9 Sarah Nicolls. "Intro to the Inside-Out Piano | Sarah Nicolls", accessed 16th October, 2024. https://sarahnicolls.com/intro-to-the-inside-out-piano/

10 Kathy Hinde. "CHIRP & DRIFT : 2018", updated 1st February, 2024, accessed 16th October, 2024. https://kathyhinde.co.uk/work/chirp-drift/

11 Kathy Hinde. "Piano Migrations : 2010" , updated 13th January, 2023, accessed 16th October, 2024. https://kathyhinde.co.uk/work/piano-migrations-installation/

12 Bart Hopkin. "INSTRUMENTARIUM | Bart Hopkin." Bart Hopkin | MUSICIAN AND INSTRUMENT DESIGNER, updated 31st December 2023, accessed 16th October, 2024. https://barthopkin.com/instrumentarium/

13 Bear Kenchington (formerly Sarah Kenchington). "Soundings #1 Sarah Kenchington" 3rd November, 2022, accessed 16th October, 2024. https://www.youtube.com/watch?v=IpUE_IZRyaY

14 Graham Dunning and London South Bank University, "Ironing in the Creases: Developing an Idiosyncratic Electro-mechanical Musical Instrument by Reinforcing Its Faults," NIME'24, 2024, accessed 16th October, 2024. https://www.nime2024.org/program/145/GD%20NIME%20FINAL2.pdf

15 Wintergatan. "Wintergatan", YouTube, accessed 16th October, 2024. https://www.youtube.com/@Wintergatan/videos

In addition, as part of this research I organised a yearlong programme of events called *Soundings*, which lifted the lid on the musical machines and working practices of many such pioneers. Common themes around action-sound[16] coupling, acousticness, performance practice and electronic music were covered, through both show & tell presentations and performances delivered by each artist.

This research is communicated in a media-rich hybrid form, befitting of the sonic and visual nature of it. Video is particularly prevalent as a means of demonstrating the coupling between action and sound when using *ams*, with work-in-progress footage also used as a means of providing insight into my working methods.

Through this research, I demonstrate the case for the design and probing of new musical instruments as a pathway to novel musical outcomes. This has been particularly fruitful where *ams* is concerned as it presents a never-before-encountered environment for music making. This forced me and others using it to interrogate and develop ways of doing so from a position of naivety and intrigue. Irrespective of its other features, *ams'* modularity alone opens the system up to fresh thinking, as one cannot encounter such instruments canonically. This led to a deep, reflexive and radical exploration of new sound making and performance opportunities.

16 Jensenius, Alexander Refsum. 2022. *Sound Actions: Conceptualizing Musical Instruments.* The MIT Press. https://doi.org/10.7551/mitpress/14220.001.0001

chapter overview

The following chapter overview outlines what is covered in each of the eight chapters that chart the development and contributions of my research, as encapsulated and expressed through the development of my acoustic modular system, *ams*. As the system itself is so central to this research, it is encountered first.

ams

Introduces *ams* as a modular musical instrument system and outlines the rationale that underpins its creation. The system itself, the thinking behind it, and its affordances in use, represent the most significant contributions of this research. This chapter and the accompanying ***ams - module catalogue*** therefore comprise in-depth commentary, specification and video documentation of *ams*.

ams - module catalogue

Details the affordances of each *ams* module and sub-module through technical overviews and accompanying videos. This is delivered in a similar form to other musical instrument catalogues with a mixture of standardised technical information along with media to aid understanding and provide a richer experience.

Design, make, experiment, repeat

Explores my iterative and experimental research methodology, through a combination of descriptive text and a video case study focussing on the development of the Shaper module and how this led to developments well beyond what was initially envisaged - see

the *Beyond the Shaper* video. The video uses work-in-progress footage to provide a direct insight into how my open and messy explorations combine to create new instrument designs, which themselves remain open to further exploration throughout.

Another cog in the machine

This chapter contextualises and situates my research through an exploration of key themes within the field of mechanical musical instrument design, reflecting on how my practice responds and engages with these areas. Work-in-progress case study videos are again used to show how my research operates in practice.

Soundings

Further situating my work, this chapter covers and interrogates the event series I ran as primary research into the field of experimental mechanical musical instrument design, which saw, and heard, pioneering musicians and instrument makers present their work. My work was presented alongside that of my peers and when considered in conjunction with the show & tell presentations, it served to frame and inform my research, as well as providing almost boundless inspiration and forward motion to my practice. Video documentation is again used to create a unique archive within this somewhat marginalised field, representing another primary contribution of this research.

Moving air

Charts the artistic outcomes of *ams* to date, covering the many different ways the system has been used in both studio and live performance settings. These are accompanied by my reflections on how they represent the state of *ams* at given points in its development and the impact on this going forward. As the process, development and outcomes of my research are so inexorably intertwined and self-referential, I consider such reflections to provide a more fitting framing of these outcomes than a lengthy commentary on the pieces themselves. I believe these to be useful and important documents but also fleeting moments in my relentlessly experimental and forward moving practice.

A moment in time

Recognising this relentless forward motion, this chapter acknowledges the current state of *ams* as representing a moment in time. A current version of itself, in an open system that will undergo further development. Some of the opportunities and future changes that the creation and use of *ams* has highlighted are also included.

(Re)solution

Highlights and explores the conclusions and contributions of this research, referring back to the research question and aims, which are outlined below.

Lastly, it is worth clarifying some key terminology used throughout this thesis. Firstly, I refer to *ams* in various ways, including ‘musical instrument’, ‘musical instrument system’ and ‘musical machine’. These are used interchangeably according to the context. *ams* is a *musical instrument*, but it's also a *musical instrument system* due to its modularity, and collectively (as well as at an individual module level) it's a *musical machine*. Secondly, the terms ‘human-machine’ and ‘human-in-the-machine’ are used to describe the embedded nature of, and physical interactions between, a human performer and a musical machine. The term ‘human-machine’ is most often used today to refer to the interaction between a human actor and an AI or digital system, whereas throughout this document the term ‘machine’ refers to physical, mechanical contraptions.

research question

In what ways and to what extent can the development of a new modular acoustic mechanical musical instrument system lead to fresh opportunities for creative expression and novel repertoire?

My research aims:

1. Probe the affordances and creative opportunities presented by *ams* as a new human-machine musical instrument system.
2. Explore how modular design approaches can deliver more bespoke and reflexive acoustic musical instruments.
3. Examine the interrelations between *ams* and electronic music to inform a post-electronic[17], post-speaker[18] soundscape.
4. Explore how visual and sonic 'coupling'[19] in such instruments can create embodied live performances.

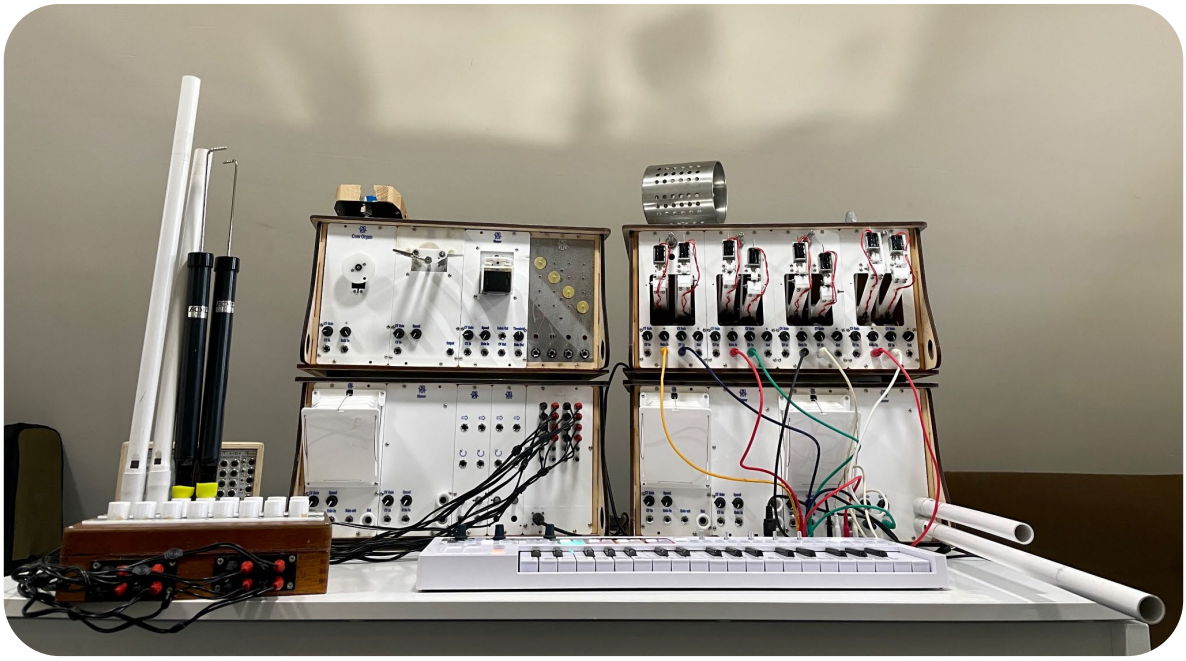
17 Wilson, Daniel. 2012. *Miraculous Agitations: On the Uses of Chaotic, Non-Linear and Emergent Behavior in Acoustic Vibrating Physical Systems*. Leonardo Music Journal 22: 35–40. http://www.jstor.org/stable/23343801

18 Bradley, Fari. 2021 (online edn, Oxford Academic, 8 Sept. 2021). *A New Materiality Post-Speaker Sound Art*. The Oxford Handbook of Sound Art https://doi.org/10.1093/oxfordhb/9780190274054.013.15

19 Sarah Angliss. Used to describe the linking of action and sound in her live performance practice. If Wet event series, Callow End, 2013. Curated and hosted by Sam Underwood and David Morton.

ams [æmz]

acoustic modular system



In this chapter and the accompanying chapter entitled ***ams*** - module catalogue, I provide an overview of *ams,* the acoustic modular musical instrument system that I created and interrogated during this research. I outline the aims and outcomes of *ams*, both in terms of what such an approach can facilitate and by providing a full technical overview of each of the modules developed, amounting to sixteen modules, across ten different module types, plus a variety of sub-modules. In doing so, I highlight how designing and building new musical instruments can reconceptualise relationships with sound and musicianship. I argue that when these relationships are founded on experimentation and exploration, some of the barriers to music making that can be experienced with traditional instruments in formal settings can be sidestepped.

This research is not about getting radical instruments broadly adopted. Rather it is about empowering *anyone* to design and build instruments that suit their wishes and aesthetic aims.

Core to the design of *ams* is its intended use as a live instrument. This objective is central to this research and underpins many of the design and aesthetic decisions of *ams*, shaping the affordances towards a setting in which machine and performer are in front of an audience. When recorded, the sounds and processes of *ams* can be hard to pin down. This can be challenging for some listeners. In a live context however, this encounter is embodied, through an open and direct action-sound coupling. Writing about my work and that of my peers in 2019, Magnusson encapsulates this by stating:

> Many of these pieces have been recorded and documented using video, but this medium does not capture the pieces themselves, as they are spatiotemporal installations that invite us to freely explore them as they are performed; their essence is beyond a documentation that is bound and guided by the subjective eye of the moving camera or microphone.[20]

Though these limitations exist, videos are used in this thesis to demonstrate that which cannot be documented through text alone. For example, in the next chapter entitled

20 Magnusson, Thor. 2019. *Sonic Writing: Technologies of Material, Symbolic, and Signal Inscriptions.* Bloomsbury Publishing. https://doi.org/10.5040/9781501313899

ams - module catalogue, each module is covered using images, text and a narrated video that showcases the core functionality.

Before moving on to the modules themselves, let's explore and interrogate the principles and drivers that underpin the development of *ams*.

I

"More than in any other of my pieces, in Exotica, the radical expansion of the instrumentation is elevated to an aesthetic principle."[21]

Where Kagel's Exotica sought to challenge performer and audience alike by placing rarely encountered instruments in the hands of Western instrumentalists, I turn to the act of designing *new* musical instruments towards similar ends. I contend that naivety and experimentation can be reinjected into how we make music, through the reframing of our relationships with the musical instruments we choose to play, allowing for more open and unencumbered exploration. Though total disassociation from all that has gone before in terms of musical instrument lineages and categories isn't truly possible, the creation of new instruments nonetheless allows the user to start from a position of curiosity, rather than preconception. Additionally, the act of designing instruments gives the user permission and agency to adapt and challenge their affordances in a deeper way than one might with an existing instrument. If a bespoke instrument does not fulfil its intended role, anything from tweaking parts of it to a wholesale redesign is feasible.

The idiosyncrasies of any musical instrument, which are predominantly based on its intended uses, shape its capabilities and ways of playing it: music that is implicit in the instrument's design itself. Some instruments can be considered limited in scope, such as alphorns and handpans with their fixed and narrow pitch range, whereas others are

21 Mauricio Kagel. Discogs. Speaking about his piece *Exotica*. Accessed 16th October, 2024. https://www.discogs.com/release/3770487-Kagel-Ensemble-Modern-Leitung-Mauricio-Kagel-Exotica

expansive, such as church organs and electronic synthesisers. As a multi-instrument system, *ams* falls into the latter category. However, crucially, each module is sufficiently limited in its capabilities to be open to the mis/appropriation and probing identified by Zappi and McPherson, who argue that highly constrained musical instruments lead to a deeper exploration and to "the emergence of diverse and unusual playing styles" [22]. This has occurred on many occasions during the development of *ams,* as I sought to broaden its capabilities. This includes amplifying motor noise, adding additional appendages, extending functionality and employing unusual playing techniques, which stemmed directly from multiple in-depth explorations of each somewhat simplistic individual module.

When listening to the recordings I have created using *ams,* I am taken by how much they sound *like ams* to me. A certain sonic vernacular has arisen through its use. Whilst it remains unclear how much this sonic vernacular is particular to my playing of *ams,* or would also apply when encountered by others, it is a given that the capabilities and nuances of any musical instrument (system) shape the outcomes in fundamental ways.

22 Zappi, Victor, and Andrew McPherson. 2014. *Dimensionality and Appropriation in Digital Musical Instrument Design*. In Proceedings of the International Conference on New Interfaces for Musical Expression, 455--460. Zenodo. https://doi.org/10.5281/zenodo.1178993

II

"Notes are not where it's at. Waveforms are where it's at."[23]

Despite its mechanical nature, sonically speaking, *ams* is anchored more in Bohman[24] 'table of tat' territory than Wintergatan[25] Marble Machine territory, in the sense that it prioritises textural and timbral considerations, and chaotic behaviour, over accuracy and the reliable production of equally tempered pitches, for example. Resonating with this approach, I use the term 'broken machine music' to describe *ams*' sound world. Referring to Angliss' epigraph above, this is a sound world one would be unable to notate in any traditional sense, as I concur, notes are not where it's at.

ams is capable of a wide and spontaneous variation in tone, pitch, timbre and rhythm, sometimes falling beyond the control of the human player. These aesthetic and technical choices are deliberate and are in part a response to the *Mammoth Beat Organ*[26], a previous modular acoustic musical instrument that I designed and built in 2018, in collaboration with Graham Dunning. The *Mammoth Beat Organ* is a large instrument that places a single shared drive system and a relentless musical inertia at the centre of its design. In many respects, *ams* is the antithesis of this approach by allowing for independent control and actuation of each module, through a variety of separate means. This results in a system that is significantly more capable of impulsive

23 Sarah Angliss. "Soundings #2 Sarah Angliss," YouTube, 19th November, 2022, accessed 16th October, 2024. https://youtu.be/iN27aGbmRmA&t=1052

24 "Bohman Brothers". Bandcamp, accessed 16th October, 2024. www.thebohmanbrothers.bandcamp.com

25 Wintergatan. "Wintergatan", YouTube, accessed 16th October, 2024. https://www.youtube.com/@Wintergatan/videos

26 Sam Underwood, Graham Dunning. "Mammoth Beat Organ", YouTube, accessed 16th October, 2024. https://www.youtube.com/@MammothBeatOrgan

and sweeping aesthetic changes, whilst still benefitting from a systemic approach. A system made up of individually simplistic modules but with wide-ranging scope and complexity when considered and harnessed holistically. Due to *ams'* reconfigurability and adherence to modular synth standards, it is also easier to expand and adapt its configuration to different musical ends. For example, restricting *ams* to a subset of modules to limit its sound making capabilities or significantly expanding and altering the tools used to sequence the system, would take *ams* in two very different directions.

III

"Collaborative instruments […] allow kinds of musical expression that are not possible through either human-played acoustic instruments or autonomous musical robots."[27]

The human-in-the-machine is writ large in *ams*. Where many automatic instruments are designed with a single human interaction in mind—that of starting the machine to perform a faithful rendition of a piece—*ams* embeds the human agent in the machine. Or maybe it's the other way round...

This leads to an inside-outness in the instrument's design, with features and approaches employed that create a system where real-time adaptation is a central tenet. I contend that this human-machine relationship creates fertile ground for exploration, whilst avoiding many of the pitfalls and complexities inherent in trying to design machines that replace a human player entirely. This is a particularly complicated task where certain classes of instrument are concerned. Aerophones, for example, require subtle and complex system-wide regulation to even approach human playing standards. I prefer instead to maintain a human-in-the-machine, capable of subtle and responsive manipulation, as well as using an extended definition of acceptable sonic outcomes to include—for example—unusual, chaotic and textural sounds.

27 Kemper, Steven, and Scott Barton. 2018. *Mechatronic Expression: Reconsidering Expressivity in Music for Robotic Instruments*. https://zenodo.org/records/1302689

IV

"As music gets quiet, so too must listening."[28]

For me, live music is about the invitation to be there, in its presence.

In 2013, I co-ran an event—with David Morton—called *If Wet*, in my village hall. The first event was attended by Paul John, a musical instrument historian, who brought along his clavichord. Many of the instruments shown at *If Wet* were acoustic, but what really made the clavichord stand out was how quiet it was. Paul ushered us up to stand right next to it as he played it. We all huddled together in silence to hear every detail unfold.

This experience has stuck with me and although I initially designed some *ams* modules with integrated microphones, I eventually took the radical step of presenting it as a 'very quiet acoustic musical instrument'.

When played live, *ams* demands a close listening environment and an attentive audience. This fosters an even greater sense of intimacy and comprehension amongst audience members, by foregrounding the action-sound relationship. That is to say that those experiencing *ams* live can, if they wish, engage with both the sound and the physical actions that shape it, or cause it to come into being. This is broadly obfuscated in electronic music, where sound generation and shaping generally occur 'inside the box'. In other forms of music, I would also argue that the action-sound coupling often

28 Tom Service. "Deep Listening: Quiet Music and Quieter Audiences | Gresham College," Gresham College, accessed 16th October, 2024. https://www.gresham.ac.uk/watch-now/deep-listening-quiet-music

lacks enough variation—in and of itself—to hold people's attention. For example, it soon becomes clear how a guitarist's fingers alter the sound generated. Within *ams* the human and machine actions are varied, unusual and exposed, forming a key performative element, alongside the sounds created.

The last aspect in what Cutler refers to as "the primary interdependent axes of an acoustic ecology: Object. Action. Space."[29] is the acoustic setting in which *ams* finds itself. This too is shaped by the amplitude it can achieve, unable to fill a large hall or excite the ears of a distant audience, ever since that fundamental fork in its development when the initial intention to route sounds via a soundsystem was abandoned.

29 Chris Cutler, host. "PROBES #33" *PROBES* (Podcast). 22nd October, 2021, accessed 16th October, 2024. https://rwm.macba.cat/en/podcasts/probes-33/

V

"THIS IS NOT MUSIC!!"[30]

Thanks to *@NuffSed* for the comment above, and the many people who left similar comments on the 2018 *Mammoth Beat Organ* video that Graham Dunning and I published. They are backed up by the Oxford English Dictionary, which states that music is, "The art or science of combining vocal or instrumental sounds to produce beauty of form, harmony, melody, rhythm, expressive content, etc.". This is not a definition I recognise, and it seems hard to imagine that any student or follower of music today could possibly consider this satisfactory. To do so would label vast swathes of long-established musical practice as not music, and certainly excludes much of what I have encountered in the experimental and noise music scenes I inhabit.

Either way, the embracing of 'not music', which at its core challenges the OED definition above, is central in my work. This has led to my development of *ams* and other instruments that are free of many constraints; be that through the embracing of accompanying machine noise, lack of repeatability, elevation of timbre and textural noise as aesthetic tools, or the eschewing of 12-tone equal temperament, for example. When these are coupled with the quietness of *ams* it is even possible for it to blend in, becoming part of the environmental sounds when experienced live. Another sense in

30 Originally posted as a comment on our *Mammoth Beat Organ* YouTube video "How Do They Make It?! Music" by @NuffSed. Since removed by user. There are other similar and extant examples such as those by users @Leonardo-yc2ji and @pcxHB. Accessed 16th October, 2024. https://www.youtube.com/watch?v=9C-Ggcv7GiA

which *ams* emphasises the ‘not music’. Many of these principles are enshrined in the manifesto below, which underpins *ams’* specification and are prominent in its output.

ams, a manifesto

This manifesto outlines the fundamental concepts, principles and working practices that underlie *ams*. As a modular acoustic musical instrument system these span concerns ranging from detailed aesthetic principles to broad systemic approaches and technical specifications. As with the system itself and my practice in general, this manifesto is a document in flux. One which has seen many updates and alterations during and through *ams'* development and use.

mechanical design principles

The mechanical design of *ams* is to be governed by the following mechanical design principles, which are unusual in mechanical/robotic instrument systems:

Maximum Interferability

The performer should, to the largest extent practical, be able to change and interfere with the action of the module while it is running. So, for example, the bellows on the Puffer (See: Puffer demonstration video) can also be squeezed by hand at any time, which would not have been possible if a rigid drive system had been used.

Welcoming of side effects

The mechanical processes of the modules have all sorts of side effects; for example, extra noises, uncommanded motion, and non-linear outcomes. These are welcome, as long as they do not swamp the intended effect of the module. Side effects may even be exploited creatively at times, such as deliberately amplifying the Shaper module's (See: Shaper demonstration video) motor noise. Such side effects are embraced as *Quirks* and are demonstrated in the module overview videos in the accompanying chapter entitled *ams* - module catalogue.

A reflexive machine

Unlike most robotic systems, *ams* should not iterate towards greater, more stable control but the opposite. Rigidity and repeatability should be engineered out where possible, with the aim of creating a system that responds reflexively to its physical environment, counteracting the precise control systems at its core.

acousticness

ams must always start from a position of acoustic sound making. The extent to which the amplitude of each sound varies from module to module should shape the structure of a piece or performance. The quietness of *ams* overall should be seen as a feature, as opposed to something one must overcome through the use of external microphones and amplification.

In a live setting, *ams* should always take the radical position of 'quiet acoustic' performance, as a provocation to audience and performer alike. This encourages and rewards close viewing and deep listening, and where possible live performances should therefore take place in-the-round.

The direct coupling between action and sound creation is a feature of acoustic musical instruments and should be foregrounded when performing live with *ams*. In the words of Magnusson, "Unlike electronic or digital instruments, acoustic instruments do not come with a manual, they are manual."[31]

31 Magnusson, Thor. 2019. *Sonic Writing: Technologies of Material, Symbolic, and Signal Inscriptions.* https://doi.org/10.5040/9781501313899

modularity

ams' modularity should be central to any decisions relating to its structure, capabilities and use. This creates a flexible system which should be reconfigured or extended to meet systemic aims, or to adapt it to given live performances or studio sessions.

fractal modularity

Beyond the broad system modularity, *Fractal Modularity*—or modularity-to-the-nth-degree—should be central when considering *ams*' design and capabilities. That is to say that where possible, each instrument/module should be created with as many layers of modularity in its design as possible, opening aspects of the instrument up to real-time alteration that would otherwise be fixed. This is key in striving to reach a position of *Maximum Interferability*.

playfulness

A playful attitude is encouraged during all stages of *ams'* design and use. This, along with collaborations and exposure through the publishing of works and performances, will help to counteract the monomania that such intense and detailed work can encounter. A strong sense of how unusual, whimsical and at times absurd *ams* looks and sounds should be internalised and exploited.

collaboration

Collaborations should be sought that extend or share the music making affordances and duties when performing with *ams*. Particularly desirable collaborations are those that free the artist using *ams* from one or more of the tasks involved in its operation, to allow for greater attention to detail in the areas of sound making and manipulation. At a systems level, *ams* should allow for collaboration, through an adherence to the modular design standards detailed below.

Collaboration should also be sought on the design and development side, as has been the case with Richard Sewell to date, as well as seeking feedback from peers on work in progress videos, to navigate the landscape of what is desirable and what is possible.

scrutiny

ams should be regularly subjected to the scrutiny of performance and publication as a route to assessing and developing its current state of being. Such encounters are to be sought as a means of 'looking in' on *ams,* in a way that is hard to achieve from the inside.

module control and design

ams modules should adhere to the 5U/MU sizing standard with ¼" (6.3mm) jacks. This larger module specification provides greater size and space for acoustic sound making and manipulation.

Modules should use an accepted voltage range (0-5v unipolar in *ams*), to ensure integration with third party controllers and modular gear. Where necessary, MIDI can also be used to extend compatability, either natively or via MIDI-to-CV converters.

Next, we will look and listen to what these principles and approaches mean in practice, through a module catalogue covering each of the existing modules that make up *ams*.

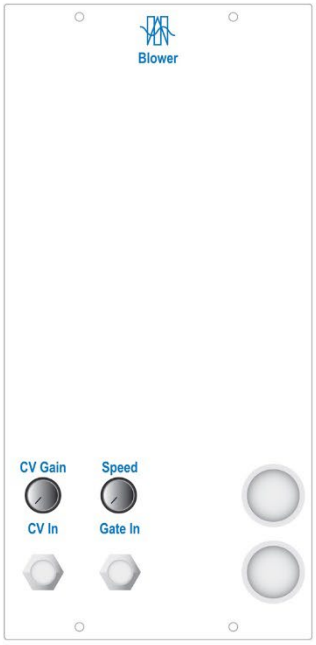
ams - module catalogue

ams currently features sixteen modules in total, across ten module designs, as follows:

- Blower (x3)
- Cow Organ
- Octopus
- Omni Feedbacker
- Piezo Feedbacker
- Puffer (x3)
- Shaper
- Tapper (x4)
- Tumbler
- *Piezo (Prototype)*

Each of these modules is outlined below, including a technical overview, a textual summary and a demonstration video showing its capabilities and uses. Below this, several sub-module instruments are catalogued, followed by details of the custom-built module cases that house *ams*. All of which extend the sound making capabilities of the system.

Blower





MODULE DESCRIPTION

Long-form, drone air with variable flow, using a centrifugal fan, split across two air outputs.

MODULE ROLE

Activation of aerophones attached to the air outputs.

OUTPUTS

Air, via the ports on the right of the module. One or the other, or a mixture, depending on the **Gate In** value.

NOVEL USES

Drone air, controllable swells.

Beat frequencies across two aerophones.

Underblowing and overblowing of attached aerophones.

CONTROLS

CV In sets the fan speed (CV value + CV Gain). **Gate In** switches between the two air outputs, via a servo-controlled valve. **Gate In** also accepts intermediate control voltage values to mix between the air outputs. **Speed** control knob sets the base speed of the Blower. When **Speed** >0 the Blower will run continuously at the speed set.

QUIRKS

Fan noise.

Currently no way to quickly go from lots of air to little air.

FUTURE DEVELOPMENTS

Venting

Braking

The Blower module is designed to provide long-form 'drone air' to any attached aerophones. It can provide shorter bursts of air but the time needed for the fan to accelerate and decelerate leads to a much longer attack and decay than in The Puffer module. As such, constant air flow or swells are a characteristic of this module.

Using a servo-controlled sliding valve, the two outputs can be used to send air to different aerophones in either a binary left/right way, or as a mixture across the two outputs simultaneously. A characteristic sound when doing the latter is shifting beat frequencies by slightly altering the air flow to two identically tuned pipes.

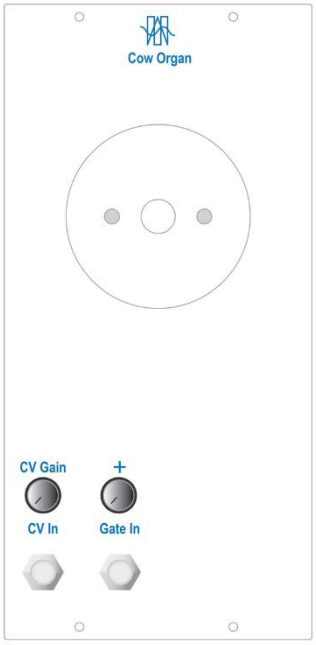
There are several outboard instruments and sub-modules that can be activated with the air from the Blower, ranging from single organ pipes to the electromechanically operated Windchest allowing for the sequencing of multiple pipes.

The fan can be heard during operation, with the frequency and intensity increasing with its speed.
The Blower and Puffer modules can be used in conjunction to create an air source that is both constant and has an added, CV-controllable, tremulant type effect.

Blower demonstration video



Cow Organ





MODULE DESCRIPTION

A vertically oriented rotary magnetic platter, with 180º movement range and hot-swappable discs.

MODULE ROLE

Tipping and agitation of attached objects.

OUTPUTS

Acoustic sound from attached objects. This can be amplified to CV-level output using the Piezo Feedbacker module, allowing for the chaotic control of other modules.

NOVEL USES

Can be set to 'jitter' attached objects to create a randomised textural noise bed. This proves especially interesting when attaching long, compliant objects. Attaching overly long items also creates an unusual visual spectacle.

CONTROLS

CV In (along with CV Gain and +) set the target position. If **Gate** is plugged in, the module will only move to that position when there's a **Gate** signal, otherwise it will stay in the rest position.

QUIRKS

Servo motor noise when repositioning.

FUTURE DEVELOPMENTS

Further attachments.

The Cow Organ module was originally intended to simply invert a 'cow noise' toy, to comic effect. To this end, it had a permanently attached 'hand' capable of clasping one. Initial exploration led to a variety of percussion instruments also finding their way into the clasp.

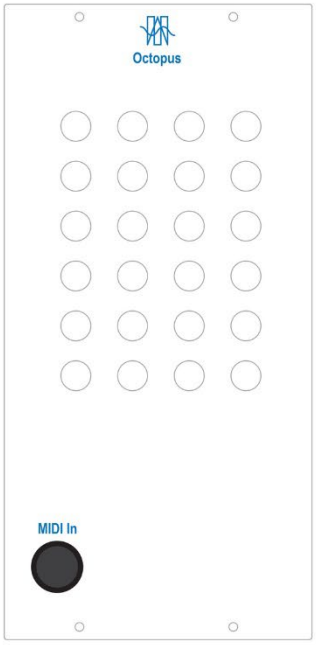
Further development of this module led to the 'hand' becoming just one of the attachments (see: *Fractal Modularity*), with a similar magnetic platter design to the Shaper adopted to allow for hot-swapping of plates / tools.

The most common role the Cow Organ now fulfils is one of textural noise creation, with detritus attached to the magnetic platters, accompanied by a jittery actuation.

Cow Organ demonstration video



Octopus





MODULE DESCRIPTION

MIDI-to-DC conversion with 24 outputs.

MODULE ROLE

Conversion of MIDI notes to DC voltage, across a 24-note chromatic range.

CONTROLS

MIDI In with note value and length determining which output is activated and for how long. Also responds to MIDI Velocity to vary the strength of actuation.

OUTPUTS

24 phono sockets.

Each outputting 12v DC at up to 5 amps per channel.

NOVEL USES

Open, flexible interface that can be used to activate a huge variety of devices.

Used to control a variety of sub-modules, outlined below.

QUIRKS

Doesn't play so well with other *ams* modules as it uses MIDI

The Octopus module is the only natively MIDI controlled module in *ams*. It simply maps MIDI note values to DC voltage, output via a panel of phono sockets. These can then be wired to a wide variety of DC powered external instruments, such as the Spinner's motor, the Windchest's electromagnetic valves and the speakers of the Popper.

This module has been left deliberately open in its spec, to allow for exploration of potential uses. It can power any 12v DC devices at up to 5 amps per output.

Octopus demonstration video



Omni Feedbacker





MODULE DESCRIPTION

A dual channel electret microphone feedback loop amplifier, with independent gain controls.

MODULE ROLE

To create in-air feedback between microphones and their paired speakers/drivers. Predominantly used to create drones in feedback pipes to date.

OUTPUTS

An amplified version of the input signal is output via the audio output. This is normally routed to a speaker or driver to create sound, through feedback.

NOVEL USES

Feedback pipes and in-air feedback offer a variety of unusual sonic outcomes, ranging from pitched drones to uncontrollable skronk.

CONTROLS

Manual gain control via knobs on the module front.

Pre-module gain can be voltage controlled, using a separate VCA module.

QUIRKS

The manual gain control can prove hard to set with great accuracy. This can lead to sudden jumps in signal as feedback reaches a new resonant state.

FUTURE DEVELOPMENTS

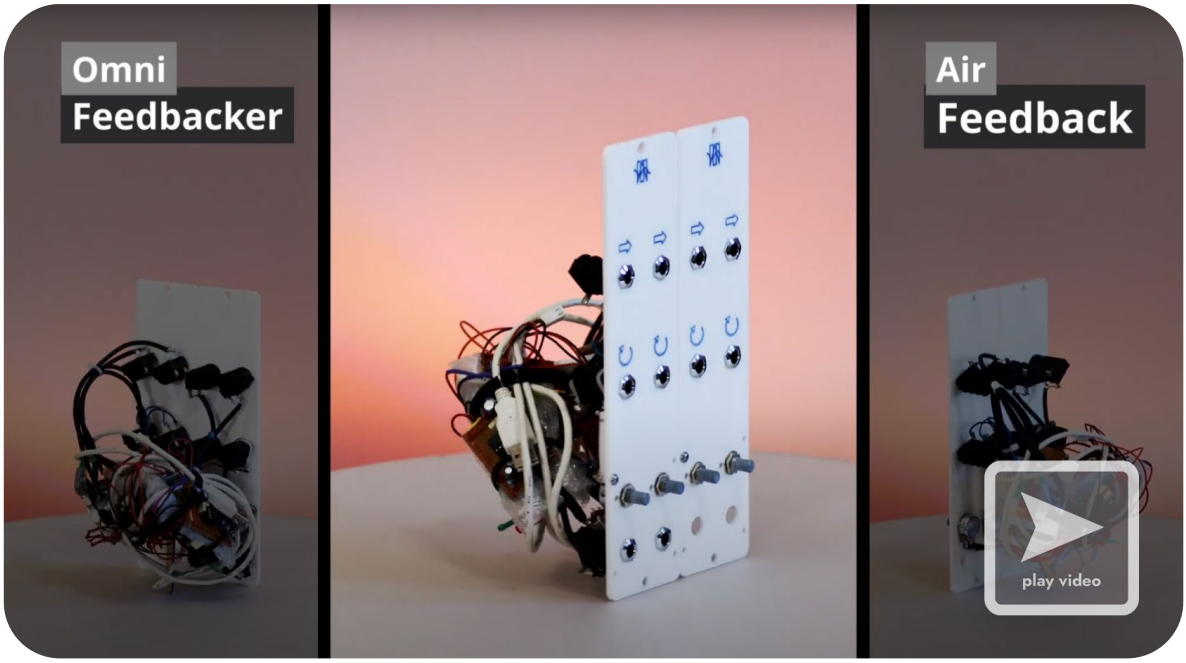
Internal voltage-controlled amplifier gain.

The Omni Feedbacker module features two separate feedback loops, created by attaching an electret microphone to the input and a driver/speaker to the output. This can be thought of as in-air feedback, as opposed to the in-contact feedback created when using the Piezo Feedbacker module (below).

The incoming signal goes through a pre-amp before being further amplified using an LM386 based power amplifier circuit. The gain of the latter is manually controlled via the knobs of the front of the module.

The output of feedback instruments can be shaped using frequency filtering, or by altering the 'resonant environment'. In the case of the Omni Feedbacker this includes a series of feedback organ pipes featuring embedded speakers and microphones, whose frequency is determined by the pipe length.

Omni Feedbacker demonstration video



Piezo Feedbacker





MODULE DESCRIPTION

A dual channel piezo feedback loop amplifier, with independent gain controls.

MODULE ROLE

To create in-contact feedback between microphones and their paired speakers/drivers. Predominantly used with feedback surface sub-module instruments to date.

OUTPUTS

An amplified version of the input signal is output via the audio out. This is normally routed to a speaker or driver to create sound, through feedback.

NOVEL USES

Grand gestures can be used to alter the resonant properties of piezo feedback instruments, creating a strong visual coupling between action and sound.

CONTROLS

Manual gain control via knobs on the module front.

Pre-module gain can be voltage controlled, using a separate VCA module.

QUIRKS

The manual gain control can prove hard to set with great accuracy. This can lead to sudden jumps in signal as feedback reaches a new resonant state.

FUTURE DEVELOPMENTS

Voltage controlled amplifier gain.

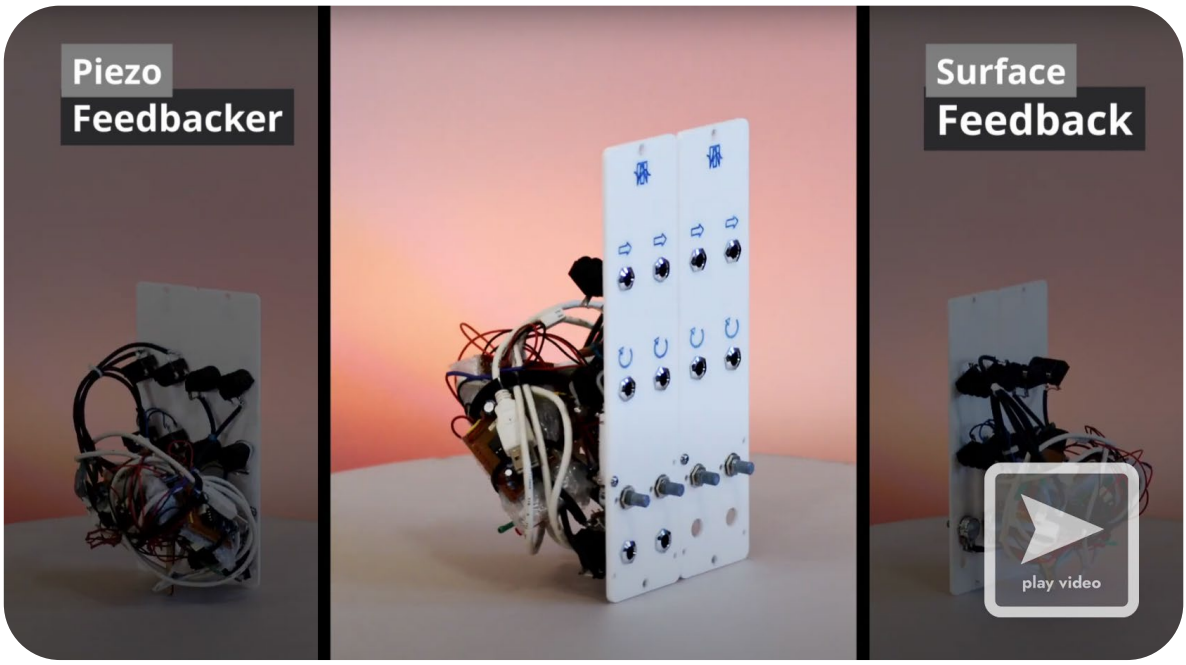
The Piezo Feedbacker module features two separate feedback loops, created by attaching a piezo element to the input and a driver/speaker to the output. This can be thought of as in-contact feedback, as opposed to the in-air feedback created when using the Omni Feedbacker module (above).

The incoming signal goes through a pre-amp before being further amplified using an LM386 based power amplifier circuit. The gain of the latter is manually controlled via the knobs of the front of the module.

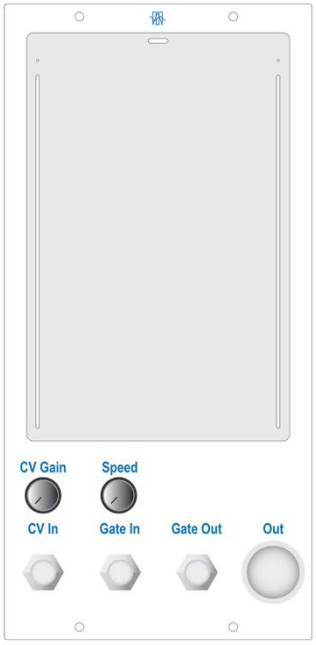
The output of feedback instruments can be shaped using frequency filtering, or by altering the 'resonant environment'. The Piezo Feedbacker is accompanied by a series of feedback surface instruments, which can be physically manipulated to alter the frequencies and timbres created. These form a distinctive part in *ams'* sonic vernacular.

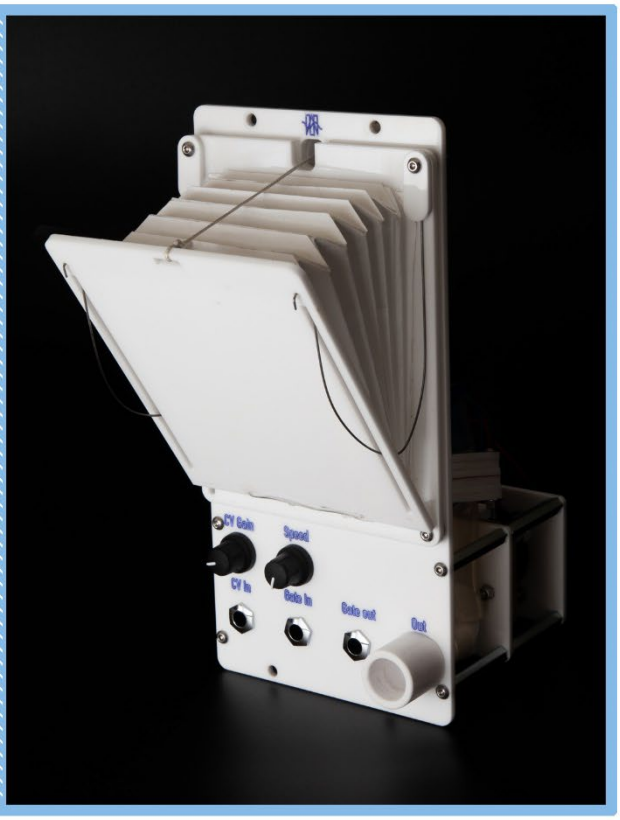
This module can also be used to boost incoming audio signals to a usable control voltage level.

Piezo Feedbacker demonstration video



Puffer





MODULE DESCRIPTION

Tight control, short-duration air generator, using a stepper motor and pleated bellows.

MODULE ROLE

Activation of aerophones attached to the output. Can also be used in conjunction with the Blower, a fan-based air module, to add a tremulant-like effect to the summed air output.

OUTPUTS

Air, via the port on the right of the module.

A **Gate Out** signal is sent every time the bellows reset to 'breathe in', creating a Puffer derived clock signal

NOVEL USES

Short pulses of air with rapidly variable pressure. 'Purr-like' at speed.

Rhythmical air pattern generation, ranging from underblown to overblown actuation.

Rapidly shifting, complex chordal patterns with multiple Puffer modules.

CONTROLS

CV In sets the speed of the bellows (CV value + CV Gain). Runs continuously in the absence of a Gate input, or with Gate, at the speed set for the duration of an incoming Gate signal. **Gate In** works in conjunction with **CV In** to trigger the bellows at the speed set over CV, for the duration set by the incoming Gate signal.

Speed control knob sets the base speed of the Puffer. When Speed >0 and no Gate is present, the Puffer will run continuously at the speed set.

QUIRKS

Any sequenced air being output is disrupted when the unit needs to breathe in. This contributes to a general non-linearity when speeding up or slowing the module down.
Actuation sounds include a mixture of rhythmical whooshing and spring noise.

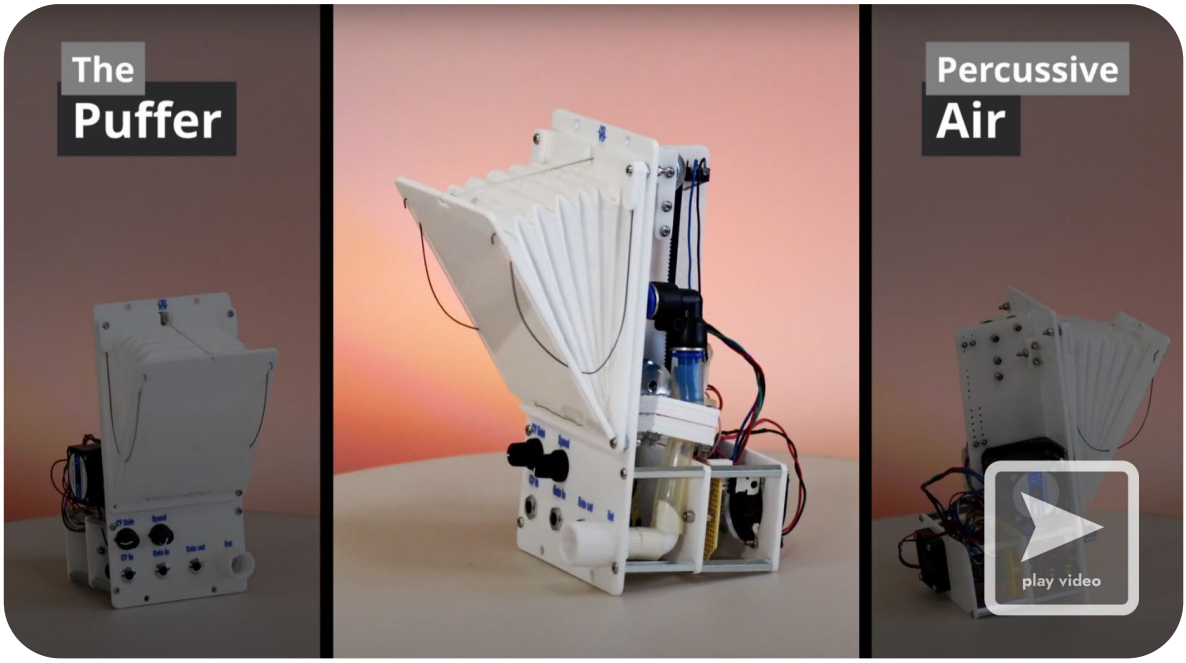
FUTURE DEVELOPMENTS

Mainly falling outside the module itself, including specially designed aerophones and an air mixer to take advantage of *ams'* many air sources.
Better non-return / pressure release systems.

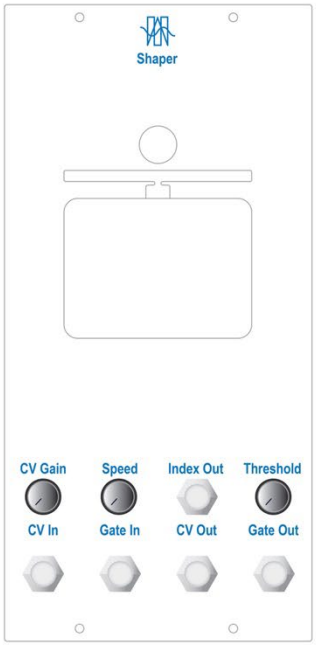
The Puffer module is designed to create short pulses of (percussive) air, via a port that allows for the attachment of a variety of aerophones. The action of the pleated bellows is controlled using a stepper motor, allowing precise and gradated control. When run fast, this results in a seemingly relentless blowing and resetting ('breathing in') of the bellows. When 'sliced' into more discreet steps the Puffer can create a 'purr-like' output. Even when used in this way, the Puffer still needs to stop blowing to 'inhale' periodically.

ams includes three Puffer modules, which can work in conjunction to create complex rhythmical patterns across three different aerophones.

Puffer demonstration video



Shaper





MODULE DESCRIPTION

A mini turntable sequencer with hot-swappable platters and 'trigger objects'.

MODULE ROLE

Control of other modules.

Chaotic sequencing / textural noise.

CONTROLS

CV In, **CV Gain** and **Speed** control the speed of rotation.

If **Gate In** is plugged, it will attempt to synchronise with **Gate In** pulses.

OUTPUTS

CV Out and **Gate Out** for controlling other modules. **CV Out** gives the range from the internal rangefinder to any object on the platter. **Gate Out** is high whenever the range is less than the **Threshold** value.

Index Out sends a **Gate** pulse once per revolution for clock synchronisation.

Acoustic sound is output when used as a chaotic sequencer.

NOVEL USES

Rotary platter sequencing as a **Gate** pulse or ‘shaped’ **CV** based on the passing object’s profile.

Developed to become a chaotic rotary platter sequencer. Used in conjunction with neighbouring Piezo Prototype module.

QUIRKS

Stepper motor noise, which is occasionally amplified with the Piezo Feedbacker module.

If running at speed it can be difficult/hilarious to try to alter the pattern in real-time.

Very non-linear when used as a chaotic platter sequencer.

FUTURE DEVELOPMENTS

Chaotic platter sequencers inspired by this module. Including a tightly controllable and much more powerful brushless motor driven platter.

The Shaper module is the most advanced control module in *ams.* It was primarily designed to output CV and Gate generated in response to objects passing an in-built proximity sensor. The mini turntable can be set to run continuously, using the Speed knob, or at varied speeds and points in time using a combination of CV and Gate.

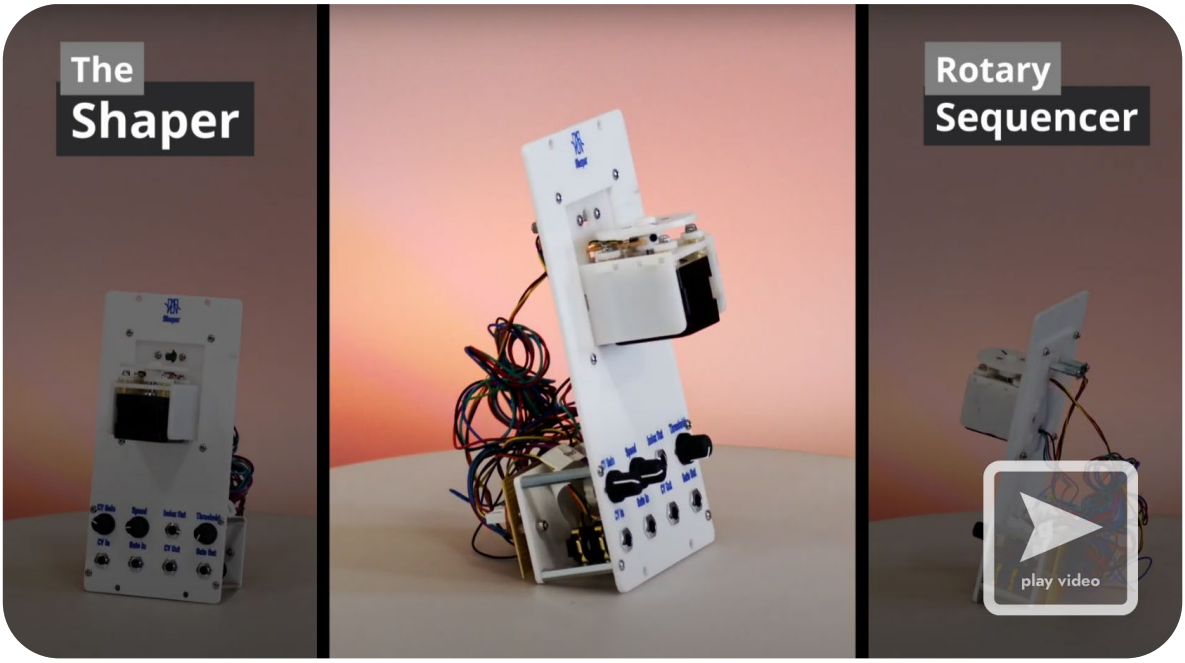
Magnetic platters featuring different numbers of divisions per cycle can be hot-swapped whilst remaining synchronised due to a polarised magnetic mount. With these rigid step-sequenced platters objects can be snapped in place using magnetic couplings, whilst in rotation. Platters with less rigid sequencing, such as plasticine or Lego structures can be used to create modulation sources that vary more over time.

As an object passes the sensor, it is 'read' and the module outputs control voltage that matches the shape of the object. A Gate signal is also generated, with a knob used to set the proximity threshold for triggering. Lastly, an Index Gate signal is output on a per rotation basis. This can be useful as a clock signal for synchronising other modules and controllers with the Shaper.

A secondary chaotic platter sequencer use of this module arose experimentally. This sees loosely coupled objects attached to the magnetic platter, which create 'structured chaos' when rotated. The outcomes of this are covered in the Shaper video below and the process of arriving at this is covered in the ***Beyond the Shaper*** video in the ***Design, Make, Experiment, Repeat*** chapter.

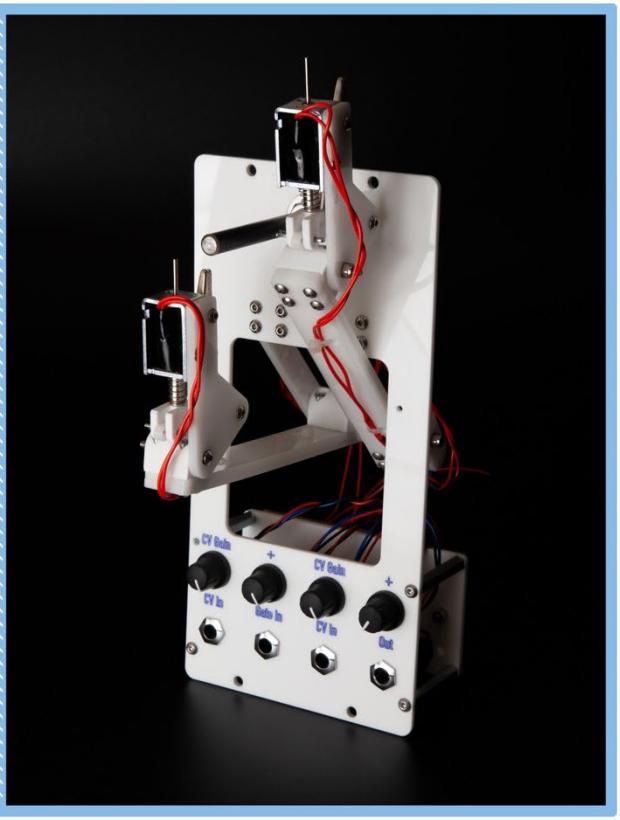
Occasionally, the stepper motor noise is picked up and amplified, creating a CV-controllable pitched motor noise that varies with speed.

Shaper demonstration video



Tapper





MODULE DESCRIPTION

A drum module with two poseable arms.

One for momentary percussive actuation and the other for fouling and damping.

MODULE ROLE

Striking, shaking and modulation of a variety of percussion instruments.

Together the four Tapper modules make up *ams'* eight-armed drum machine.

OUTPUTS

All acoustic and arising from what is struck, shaken or modulated.

NOVEL USES

Poseable arms and beater holders allow for real-time adaptation, whilst maintaining a rhythmical pattern.

Very rapid playing results in textural drone sounds. Flams, inflections and polyrhythms are created when used in conjunction with compliant beaters.

CONTROLS

Left Arm: **CV In** (along with CV Gain and +) sets the hit strength, Gate triggers the hit.

Right Arm: **CV In** (along with CV Gain and +) sets the arm pressure.

QUIRKS

Clicks from solenoids.

Out socket is unused – originally used for integrated drum mic.

FUTURE DEVELOPMENTS

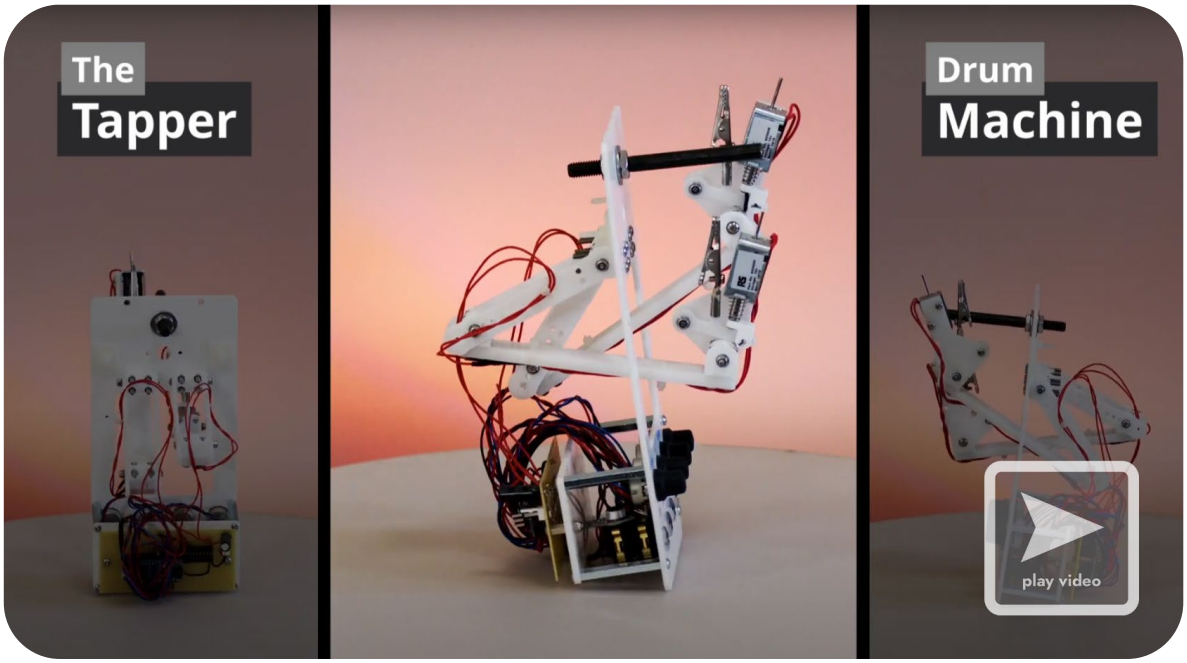
A set of four case-top tilting drums that exploit the polyrhythmic capabilities of the flexure beaters.

The Tapper module is a two-armed solenoid drum module. Both solenoids are on poseable arms and feature crocodile clip beater clamps, to allow for real-time replacement, repositioning and intervention.

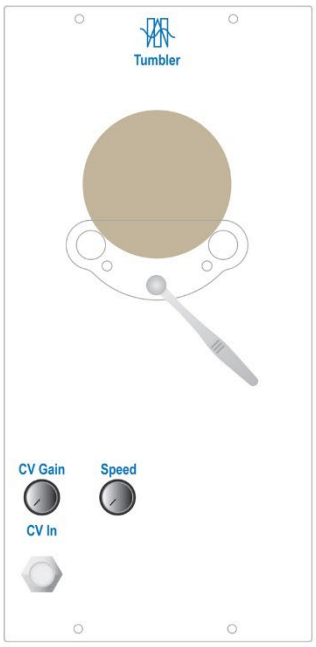
The left solenoid is activated momentarily on receipt of a Gate signal, with the strike strength varied using CV. The right solenoid is capable of 'pressing and holding' according to the CV value received, using Pulse Width Modulation. This acts as a damper or fouler to vary the timbre of the object struck by the left beater.

The Tapper module's unusual design leads to a variety of novel uses that are not present in more set-and-forget robotic drum machines. For example, using compliant beaters whilst varying the distance to the struck object can result in profound rhythmical alterations, with no change to the triggered patterns themselves.

Tapper demonstration video



Tumbler





MODULE DESCRIPTION

A noise tombola.

A controllable object tumbler, akin to a gem polisher.

MODULE ROLE

The creation of constant or intermittent noise through the tumbling of shakers and barrels.

Modulation of other case-top sounders.

OUTPUTS

Acoustic only output.

NOVEL USES

Using two narrow barrels with different numbers of facets creates polyrhythms.

The front-mounted crocodile clip allows for the attachment of scrapers and foulers.

A piezo element can be attached to amplify the tumbling and motor noise.

Modulation of case-top instruments.

CONTROLS

The **CV** value (**CV In** + **CV Gain**) sets the speed of the tumbling motion. This can range from brief pulses to constant motion.

The **Speed** knob sets a base constant tumbling speed.

QUIRKS

Some stepper motor noise.

Can strain and struggle if loaded excessively.

FUTURE DEVELOPMENTS

Wider range of rotary modulators and sounders.

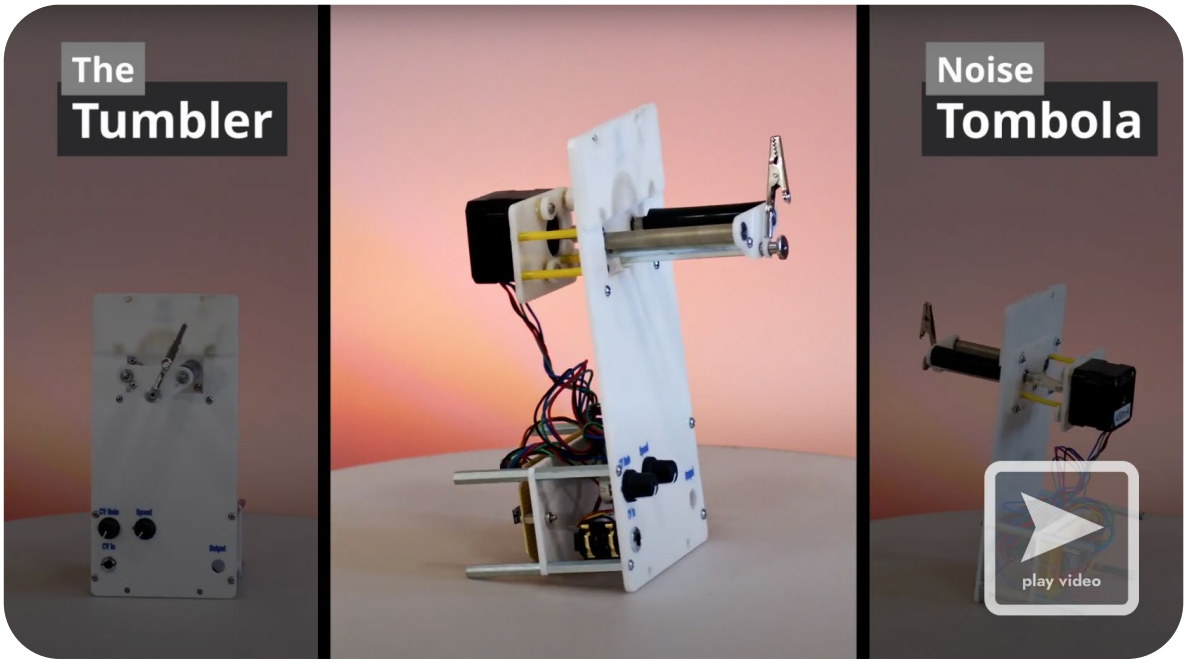
The Tumbler module was designed as a textural noise module. It is derived from a class of instrument I have made previously, that I refer to as noise tombolas.

The control options allow it to create a constant noise bed or percussive noise, in time with other instruments being played. The sound it creates can be quickly altered by simply replacing the tumbling shaker / barrel.

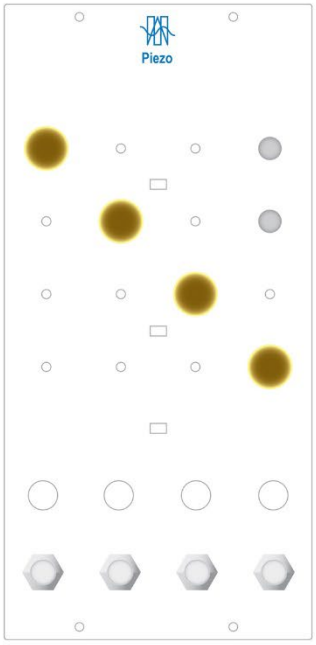
Through experimentation, a series of large Tumbler barrels were created, allowing for the creation of deeper sounds and scraped surface noises. These can also be used to modulate the sounds created by case-top instruments, such as the feedback pipes.

As one of the quietest sound sources in an already quiet instrument system, the Tumbler is often used to create a noise bed that is only fully apparent when other sounds cease.

Tumbler demonstration video



Piezo





MODULE DESCRIPTION

A *prototype* microphonic surface module with four piezo elements, each wired to an audio output.

MODULE ROLE

Passive surface pickup to feed sounds into other modules.

OUTPUTS

Four audio outputs. Each wired directly to one of the piezo elements.

NOVEL USES

Extremely sensitive to microsound / textural noises. Can be used to make the whole module case broadly microphonic, and for feedback purposes.

Amplification to CV-level creates a CV control surface that can be tapped or struck to trigger other modules.

CONTROLS

None. This module is passive. Although there is a significant difference in the surface resonance across the four piezo elements and outputs.

QUIRKS

Surface can be scraped as well as struck.

Plays well with the neighbouring Shaper module, by amplifying the results of its use as a chaotic sequencer

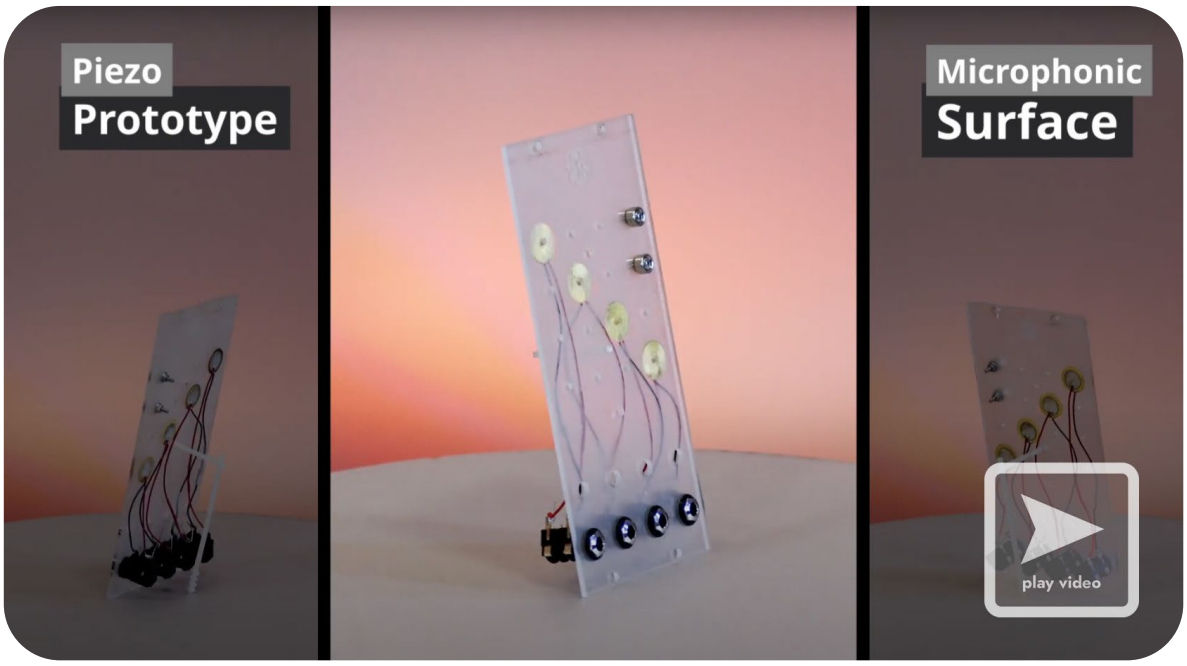
Has two module mounted magnets to hold springs and other detritus in place.

The Piezo (prototype) module is a four piezo element module that functions as a 'multi-contact mic surface', sending audio via four separate outputs. The audio from these can be amplified within *ams* to create an 'acoustic-plus' (*ams* never gets very loud) sound source. Or even to an extent that allows it to function as control voltage for controlling other modules.

This module is designed to work in conjunction with the Shaper module and was developed entirely experimentally, in response to findings made when using and manipulating the Shaper.

The Piezo module has gone on to fulfil many roles in *ams,* from basic amplification to feedback and control voltage generation.

Piezo (Prototype) demonstration video



sub-modules/instruments

ams features several instruments that sit outside of the module cases, extending its capabilities. These include purchased items used in conventional ways (clock divider module, filters etc.), purchased items used in unconventional ways (bat detector, clock chimes etc.), and a series of specially designed *ams* specific instruments. The most prominent of these are included in the module overview videos above and are catalogued below:

the windchest



The Windchest is a sixteen-output air sequencer using electromagnetic valves (pallet magnets) to open and close the apertures on the top of the module. Continual air is normally supplied by the Blower module, or a large chamber, and is released into attached aerophones on valve activation via the Octopus module. Aerophones can be hot-swapped during playback, altering the sound created by a given output, or as a means of venting the air. The input cables can also be removed and swapped in real-time, providing another way of altering the pattern during playback. Pallet magnets are fast-acting, which allows for hyper-virtuosic playing, alongside the *Fractal Modularity* and *Maximum Interferability* already outlined.

Demonstration: *Blower video @ 03:40*

the popper



The popper uses DC pulses sent directly into eight speakers to create short popping sounds. The cones of the speakers are exposed and upwards facing to allow for the placing of resonators, foulers and detritus directly on to them, to shape the sound each cone makes when actuated. This sub-module is also normally controlled using the Octopus module and has hot-swappable inputs like the windchest. It is sometimes used as an eight-channel audio player, with sounds again open to being shaped by what is placed on or over the speakers.

Demonstration: Octopus video @ *01:02*

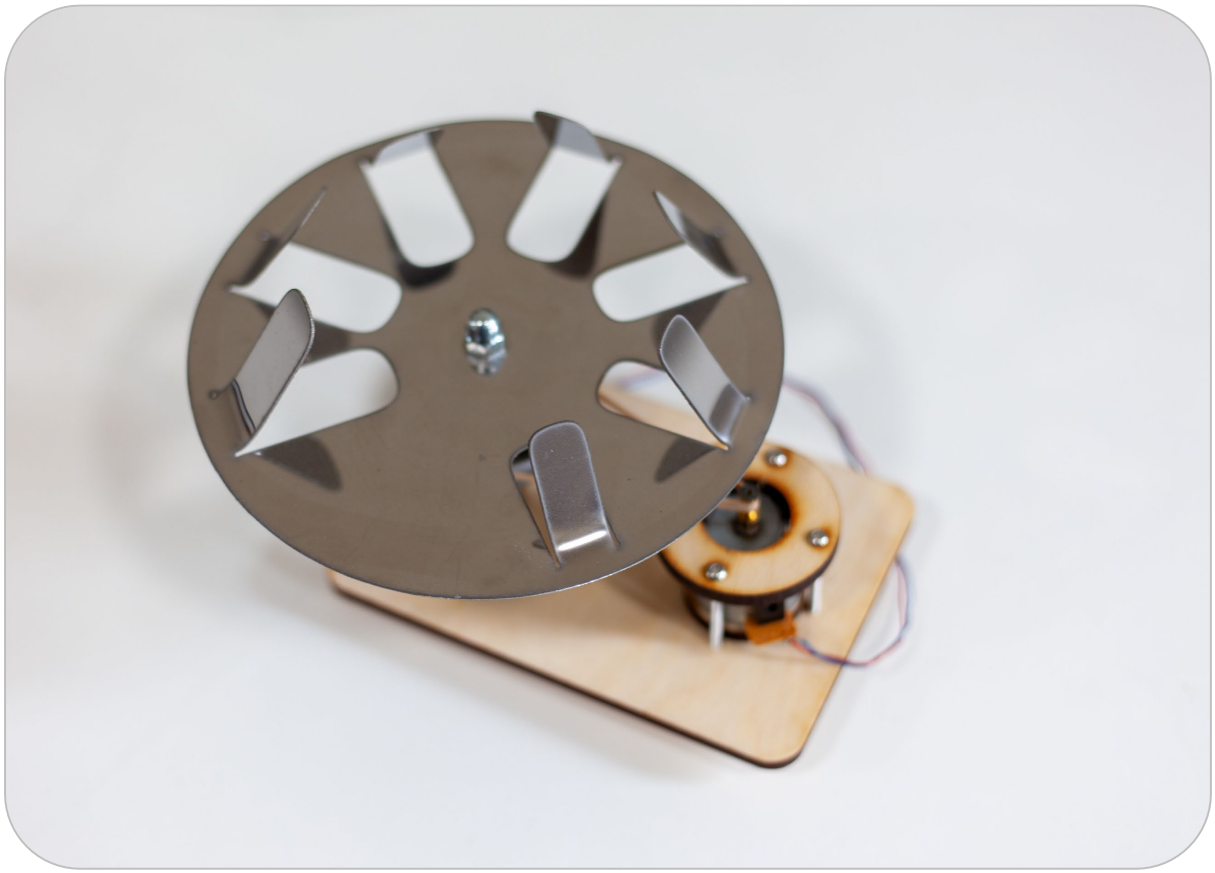
the feedback plate



The feedback plate consists of a loosely coupled thin magnetic metal plate (the bottom of a Crybaby wah pedal) with a piezo element and surface transducer attached to the underside. In normal use, a feed is taken from the piezo element and amplified using the Piezo Feedbacker module before being output via the in-built transducer. This creates anything from a tone to runaway squealing feedback, according to gain settings and the loading of any objects placed on the plate. This is one of the most successful *ams* instruments in the terms set out in *ams'* manifesto. It responds quickly to interference, with tiny changes to the loading altering the tone and timbre of the sounds, therefore displaying a strong action-sound coupling. It is also fractally modular with many ways of manipulating the sounds it creates, both on the input and output sides.

Demonstration: Piezo Feedbacker video @ *00:21*

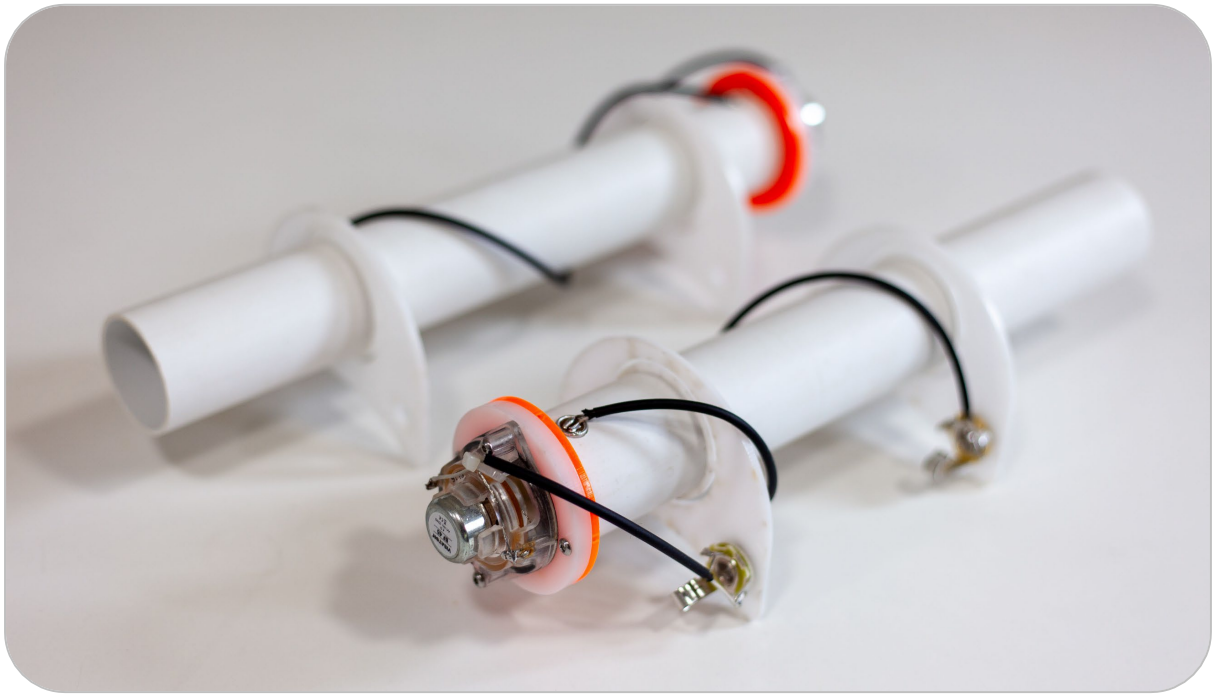
the spinner



The spinner is a simple resonant percussion instrument, cut from stainless steel and spun using a DC motor. This modulates the sound it makes when struck, according to the resonant properties of the section being struck. This is normally actuated using the Octopus module, which allows for sequencing of the spinning, in time—or not—with any rhymical pattern that may is being played.

Demonstration: Octopus video @ *04:40*

feedback pipes



The feedback pipes use a speaker and microphone coupled to a tube to create a tone when amplified. The microphone's signal is amplified using the Omni Feedbacker module and is then output by the speaker, creating a feedback loop. The resonance of the tube determines the frequency of this feedback tone. The pipes then act similarly to standard organ pipes in terms of their response to gain (air pressure in organ pipes), length, partial covering and full stopping. Together the two feedback pipes are often used to create beat frequencies with tuning tweaked through physical intervention or varying gain. There are many opportunities for physical modulation of their tone and timbre, as well as feedback noise effects through injecting additional audio signals.

Demonstration: Omni Feedbacker video @ *00:24*

the whoopee



The whoopee is a membrane reed instrument that came about through the probing of latex as a resonant material, as part of *ams'* early development. This exploration was undertaken with my intern at the time, Miles Worner, as we sought to make low frequency sounds at *ams'* small scale. Together we arrived at several designs, including the whoopee. Most membrane reed instruments, including others within *ams,* employ a secondary resonator (normally a pipe) to set the frequency produced. In this case a broad membrane and no additional resonator are used, so resonance is derived from the latex itself and how it is coupled. This makes it capable of deeper tones and opens it up to physical intervention. The latex membrane is brought into motion by constant air from the Blower module, as the air passes through the latex 'flapping valve'.

Demonstration: Piezo Feedbacker video @ *04:16*

module cases



All *ams* modules are housed in custom designed module cases. These have the following features:

- 5v power: for microcontroller and other low power applications
- 12v power: for higher power applications, such as stepper motors
- Magnetic case tops: for coupling items and instruments atop the cases
- Piezo element and surface transducer attached to the inside: for amplification and feedback purposes, via 3.5mm jack sockets

Demonstration: Piezo Feedbacker video @ 02:47

in conclusion

In *ams* I have created a system that is now in regular use for recording, live performances and collaborative music making. A system capable of producing wide-ranging and novel sounds, featuring an unusual combination of electronic control standards and acoustic sound making. An interface that demands a new way of engaging with it, for performer and audience alike.

ams itself represents the bulk of this research. The investigation is embodied in *ams* and its use, and in the wide-ranging processes that have fed into the development of this novel musical instrument system. We come on to explore these processes next.

Design, make, experiment, repeat

my recursive methodology

I am a reflective practitioner; my process is intuitive and experimental. My workshop is a smorgasbord of musical instrument parts, materials, and tools. My practice-research process is one driven by moments of inspiration and an ability to put my hand on the items needed to realise a variety of prototype designs. These provide forward motion to my recursive design methodology, which is hands-on, experimental, and relentlessly inquisitive. In many ways, the space itself embodies my process, providing snapshots into the different stages of development of each research strand; from the impulsive and messy explosions of inspiration to the structured production lines required to realise more finalised designs. This too is modularised. When I run out of steam with one strand of my research, I switch to another. The space is one of experimentation and knowledge-creation in my research, as well as a graveyard for previous designs and artefacts, in the hope that they might inspire and inform future work. Fisher and Fortnum's description really resonates with my experience, describing a 'living' room where "the productive to-ing and fro-ing between the known and the unknown" occurs.[32]

32 Fisher, Elizabeth, and Rebecca Fortnum. 2013. *On Not Knowing: How Artists Think*. Black Dog Publishing.

Throughout this research I have produced work-in-progress videos which act as snapshots of points of interest, as aide-mémoires, and as a means of sharing findings with collaborators and peers. Much of this process is messy and driven by experimentation, relying heavily on embodied knowledge and hard-to-pin-down prior experience, and a desire to find things out *in* and *through* practice. Schön captures this essence well in his 1983 book, *The Reflective Practitioner*.

> I begin with the assumption that competent practitioners usually know more than they can say. They exhibit a kind of knowing in practice, most of which is tacit. Indeed practitioners themselves often reveal a capacity for reflection on their intuitive knowing in the midst of action and sometimes use this capacity to cope with the unique, uncertain, and conflicted situations of practice.[33]

33 Schon, Donald A. 1991. *Reflective Practitioner: How Professionals Think in Action*. London, England: Ashgate Publishing.

I

"If at first you don't succeed, try, try failing."[34]

When developing experimental acoustic musical instruments, including *ams*, the path to arriving at a more finalised design is never fully clear at the outset. As Haseman describes in A Manifesto for Performative Research, I "…tend to 'dive in', to commence practising to see what emerges." and "…eschew the constraints of narrow problem setting and rigid methodological requirements at the outset of a project."[35]. As such, my instruments are not only intended for use in experimental musical contexts, they are also born of an experimental practice; from the initial inception to the more finalised instrument and its use. Prior and current embodied knowledge and experience play a part in determining what aspects of a design are working or show promise, and how to fix, develop or abandon those that are not. Moreover, in developing *ams*, it has been vital to understand what tangential designs are worthy of further exploration as and when initial prototypes failed to function as anticipated, a skill already developed over many years. Finally, perseverance and an open mind were vital. Many designs do not translate as anticipated from paper to physical object, and the path to a more finalised design is often long and arduous. I use the term 'more finalised' intentionally throughout,

34 Taken from the famous saying "If at first you don't succeed, try, try again." (origin debated) and appropriated in the Garfield cartoon.

35 Haseman, Brad. 2006. *A Manifesto for Performative Research*. Media International Australia 118 (1): 98–106. https://doi.org/10.1177/1329878X0611800113

as I tend to view every instrument I have ever worked on as being in an ‘open’ state, always receptive to further tweaking and development.

II

"Fn = Fn-1 + Fn-2"[36]

I have devised a recursive (re)design and (re)experimentation (re)search methodology, with incremental results leading to more finalised designs, through a stepwise process of testing and modification. This generally includes initial scribbles in a notepad, discussions with collaborators, simple mechanical proof-of-broad-concept prototypes, sharing of video demonstrations, functional prototypes, testing, presentation, performance, tweaking and retesting; often on loop until a satisfactory design is arrived at. This process and what it results in is covered in the ***Beyond The Shaper*** video below, showing how this approach can lead to broadly anticipated developments as well as tangential and entirely unpredicted findings. This includes footage shot throughout this research, which I also used to share my findings at the time of recording. Though the main purpose of these work-in-progress videos is to document developments for future reference, as a point of interest or a juncture in the design. They form an extensive video archive which is itself an outcome of this research.

The practical experimental approach I employed is vital to this investigation, as many of my research aims are hard to address through simply referring to published material or by relying on that which can be modelled. Physical acoustic systems are messy and

36 Wikipedia contributors. "Fibonacci Sequence" Wikipedia, updated 15th October, 2024, accessed 16th October, 2024. https://en.wikipedia.org/wiki/Fibonacci_sequence

what passes for progress is not always clear at the outset. This throws up challenges beyond those generally faced in more defined areas of design, where the desired outcome and a stepwise route to that outcome are easier to determine. Instead, a series of probes are often required simply to establish if an idea has legs, before deeper investigation is entered into. There is also a lot of messiness in the human-instrument interaction, where finding expressive ergonomics requires further experimentation.

After the initial ideas and drawing stage, reading and online research are undertaken. This can be fruitful, though the majority of published scientific findings tend to lie in traditional instrument making fields, and whilst these can be of assistance, they normally only inform a line of enquiry, as my intentions soon fall off the end of what is covered. Where I am able to comprehend physics research, this can be helpful too, but a more fruitful approach tends to be referring to what has been published in the field of new experimental musical instrument design. Books such as Bart Hopkin's *Musical Instrument Design* and Nicholas Collins' *Handmade Electronic Music* are particularly helpful in providing a basis, before employing the experimental methodology outlined.

The development of *ams* involved in-depth exploration of mechanical control systems, acoustic sound creation, and its subsequent manipulation. On the control side, the methods of sequencing and of structuring instruments to allow for modulation and wider real-time adaptability, were central to my exploration. Once an initial system basis was in place the detailed work of addressing the acoustic sounding elements began, as well as a deep exploration and learning of *ams* as a tool for recording and live performance.

Such developments necessarily stem from *doing*, hence my commitment to releasing recordings and performing live throughout.

My research is often concerned with fine changes to material properties, structure and harnessing, with tiny alterations responsible for outcomes that are either successful or not fit for purpose. This process involves intuition and prototyping when making instruments using new materials and techniques. This can lead to interesting and unpredicted findings, though much of the first order success or failure of an instrument relies on a good basic understanding of how an instrument, device or mechanism of that type functions. *ams* threw up some distinctive challenges in these terms, in part due to the small scale of each module. As a much smaller instrument than, for example, the *Mammoth Beat Organ,* the tolerances at play are also much finer and challenges such as creating low or loud sounds were commonplace. This led to the use of novel materials, such as latex for creating bass membrane instruments, and clock chimes for their high resonance when struck with relatively low force.

ams is capable of a wide and spontaneous variation in tone, pitch, and timbre, which is reflected in the design process employed. With *ams* and more generally, I rarely seek to create instruments that put faithful pitch reproduction and duplicability at the fore, preferring rather to concentrate on timbral exploration, happenstance and in many senses process over, or as, outcome.

Where handmaking used to be central to my work, I have spent much of the past few years training in the use of computer-aided fabrication, laser cutting and 3D printing. This has significantly altered my process and the techniques I employ, and was

particularly prevalent in the development of *ams*, which required many precision parts. As well as opening up my research to new materials and procedures, the precision of such methods of production has altered my working practices to become more akin to a scientific exploration, where individual elements of a design can be tweaked iteratively, without the risk of disrupting any other parameter, as can be the case when handmaking. The outcome of each phase of development is then once again explored experimentally, through testing, modification and use.

III

"We're not on the outside looking in, we're on the outside looking out."[37]

Creating moments of experiencing one's work with a degree of objectivity and lucidity can be hard. Embedding show & tells, live performances, releases and radio play into my process is the most effective way I have found of doing this. Each of these places its own demands on your work and juxtaposes it with the work of others, propelling it and creating moments of scrutiny. Such events often lead to increased focus and development in the run up and an appraisal afterwards, in the form of note taking, discussions and reviewing of documentation.

Such probes and provocations have formed a key part of the development of *ams* and have led to many realisations and changes to the course of my research. These are covered in detail in the chapter ***Moving Air*** but include some fundamental changes to the aims of this research, such as shift away from my briefly held, lofty ambition to create a fully robotic aerophone playing robot, my radical advocacy of quietness, and a firm commitment to collaboration when performing live with *ams*.

37 New Art Publications. "BOMB Magazine | John Zorn," BOMB Magazine, 1st July, 2002, accessed 16th October, 2024. https://bombmagazine.org/articles/2002/07/01/john-zorn/

IV

"Art is a collaboration between God and the artist, and the less the artist does the better."[38]

I value collaboration greatly in my practice. Most of the projects I undertake are collaborative in some form, with carefully selected partners adding skills on the technical and creative sides of my instrument design and performance practice. This ranges from one-off live collaborations to yearslong projects, spanning collaborative design, implementation, recordings and live performances.

In the case of *ams*, collaborations on the recording and live performance fronts formed a key element of its development and ultimately led to fundamental realisations about what I was trying to build and how I felt it should be encountered.

ams' development also included a new collaboration with creative technologist Richard Sewell[39] to help design and deliver the system. This is somewhat different to prior collaborations, in that Richard significantly extended the possibilities on the technical side, which isn't unusual in my performance practice, but is far less common where my musical instrument design practice is concerned. The beauty of working with Richard is that he feeds into every aspect of the creative process, from initial design thinking to

38 "A Quote by André Gide", accessed 16th October, 2024. https://www.goodreads.com/quotes/1285514-art-is-a-collaboration-between-god-and-the-artist-and

39 Richard Sewell. "Jarkman at Home", accessed 16th October, 2024. www.jarkman.co.uk

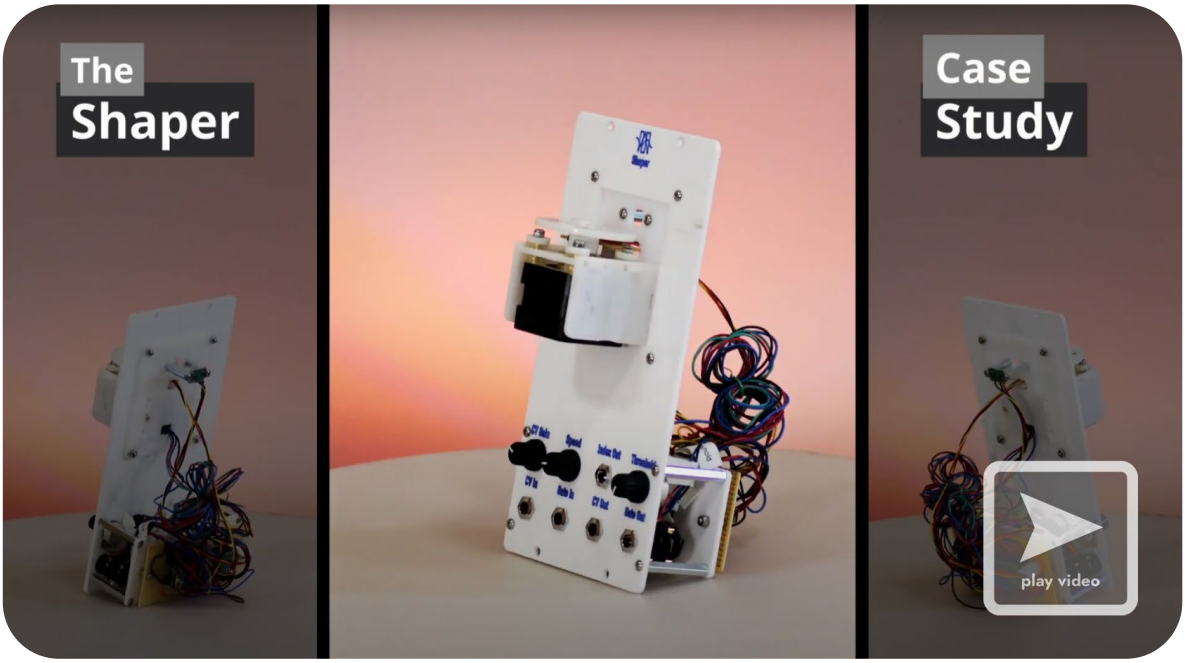
further developments following physical testing, and even through discussions following recordings and live performances he has encountered. All from a position of technical competence and working—as I do—through iterative prototyping. Richard helped me to navigate the landscape of what was desirable and what was possible, which has resulted in a much more rounded and well considered outcome. I anticipate such collaborations will continue to be a key part of my research methodology going forward.

Beyond The Shaper

a case study

As with other aspects of this research, I have chosen to demonstrate how my methodology works in practice through video documentation. This case study follows the development of the Shaper module, showing what ***Design, Make, Experiment, Repeat*** looks like in practice, when unanticipated ideas and uses come into being, alongside the core and intended outcomes, through a natural and deeply ingrained inquisitiveness. In it, we see an initial version (*Design*) of the Shaper module created (*Make*) and added to the *ams* modules, which is tested in a variety of anticipated and unanticipated ways (*Experiment*), resulting in alterations and extensions to the Shaper itself and ultimately to the creation of a neighbouring module that wasn't initially envisaged at all (*Repeat*). I also highlight how all these processes are intertwined and self-referential, making the case for my whole system practice-research approach, expanding the Smith & Dean model[40].

40 Smith, Hazel, and Roger T Dean. 2009. *Practice-Led Research, Research-Led Practice – Towards the Iterative Cyclic Web.* In Practice-Led Research, Research-Led Practice in the Creative Arts, 1–38. Edinburgh University Press. http://www.jstor.org/stable/10.3366/j.ctt1g0b594.4


The
Shaper
Case
Study
play video

Another cog in the machine

contextualisation and findings

Although *ams* is a novel and distinct musical instrument system, it is situated in a flourishing field of experimental and automatic musical instrument design, in which there has been a shift towards embodied and (electro-)acoustic instruments over recent years.[41] This chapter explores core themes that have been discussed in relation to musical machines over the centuries: expressivity, agency and hyper-virtuosity. I propose that these themes are still worthy of consideration, and I use them to identify where my research sits in these terms.

Videos are again used to showcase and contextualise my work. Those included in this chapter are created using work-in-progress footage shot during the development of *ams*. They do not contain any commentary and are presented as they were originally captured, to log and share points of interest.

41 Long, Jason, Jim Murphy, Dale Carnegie, and Ajay Kapur. 2017. *Loudspeakers Optional: A History of Non-Loudspeaker-Based Electroacoustic Music.* https://doi.org/DOI:10.1017/S1355771817000103

expressivity

"Can you expect people to work up enthusiasm for what is essentially a big group of server [sic] motors and pneumatic fingers? You can't go, 'This is what they were feeling when they wrote this,' because there's nothing there."[42]

The expressive playing capabilities of musical machines often shapes their development, with systems generally progressing over time to add in such features. A clear example of this is the player piano, and later reproducing piano (which no longer required the human operator at all). These saw many additions aimed at enhancing expressivity, despite the core pneumatic actuation system operating in a similar fashion for decades after the player piano's introduction in the late 19th Century. Such developments included additional 'tracks' for the encoding of dynamics or to operate the pedals of the piano, with some going on to allow for the recording of performances to paper rolls, in order that they might include the interpretations and inflections of a given pianist when played back.

Patteson covers this era in his 2016 book *Instruments for New Music: Sound, Technology, and Modernism*[43] in the chapter entitled 'The Joy of Precision'. This

42 Lanre Bakare, "Meet Z-Machines, Squarepusher's New Robot Band" The Guardian, 22nd February, 2018, accessed 16th October, 2024. https://www.theguardian.com/music/2014/apr/04/squarepusher-z-machines-music-for-robots

43 Patteson, Thomas. 2016. *Sound, Technology, and Modernism*. University of California Press. http://www.jstor.org/stable/10.1525/j.ctt1ffjn9k

documents the clash between proponents of machine music and classical music over the validity or otherwise of each other's artform, of which Hindemith wrote that “no other aspect of musical life has been so hotly disputed in recent times as that of music made by mechanical instruments.”. These clashes often centred on discussions about the expressive playing capabilities, or otherwise, of these musical machines.

One wonders whether such debates were had in 9th Century Baghdad when the Banu Musa brothers devised their musical machines, or when church bells were automated using similar mechanisms to those the brothers invented. Though it must be said that it is hard to conceive of an instrument less capable of expressive playing than a carillon.

The desirability of expressiveness in musical machines is of course itself contested. Some proponents of these machines, such as Strobel, lauded them for precisely the features their opponents detested.

> It is no longer a question of “capturing in music” events or feelings. One constructs something with tones that is most comparable with a building. Real “creativity” lies not in the desire to “express,” but the desire to “form.” The ordering, constructive work of forming is the actual “content” of music. That it is nonetheless a kind of “expression” is self-evident—but it is not an “expression” that can be interpreted in terms of feeling (sorrow, joy, lament, contentment, etc.), but rather expression in a higher, spiritual sense, independent of the ego—an ordering and forming.[43]

My view on the matter stems from the foundational story, mentioned in the main introduction, of why I got into musical instrument making at all, which hinges on the question, “What is the invitation to be at this performance?”. I find mechanical musical instruments that simply ‘play back’ a score interesting in many ways but not truly engaging in a performative sense. I choose to counteract this by placing (a) human player(s) into my machines. By doing so, my work, as encountered here through *ams*, seeks to embed expressive playing at a system level, through an integral collaboration between human and machine. As a new acoustic musical instrument system, designed with this capability in mind from the outset, little further effort was required to add expressivity back into the machine, as one might when designing a purely robotic drummer, for example.

Additionally, alongside the human player, I have sought to disrupt the rigidity with which automatic instruments inherently operate. This features in much of my research and takes many forms in *ams*. One such example is my development of a series of compliant beaters, using laser cut flexures. These can be used to add varying amounts of flex and mass along the length of a beater, by cutting a series of slits through the material or altering its shape. In some cases, I have included magnets in the beater heads to allow for the altering of mass loading on the fly.

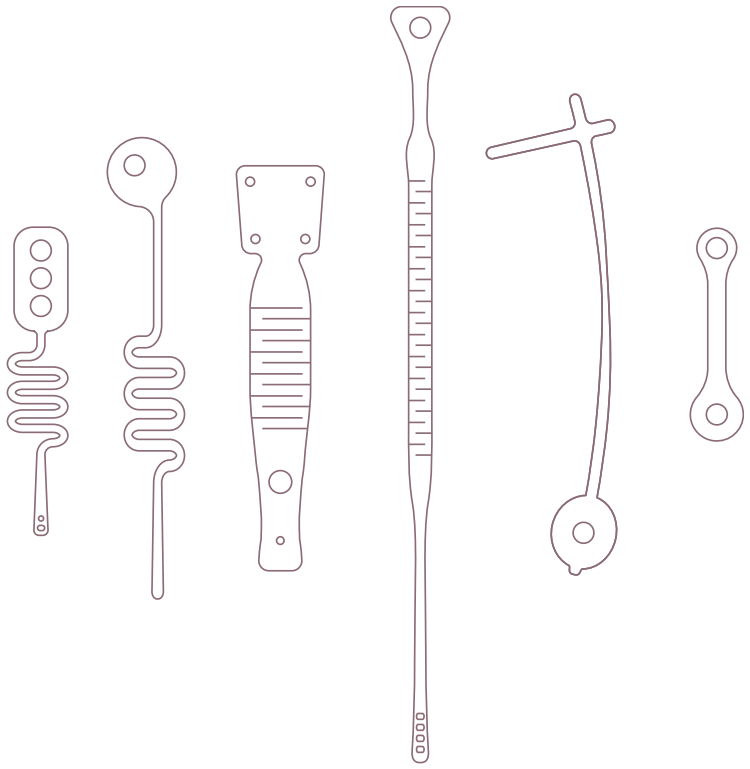


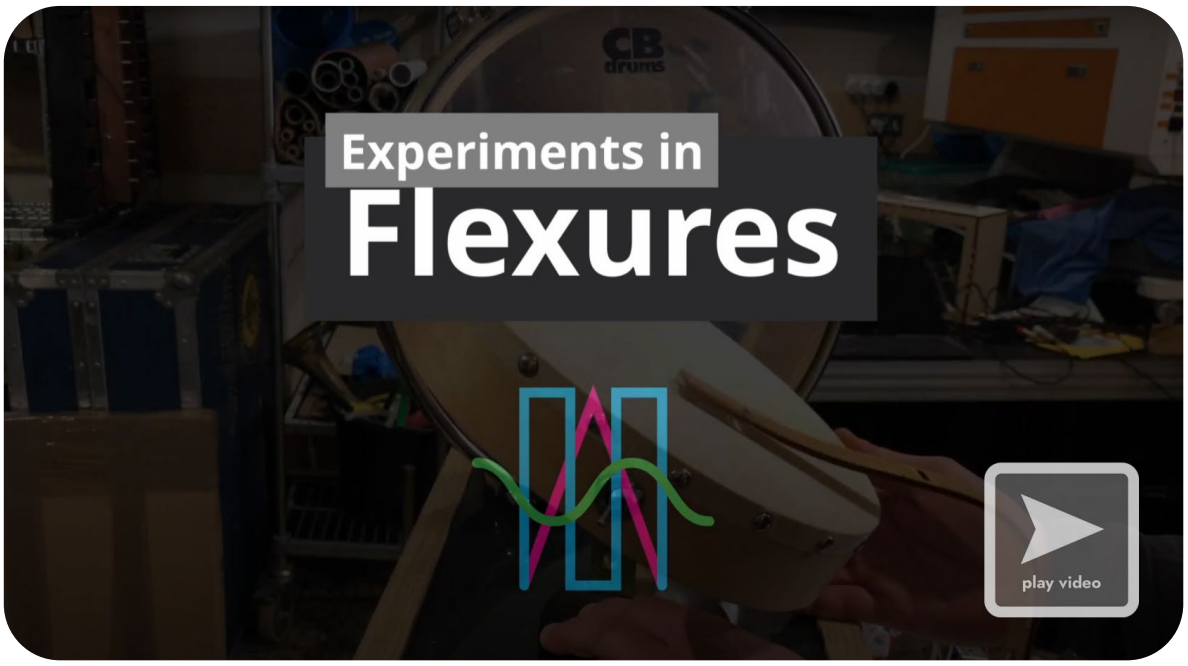
Figure 2 – Beaters with flex

Left to right: *1&2 Spring flexure beaters with push-fit magnets in head | 3 Living hinge flexure beater with screw fittings for beater head | 4 Living hinge flexure beater with push-fit magnet in head | 5&6 Magnetically coupled beater attachments / foulers*

This results in a deliberately less determinable response to an impulse created by the machine. For example, with a flexible beater, rich timbral variation and polyrhythms can be created by altering the physical relationship between the beater and the struck surface, without any change to the sequenced patterns. Within *ams* this approach is not restricted to the use of formal flexure beaters alone. Sloppiness is added through features such as compliance, loose couplings, and structural laxness across the system. For example, the module case tops are magnetic, allowing for the coupling of small percussive instruments in a way that alters their position when struck. This modulates the sound made in a way that is similar to how a human might adapt the

sound of a shaker through how they hold it. In many senses, I perceive these features as giving the machine expressive—or at least reflexive—characteristics that respond, through simple physics, to the inputs received. The concept of expressivity I propose here is encapsulated in the *Experiments in Flexures* video below.

Experiments in Flexures video



agency

"Instruments play us just as much as we play them"[44]

Much of the debate about expressivity stems from issues of agency. Critics contending that music is rendered worthless by the removal of the human as music maker. Indeed, Pringsheim argued that the essence of music lies in the act of performance: 'What is music,' he demanded, 'if not the content of music making? [. . .] Why go to a concert, when there's no longer an artist to see?'.[45] Conversely, proponents such as Stuckenschmidt lauded machines as fulfilling 'composers' long-held desire for absolute creative autonomy. […] free from the interference of artistic middlemen.'.[45]

Of course there is much ground between such polarised views, and my work lies somewhere in the middle on the issue of agency. My musical machines, including *ams*, maintain the human performer, thus requiring a relinquishing of some agency by both parties; human and machine. Additionally, precise reproductive capabilities are not at the forefront of my thinking when developing instruments, so both machine and performer relinquish some agency to chance. Though applied in a different context,

44 Wallmark, Zachary. 2019. Journal of the American Musicological Society 72, no.1: 256–60. https://www.jstor.org/stable/26643965

45 Patteson, Thomas. 2016. *'The Joy of Precision': Mechanical Instruments and the Aesthetics of Automation. In Instruments for New Music: Sound, Technology, and Modernism*, 32. University of California Press. http://www.jstor.org/stable/10.1525/j.ctt1ffjn9k.6

these combine to create what Pickering[46] described as a 'dance of agency' between humans and the more-than-human.

Beyond this, as introduced above, I have long welcomed chaos and indeterminacy into my musical machines, by deliberately incorporating design features that create unruly outcomes, which fall beyond the control of the machine or the human in it. Within *ams,* two particularly fruitful systems for doing so are the chaotic sequencing tools and the feedback instruments. The former is used to create rhythmical patterns of a complexity beyond that of the control asserted, through the deliberate use of loose and astable couplings. The latter results in broadly uncontrollable frequency outcomes, despite responding very directly to physical intervention. These approaches are shown in the *Experiments in Chaos & Indeterminacy* video below.

46 Pickering, Andrew. 2012. *The Robustness of Science and the Dance of Agency*. In Characterizing the Robustness of Science: After the Practice Turn in Philosophy of Science, edited by Léna Soler, Emiliano Trizio, Thomas Nickles, William Wimsatt, 317–27. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-2759-5_13

Experiments in Chaos and Indeterminacy video



hyper-virtuosity

"Now you get kids who can do things with such extraordinary brilliance on the keyboard that they belong in the circus."[47]

The term hyper-virtuosity is used to refer to the super-human playing capabilities of musical machines. These are numerous but include aspects such as extremely fast, slow or complex playing, precise and relentless repetition, or pieces where humans simply lack the necessary digits to perform them. For some composers working with machines, such as Conlon Nancarrow, who created dense and complex paper roll compositions for player piano, this attribute of their work is seen by many to define it.

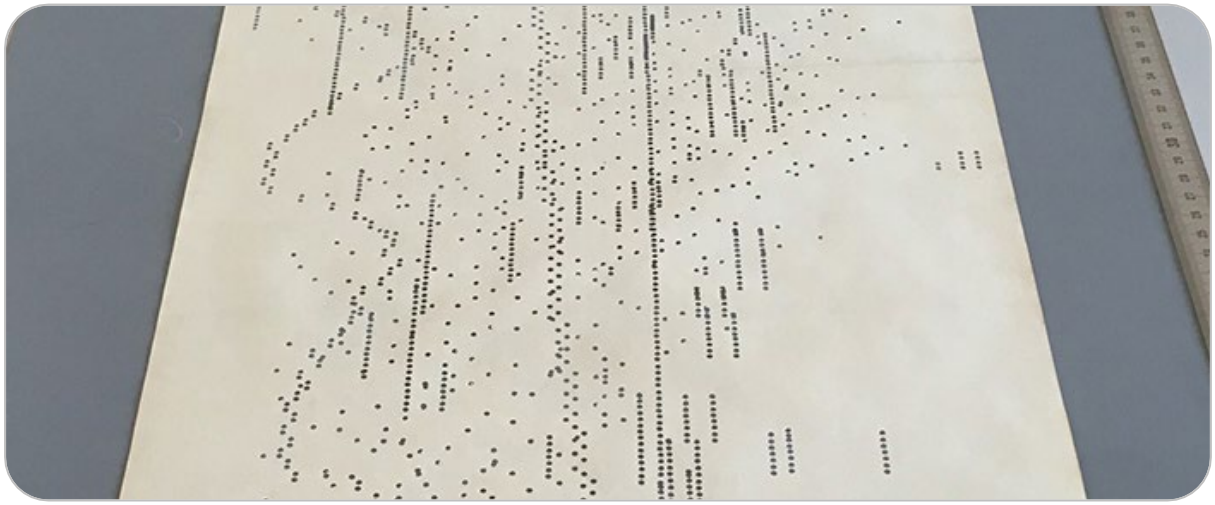


Figure 3 – Section of Conlon Nancarrow player piano roll (R179) [Cropped image] [48]

47 Cross-Eyed Pianist, "Keyboard Circus Tricks 'Ain't Got Nothing to Do With Music-making'" 8th Apri, 2021, accessed 16th October, 2024. https://crosseyedpianist.com/2021/05/03/keyboard-circus-tricks-aint-got-nothing-to-do-with-music-making/

48 Conlon Nancarrow, unknown early piece, player piano roll (R179), Conlon Nancarrow Collection, Paul Sacher Stiftung, Basel. "Paul Sacher Stiftung - Identification of Documents", accessed 16th October, 2024. https://www.paul-sacher-stiftung.ch/en/research/1-2-Conlon-Nancarrow-Edition-project/3-identification-documents.html

My use of hyper-virtuosity in the context of *ams* is twofold. Firstly, the sonic potential created by such capabilities, where super-fast or cluster playing can transform individual sounds from discreet pulses into spectral, drone or textural sounds. This certainly does not always require a machine to be achieved, as similar effects can, for example, be heard in Ligeti's Continuum, whether performed by human player on harpsichord[49], or when adapted for barrel organ[50]. Nonetheless, such capabilities are native in many musical machines, from the new, such as the super-fast pneumatic solenoids of Squarepusher x Z-Machines[51], to the old, such as a player piano that allows for the detailed playing of many more notes at once than a human has the digits to muster. These types of features form part of what I exploit aesthetically within *ams*.

Secondly, *ams* shares part of the task of sound production and sequencing with the human player. *ams* tends to assume control of time, and the performer of sound and timbre. It allows for the initiation and automation of many musical tasks simultaneously, freeing up the human-in-the-machine to focus on the plethora of other aesthetic choices one makes in the act of music creation, while *ams* dutifully continues to run. This form of hyper-virtuosity lends itself particularly well to the creation of dense durational pieces, which feature many relentless actions running concurrently.

One final aspect linked to all the features and characteristics covered in this chapter is the way in which *ams* and other automatic instruments can remove barriers for people wishing to make music. Many acoustic instruments require a lot of practice to reach

49 "Continuum for Harpsichord - György Ligeti". YouTube, 10th July, 2009, accessed 16th October, 2024. https://www.youtube.com/watch?v=iPgwF3G5i4k

50 "Adaptations for Barrel Organ: Continuum". YouTube, 24th September, 2014, accessed 16th October, 2024. https://www.youtube.com/watch?v=GsLvNBfaXzI

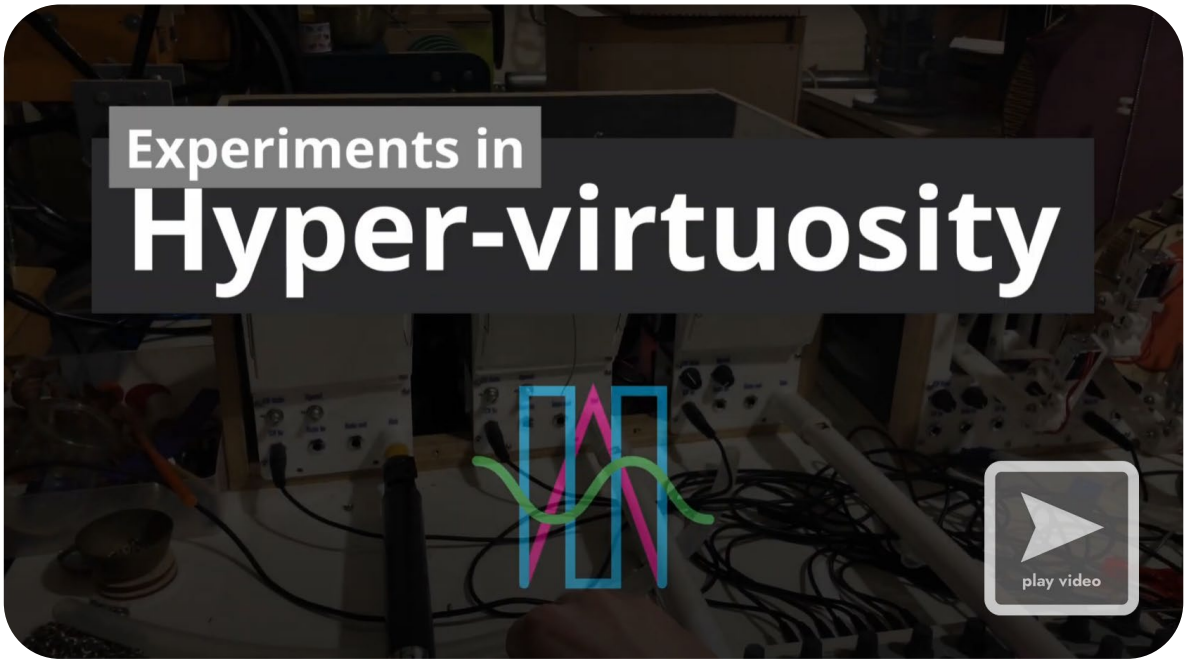
51 "Squarepusher X Z-Machines - Making of 'Music for Robots'". Vimeo, accessed 16th October, 2024. https://vimeo.com/92124413 (01:58)

even a low level of competency or sound making. Take for example my experience, some years ago, of learning to play the tuba. This required many weeks of practice for me to reliably create a sound at all and years of practice to play with the tone and fluency I sought. *ams* is much more immediate, in a similar way to many electronic musical instruments. Though one might argue that beyond the initiation, shaping of the resultant sounds within *ams* is even more accessible and adaptable than experienced when using electronic synthesisers, as everything in *ams* presents physically. The sharing of tasks and agency with the machine, along with the system's openness and ability to be controlled using familiar interfaces, lowers the barrier to entry significantly and allows the player to quickly progress to experimentation and reflexive making music with *ams*. I believe such ways into music making are important and can help to broaden engagement. I also believe that there is a depth to the expressive and performance capabilities of *ams* that allows for progression and even virtuosity over time.

All these aspects are shown in the *Experiments in: Hyper-virtuosity / Machine that runs / Children using ams* video below.

Experiments in: Hyper-virtuosity / Machine that runs /

Children using ams video[52]



52 Permission was sought and granted for all parties included in this video

Soundings

event series

Acoustic musical instruments are best experienced firsthand; in a space, embodied, in person. In this setting the resonant complexity and richness of such instruments is tied to their physical properties and the forces that act on them, creating a depth of experience beyond that of the recorded environment. As a result, a significant strand of my research into the field of mechanical acoustic musical instrument design was carried out as primary research, through my programming and running of an event series in Worcester between September 2022 and September 2023.

During the five *Soundings* events, eight prominent mechanical musical instrument makers presented their work. This took the form of a show & tell, followed by a live performance. In addition, several other artists presented their work as part of an informal invitation to do so, called a *Takeover*. I also presented my work at each event, including the *Mammoth Beat Organ* and *ams*.

We encounter each event in chronological order below. All events were fully video documented, and each artist section opens with their video and a quotation from it. I use this to reflect on my research, with the intention of providing a deeper insight into where my work fits in the field, and how my artistic practice operates.

soundings highlights



soundings #1

The inaugural *Soundings* event featured the work of Bear (formerly Sarah) Kenchington, Lee Patterson, and Graham Dunning and myself presenting the *Mammoth Beat Organ.* Whilst this work happily co-exists under the banner of 'experimental mechanical musical instruments', the approaches and system-level distinctions were many and varied, fundamentally shaping the affordances of each.

Even when comparing two musical contraptions where the approaches and aesthetic aims overlap, such as Bear's pedal-powered orchestra and the *Mammoth Beat Organ,* root decisions around issues such as agency, drive system, and real-time interactivity profoundly shape the system's playability, performance and the musical outcomes.

bear kenchington

(formerly Sarah Kenchington)



"Like I was saying, I'm always striving to give the control back to the instruments."[53]

The extent to which one cedes or exerts control over a musical instrument shapes the music created. In principle, *ams* is capable of tightly controllable and repeatable outcomes but my development of it has led me to deliberately disrupt this capability by

53 Bear Kenchington. "Soundings #1 Sarah Kenchington" YouTube, 17th September, 2022, accessed 16th October, 2024. https://youtu.be/lpUE_IZRyaY&t=770

building sloppiness and happenstance into the way physical actions are expressed. This keeps the operator on their toes, engaged in the performative act of music making.

Individual instrument designers in this field determine where on the human-machine (or machine-human) continuum their work lies. Some mechanical instruments are designed with faithful reproduction at the fore, where others might be entirely human-powered and adaptable on the fly. These choices are fundamental to how one engages with the instrument and the resultant musical outcomes. In their 2017 paper[54] Tuuri, Parvianen, and Pirhonen draw the distinction between more traditional task-oriented, 'control over' musical instrument interactions, where the operator is on the outside, and what they term 'indwelling' where the musician is part of a system, exploring and creating music in conversation with the instrument. My research falls into the latter category. I have long embraced indwelling as a central design principle of my modular instruments, including *ams*. Bear literally climbs into their instrument (06:47) to play it.

Even in the instruments that I have designed with indwelling in mind, design approaches determine the extent to which the human agent and instrument can operate responsively in any 'conversation' they are engaged in. When contrasting Bear's pedal-powered orchestra with our *Mammoth Beat Organ* at *Soundings* it was clear that, despite obvious similarities, they were in quite different positions on this continuum, with distinctive opportunities presented to the performer(s) as part of each musical system for engaging in indwelling. The former is pedal-powered and highly adaptable in real-

54 Tuuri, Kai, Jaana Parviainen, and Antti Pirhonen. 2017. *Who Controls Who? Embodied Control Within Human–Technology Choreographies†.* Interacting with Computers 29 (4): 494–511. https://doi.org/10.1093/iwc/iww040

time, whereas the *Mammoth Beat Organ* has a relentless motorised drive system meaning the human agents (Graham Dunning and I) are less able to make wide ranging and abrupt changes to the music created. Bear speaks to these distinctions and their version of indwelling (from 09:53), highlighting their interest in the way "this machine is turning me into a machine, and I'm trying to turn it into a person." and how they perceive the *Mammoth Beat Organ* is trying to get control, where Bear states, "I am trying to lose control."

The *Mammoth Beat Organ* certainly lends itself more intrinsically to rhythmical, dance music adjacent outcomes, or longform, slowly morphing soundscapes. These idiosyncrasies, as well as the sheer scale of the *Mammoth Beat Organ*, shaped the development of *ams,* which is capable of much faster, more impulsive expression and variation.

lee patterson



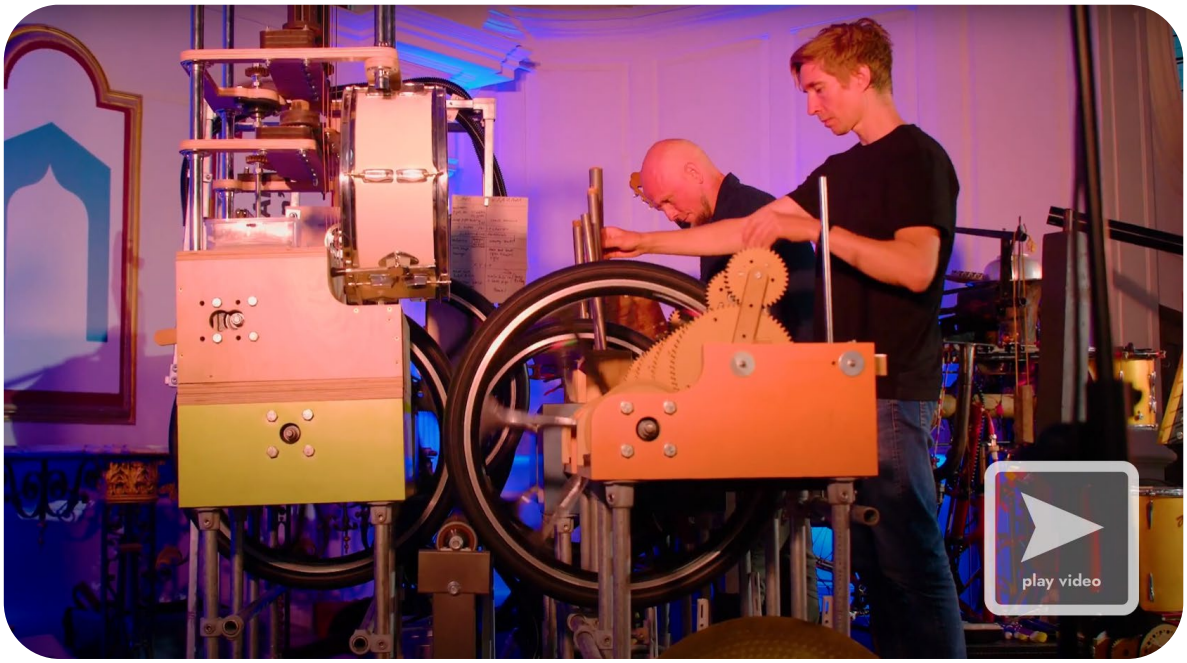
"Maybe I'll find a piece of rock or a bit of wood or a plant and wonder, how does this sound? What is the condition of this thing?"[55]

Patterson's epigraph above speaks to my wider work as well as this research and the aesthetic principles that underly the development of *ams,* by highlighting the unpredictable and organic nature of much of what one encounters within the realm of experimental acoustic musical instrument design. It is often the slightest quirk or detail

55 Lee Patterson. "Soundings #1 Lee Patterson" YouTube, 17th September, 2022, accessed 16th October, 2024. https://youtu.be/FiK1vikrtoE&t=122

that elevates something from the mundane to the sublime. Sometimes instruments are built to operate in a deliberately astable state, which means that some of the exploration of such subtleties unfolds when playing them. In *ams* this experimentation and unpredictability of outcomes is encountered both through its design phase *and* its playing. This leads to an open and rich engagement in the detail of sound making, experienced by me as instrument designer and performer, and by those witnessing this process unfold through my work-in-progress videos and live performances. Due to the openness of its design and my aesthetic aims when using it, this has sometimes led to the gathering of items in a similar way to that which Lee describes above: the dried leaf beater, seedhead shakers and resonant pasta shells are very welcome additions to *ams*.

mammoth beat organ



"One of the ways this is different to some other mechanical musical instruments is that everything is open, everything is available for us to change the sounds as it's playing."[56]

The inside-outness of my instruments is central to their intended use and playability. I first encountered this term in reference to a musical instrument through Sarah Nicolls'

56 Graham Dunning. "Soundings #1 Mammoth Beat Organ" YouTube, 17th September, 2022, accessed 16th October, 2024. https://youtu.be/6zmVDBMpCoQ&t=757

original Inside-Out Piano[57]. It immediately spoke to me as a core design principle, which I have applied to many of my instruments over the years. In the case of the Inside-Out Piano, the soundboard of a grand piano is made accessible to the performer, without disrupting access to the keyboard, by reorienting it vertically. Sarah also insisted that all strings were parallel and fully accessible (i.e. not crossed underneath, as with most pianos, and struck from the rear). These may not sound like revolutionary acts but the ways in which they open the piano up to entirely new forms of playing and real-time sound generation and manipulation cannot be overstated. It's worth mentioning that Nicolls initially made this change primarily in response to contemporary piano pieces she was being asked to perform, which demanded actions such as the plucking, fouling and scraping of strings. On doing so, many of the extended techniques she now employs were arrived at experimentally, having fully identified these only after the reorientation of the soundboard.

When writing about this and coming to reconsider the formative nature of encountering Sarah's Inside-Out Piano in terms of my own practice, I decided to ask her some further questions. Here she describes the process discussed above:

> I knew what I was going for. That I was going for this kind of every part of every string thing. And that felt really important. But of course, I didn't know what being able to reach every part of every string like that would do. I mean, just last week, I found two new sounds. So, it's that

57 Sarah Nicolls. "Inside-Out Piano II | Sarah Nicolls", accessed 16th October, 2024. https://sarahnicolls.com/project/inside-out-piano-ii/

> thing where you can't possibly predict the things you'll find, but you can try to. [58]

She went on to touch upon this process in a way that felt very pertinent to my research:

> I think there's also a kind of relinquishing, perhaps, that goes on in instrument development, where you think you know what you're doing, and actually what you're doing is building a mountain, and then you climb it, and you don't really know what's going to happen on the mountain until you get up there. So, I think there's quite a long process perhaps.[58]
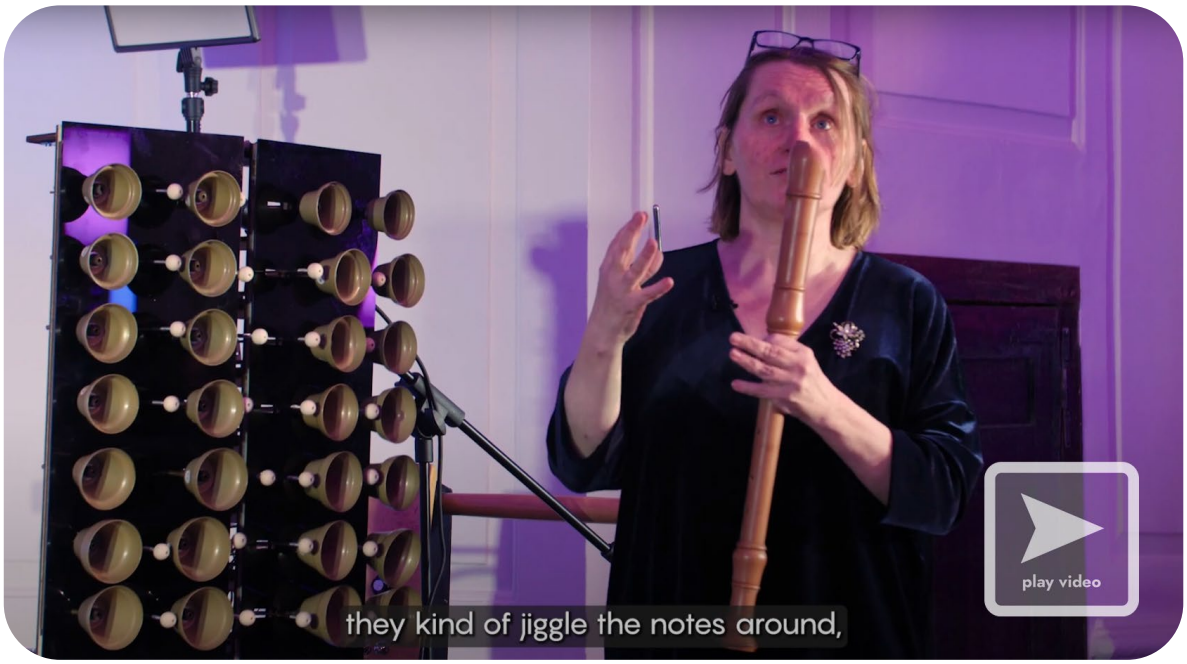
When applied to the *Mammoth Beat Organ* this inside-outness means that once set in motion, the machine can be left to fulfil a role, reliably and without end, whilst the performer shapes and disrupts the outcomes, through activation and deactivation of modules, physical access to its mechanisms and altering what is being sounded. As a central tenet of my work, this shapes an instrument's design from the conceptual stage and informs approaches taken across a system such as the *Mammoth Beat Organ* and *ams*. Every opportunity is taken to expose the workings, actuators and sounders to human intervention, often leading to designs where less conventional mechanisms and couplings are employed, all in the name of inside outness and *Maximum Interferability*.

58 Interview with Sarah Nicolls, 17th September 2024

soundings #2

The second *Soundings* event featured the work of composer and multi-instrumentalist Sarah Angliss. This event also included my first public live performance using *ams.* Sarah spoke about and demonstrated much on the physicality of acoustic sound and space. Also, eloquently illustrating how the design of an instrument fundamentality shapes its musical capabilities, though an examination of her portative organ. *ams'* first live outing was both invigorating and helped to inform my next steps in its design. It was also the first opportunity I had to rationalise it in front of an audience, with the full system present.

sarah angliss



"It was never about the notes. It was about the air and what you were doing to the air, and what you were doing to the room."[59]

I think of *ams* as having a hierarchy of how best it is encountered. Top of this list is physically, in a space, in front of your eyes and ears. At the other extreme is a purely recorded audio context in which the coupling between action and sound is lost. Whilst this abstraction may itself prove intriguing to some, I would contend that it masks much of the wider context and intrigue of an instrument like *ams*.

59 Sarah Angliss. "Soundings #2 Sarah Angliss," YouTube, 19th November, 2022, accessed 16th October, 2024. https://youtu.be/iN27aGbmRmA&t=1106

Angliss' work and working methods have long been of great inspiration to me and many of the wider themes she lucidly conveyed during her show & tell underpin my work too. In it she would often draw parallels between *ams* and her instruments, contending that we are hungry for such instruments, and that it creates excitement when they are in a room (from 13:46). Moreover, Angliss' reflections on why these offer a richer experience than simply playing samples through speakers, forms the nub of why I work in the way I do, and why *ams* is a physical system in the first place. From 14:17, discussing her robotic carillon:

> You are getting a lot for free. […] There's a lot of richness in them. […] When they are all playing together, they all sort of work in sympathy. And so, you know, one bell sets off another bell. […] You could model it on a computer, but you'd have a very hard job. Whereas, if it's the actual bells, in the actual room, hitting one another and going off in sympathy with one another, you get all that for free.

As detailed in the chapter *Moving Air,* the recorder would play a role in steering the overarching trajectory of this research. Following an *ams* recording being juxtaposed with a solo recorder piece on BBC Radio 3's Late Junction, I would rethink my grand aims somewhat, due to factors Sarah touches upon. First, she discusses the recorder (from: 01:52) and how expressive it is, saying that "you can feel the human in it" and that "you can never divorce the pressure, which affects the loudness, from the pitch". These conditions may at first seem deceptively simplistic, especially to those who have

played or made recorders, but if viewed from the perspective of someone wishing to emulate this in a self-playing instrument, these are deeply complex variables, and that's before you even consider factors such as the fingers, the mouth and the movement of the instrument in space. Sarah touches on this complexity (from: 07:07) when talking about her experience as a musical instrument maker, stating "what you often discover is that something, the most simple thing like a volume control on something that's a pipe, it's just a whole heap of questions.". Concluding that it is also "a whole heap of possibilities, and that to me is what's exciting about instruments.".

When considered alongside the preference Angliss expressed for exploring sound in and of itself, in all its timbral complexity, as waveforms as opposed to notes, she does a pretty good job of entirely encapsulating why *ams* is acoustic and to a large extent why it exists at all.

soundings #3

The third *Soundings* featured the work of Pierre Bastien, discussing his work and playing his Mecanium, an acoustic musical instrument system, housed in a suitcase. This was a masterclass in how to design and build an expressive and engaging mechanical musical instrument. Even more impressive that it fits in a suitcase but isn't lost on stage due to Bastien's use of shadow projection to scale up the movements for the audience.

pierre bastien



“I don’t have much to say about the little machine you see behind me because rapidly you will understand everything.”[60]

Beyond merely experiencing *ams* live and in a space, close viewing and deep listening[61] is encouraged. Everything unfolds in real-time before those who experience it in this way. Moreover, very few aspects of how *ams* creates sound, and certainly the coupling between action and sound, are veiled. Rather, audiences experience transparent

60 Pierre Bastien. “Soundings #3 Pierre Bastien,” YouTube, 18th February, 2023, accessed 16th October, 2024. https://youtu.be/fAZ6OEE9A_0&t=40

61 Oliveros, Pauline. 2005. *Deep Listening : A Composer’s Sound Practice*. New York: iUniverse.

physical relationships and acoustic sonic outcomes. This is partially to create an open and direct way of interacting with *ams* as a performer but also based on what O'Callaghan identifies in *The Multisensory Character of Perception*, where he states that "using multiple senses in coordination makes novel features, not revealed through any sense working on its own, available to conscious perceptual awareness."[62]

One source of regret in the design of *ams* in these terms was my unconscious acceptance of the standard modular synth 'back to the audience' staging. This means that my physical presence blocks both the visual and sonic outcomes to a degree. The solution often employed to overcome this involves the use of an overhead camera, but this runs somewhat counter to my aesthetic aims. Bastien's approach to this is well known and extremely elegant. He uses lights to cast a 'shadow puppet' style animation of his instrument in action, whilst he and his machine stand side-on to the audience.

It was also fascinating to hear Bastien speak of his first ever musical robot (from 03:35), a metronome, and how he adapted it, through experimentation, to accompany his guitar playing. In the most relatable way, he had spoken to the processes of exploration and inquisitiveness that underpin my research. At times, this is no more complicated than adapting the outcomes of a metronome, through the placement of items either side of it, but as with Bastien's Mecanium and wider work, when such devices are used collectively they take on a greater depth of expressive capability.

62 O'Callaghan, Casey. 2019. *A Multisensory Philosophy of Perception*. Oxford University Press. 10.1093/oso/9780198833703.001.0001

soundings #4

The fourth and penultimate *Soundings* event featured the work of Japanese one-man-band ICHI, alongside my first collaborative performance with *ams* in which it was controlled through live coding, courtesy of hellocatfood. ICHI's theatrical musical instruments and performance style was joyous, and far less tethered to the stage or musical contraption than performances at *Soundings* to that point. My performance with *ams* being sequenced and actuated by hellocatfood was a revelation. I was able to work on the detail of shaping and manipulating *ams'* sonic outcomes in a way that can be elusive, or at least slower moving, when responsible for all aspects of a performance, when playing solo.

ICHI



"I wanted to add more and more different sounds."[63]

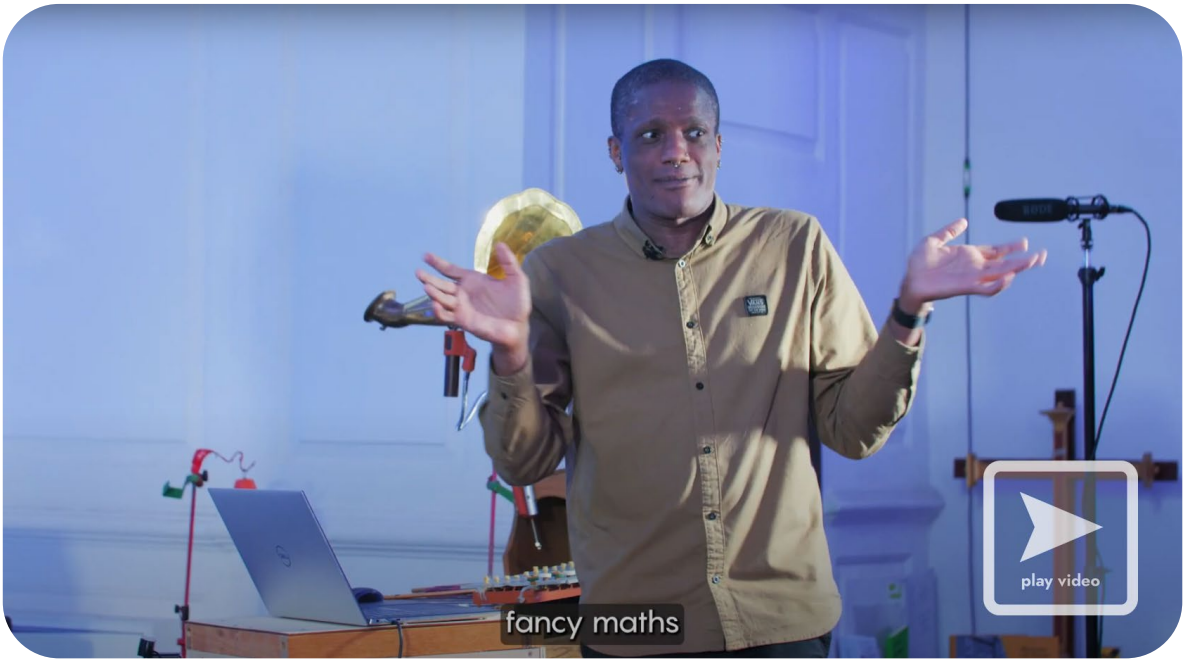
This quotation from ICHI's show & tell exposes a core tension in my work: where is the boundary between the development of a musical instrument and its use? In fact, as discussed previously, I tend to consider this holistically. Development is use and use is development. Nonetheless, as described in the ***Design, make, experiment, repeat*** chapter, my instrument design methodology relies on relentless interrogation and attention to detail. This can be somewhat all-consuming and expansive—boundless

63 ICHI. "Soundings #4 ICHI," YouTube, 20th May 2023, accessed 16th October, 2024. https://youtu.be/OJi9r_pZ3BM&t=327

even—especially when creating modular instruments, where it is possible to switch to an entirely different line of investigation with ease, without straying from the instrument system as a whole. This all reinforces my natural state as an obsessive tinkerer who is prone to getting, happily, lost in the fascinations and detail of an instrument design or acoustic system. This is why embedding points of public exposure of my work during this research was so vital.

Although playing my own instruments and recording the results in my studio fulfils a key role in this process, there is no substitute for live performances in front of an audience when assessing such affordances. Organising, rehearsing, and delivering performances requires a lot of attention in its own right, and is something I find challenging on many levels, but I have embedded it regularly throughout the development of *ams* to ensure this was properly interrogated, no matter how counter to my "add more and more sounds" instinct this was on occasion.

ams x hellocatfood



“We’ve only had a bit of smoke happen once, actually.”[64]

Sometimes things catch light. Sometimes they explode. More often than not, they just don’t do what you hoped they might. Occasionally though, magic happens. This relentlessly experimental approach is what uncovers new pathways in my research, resulting in novel findings and instrument designs.

This experimentation often extends to exploring *ams* in collaboration with others. In this performance, hellocatfood (Antonio Roberts) controlled *ams* through live code, over

64 hellocatfood. “Soundings #4 ams vs hellocatfood” YouTube, 20th May 2023, accessed 16th October, 2024. https://youtu.be/QaQ5OcpRju0&t=825

MIDI. This separation of roles was particularly fruitful (discussed from 03:23), as hellocatfood controlled the actuations, and I focused on adapting the sounds created. This collaborative performance and the implications of this division of labour is covered in greater detail in the chapter ***Moving Air***, but suffice to say that it represented a formative moment in my research as I came to understand that such an approach would lead to an ability for me to be more focussed on some of the core principles that underpin *ams*, such as *Maximum Interferability* and playfulness.

The video above starts with a show & tell in which I cover some of the principles and approaches that underpin *ams*. This includes an outline for a broad audience of *ams'* modularity, acousticness, control, and the aforementioned division of labour, which I discuss thus:

"If I'm simultaneously trying to control all of what ams is doing and adapt the sounds that it's making, and kind of rub my head and pat my tummy at the same time, it's just too much stuff"[65]

65 Sam Underwood. "Soundings #4 ams vs hellocatfood" YouTube, 20th May 2023, accessed 16th October, 2024. https://youtu.be/QaQ5OcpRju0&t=226

soundings #5

The fifth and final *Soundings* featured Rie Nakajima & Pierre Berthet, performing as *Dead Plants and Living Objects*, alongside Graham Dunning's *Mechanical Techno*. In the context of the entire *Soundings* event series, these performances arguably represented two extremes. *Dead Plants and Living Objects* used the entire space for their distributed acoustic performance. Graham Dunning in counterpoint, playing through a soundsystem, delivered the loudest, least acoustic performance of the series. What tied them to *Soundings*' central themes was their mechanical nature and exposed workings.

dead plants and living objects



“Nothing. No rehearsal.”[66]

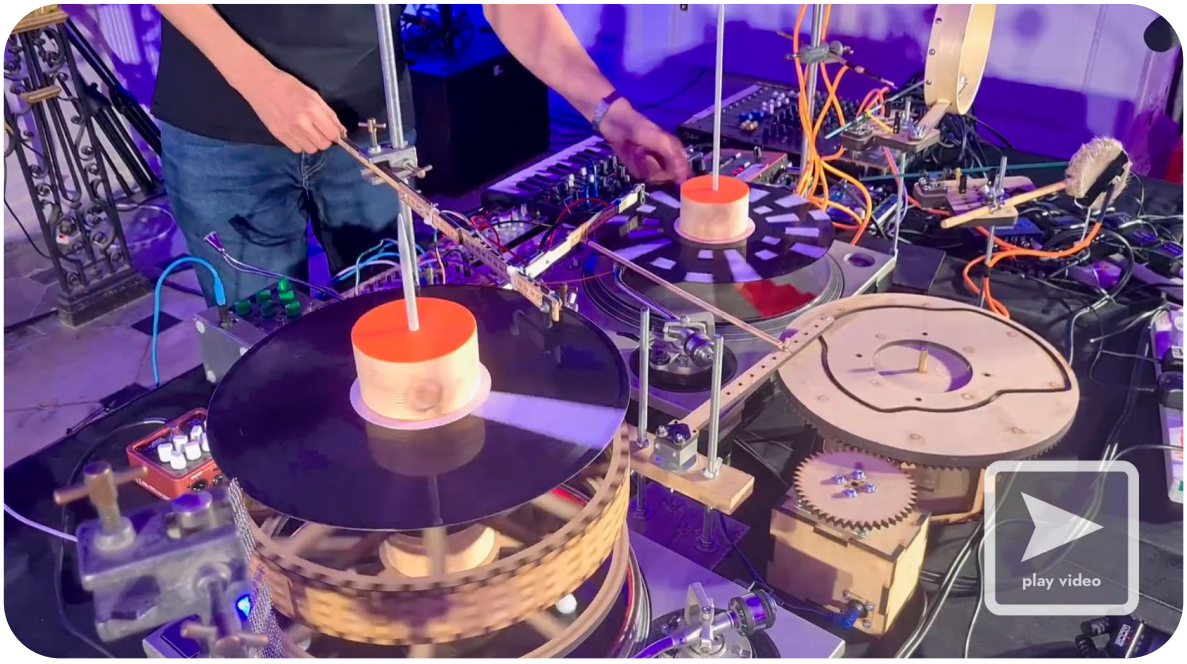
My instrument designs leave the door ajar to happenstance. Whilst I rarely perform having not rehearsed at all, a significant part of the outcomes when playing live cannot be sufficiently controlled to warrant worrying about them in great detail. With *ams* there are practical and technical considerations on the setup and control side that must be adhered to in order to activate the intended module or movement, but sonic outcomes

66 Rie Nakajima. “Soundings #5 Dead Plants & Living Objects” YouTube, 23rd September 2023, accessed 16th October, 2024. https://youtu.be/lVxuS1KXSEs&t=2122

rely on a mixture of these, plus aesthetic choices made in the moment by the performer, and the messiness of physics. Contrary to much performance practice, I would contend that such approaches lead to truly performative outcomes, where interactions with an instrument, through embodied knowledge and one's affective self, are expressed uniquely in that moment; as the music is uttered.

Another parallel between *ams* and *Dead Plants and Living Objects'* performance at *Soundings* is the smallness of the sounds used. This could be seen to draw the audience in to encounter the sounds more deeply. Although the sounds are more distributed in a *Dead Plants and Living Objects* performance, this experience strengthened my view that where possible *ams* should be experienced at close quarters and in-the-round, reducing barriers to audience experience and understanding.

mechanical techno



"...that's one of the idiosyncrasies of this setup I suppose, which I'm kind of working with, or it's working against me maybe."[67]

Graham Dunning's comment above, more than any of the other quotations in this chapter, points to the 'why' of my practice. Such embedded idiosyncrasies, such as timbral, frequency and control choices, shape the musical possibilities and outcomes of an instrument in a way that is more fundamental than through the adaptation of existing instruments, or the use of extended technique. When self-building experimental musical

67 Graham Dunning. "Soundings #5 Mechanical Techno" YouTube, 23rd September 2023, accessed 16th October, 2024. https://youtu.be/XQAV_Cx2bAI&t=1660

instruments, one can design features, or even foibles, at the core of the instrument, which go on to fundamentally shape its strengths, weaknesses, and capabilities.

One other factor when designing and making your own instruments is the open invitation to develop and adapt what is created. This is a central predisposition of my research and design process, as explored in the chapter ***Design, Make, Experiment, Repeat***. The outcomes of which are highlighted in the ***Beyond The Shaper*** video.

Dunning's recent NIME paper[68] and video[69] entitled *Ironing In The Creases: Developing An Idiosyncratic Electro-mechanical Musical Instrument By Reinforcing Its Faults* elaborates on many of the themes he discussed at *Soundings*. This paper offers insight into Dunning's oeuvre and clearly highlights the shared interests and values that underpin our practices. Reading it, it is clear to see why we collaborate. I have chosen to highlight two passages from the section *Iteration But Not Refinement* where Dunning talks about his instrument making and performance practice, as these state my position on these issues and what I have called the 'invitation' to attend a performance.

> By not fixing the errors in the workshop, I can ensure that they occur in the next performance, delaying the act of troubleshooting to a point in time when I will be in front of an audience again, and folding in that process to become part of the performance.

68 Graham Dunning. 2024. *Ironing In The Creases: Developing An Idiosyncratic Electro-mechanical Musical Instrument By Reinforcing Its Faults.* https://doi.org/10.5281/zenodo.13904840

69 NIME_2024, "Ironing in the Creases" YouTube, 2nd September, 2024, accessed 16th October, 2024. https://www.youtube.com/watch?v=IL9ADTHZPYw

Honing, fine-tuning, and tweaking in most instrument design would happen in the workshop, before taking the instrument or machine on stage. These processes are present in my practice, but are deferred so that they happen during the performance: If the design of the machine was such that it worked perfectly every time, there would be little for me to correct, no tweaking for me to undertake in the performance space, and hence, no performance.

Soundings

in conclusion

As mentioned in the introduction to this chapter, discussing, experiencing and presenting such work in a live acoustic environment is necessary to create transparency and a depth of experience. Using show & tells alongside performances helped to expose both the artists' raisons d'êtres and the resultant outcomes. Even within a specialist field, work varied greatly according to fundamental aesthetic concerns and individual instrument design decisions. Bringing so many pioneers to Worcester and experiencing best practice at close quarters was extremely enlightening and I would argue vital, given the nature of the work.

Aside from experiencing the work of others, the opportunity to present my work at each event, including the *Mammoth Beat Organ* and *ams* on two occasions, created moments of deep reflection and progression in my research. Through the video documentation, I was able to review my presentations and performances, which further fed into this process.

The video documentation of the *Soundings* event series is a significant part of my contribution to learning and the feedback received from attendees regarding the work experienced (gathered formally as this was an Arts Council England funded project) was resolutely positive. It also impacted the work created by those attending, especially the artists who did *Takeovers*, with some inspired to develop new works and even

awaken their dormant practices as a result. This series was a particularly novel contribution to Worcester's artistic landscape.

The fundamental themes I identify in my research, such as working acoustically and physically to maintain a strong action-sound coupling, responding to experiences of electronic music in a live setting, and creating new instruments as a route to new sonic and performative ends were ever-present. Naturally, individual responses to these aspects varied and created a richness of expression for all to behold.

Aside from the impact *Soundings* had on those attending or viewing online, it had deep implications for my own work. As has been discussed, performing with *ams* first solo and then collaboratively created a light bulb moment, which fundamentally influenced my subsequent work with it. Also, living rurally, it is difficult to experience best practice over such a long period of time. Coupled with my depth of engagement as the programmer and host, and the forward motion this gave my own work (*ams* in particular), *Soundings* fundamentally shaped my research. This is explored further through the recordings and live performances included in the next chapter.

Moving air

playing (as part of) *ams*

The work catalogued below charts the use of *ams* as a musical instrument system. Each piece or release is introduced to indicate what aspects were being probed at that point, but these pieces are intended to be encountered in their own right, as pieces of music, or performances.

As discussed in the chapter overview in the main introduction, the commentary that accompanies these pieces isn't intended to analyse them in great detail but is used to frame and discuss what they represent in terms of the state of *ams* and its music making and performance capabilities at that time. This reflects my holistic approach, which sees the development of *ams* and its use as one and the same thing. In my musical instrument development practice, the 'use' is crucial to furthering understanding and progression of a given design. The commentary in this chapter views the recordings and performances through this lens (or listens to them through this ear trumpet?).

What is highlighted throughout this chapter is a development in the musical and performances affordances of *ams,* starting with *ams'* debut album and performance, before covering a variety of settings, working methods and collaborations. Through this recursive methodology, with the light of this exposure regularly shone on *ams*, the system developed to include a wider gamut of sound making and control options, and a preferred collaborative live performance staging emerged.

This progression in *ams'* affordances as a musical instrument system developed hand in glove with the recordings and performances themselves, forming a central part of this practice-research. Taking *ams* from its humble beginnings to a system capable of the sorts of outcomes I had always envisaged.

I

Umber Ne

Debut *ams* album, released on State51 Conspiracy, September 2021



Click above image to listen on Google Drive

Nternal	*11:49*
Ilt	*08:25*
Rone	*06:07*
Nder	*03:23*
Ell	*02:09*
Aster	*05:11*
Indy	*09:15*

This debut album was recorded using an early version of *ams* and helped to define its onward development. The blurb written at the time states:

> 'Umber Ne' explores the instrument's sonic possibilities over seven pieces, each recorded in one take with me and *ams* performing a series of precarious contorted duets. This is an album that didn't exist before the creation of *ams*, and one that couldn't have existed.

These pieces vary greatly in style, from the wonky techno of *Nder* to the drone layers and textual noise of *Indy*. The process of creating and recording each piece was broadly the same and, as is typical, stemmed from experimentation. I would work through *ams* to explore what music it would create with me at the helm[70]. Some pieces would include sub-instruments and detritus, but each was performed by me, at a table with *ams* on it, often contorting my body to play all the elements together at once.

For example, expanding on the pieces mentioned above, *Nder* was mostly created using a standard drum sequencer (an Arturia BeatStep Pro), which I tweaked in real-time, alongside changes made to the items *ams* was playing when activated, such as organ pipes and percussion. It also featured a precariously balanced tom and cymbal under the table that I played as best I could along with the rest of the piece. This leads to its stumbling off-kilter nature, despite the grid-based step sequencer at its core.

Indy's textural noises were controlled using a Koma Elektronik Field Kit (Electro Acoustic Workstation), which provided the 'dirty LFO' to create the chaotic textural bed

70 Note: *Nternal* is one exception as my intern at the time, Miles Worner, was at the *ams* helm and I played the Indian harmonium.

underneath the drones. The drones themselves featured various *ams* activated custom-made latex membrane reed aerophones, alongside a sprawling bagpipe-esque instrument powered by a large balloon and a barely controllable 'vocal cord' instrument. These instruments were all built as part of *ams'* development to be simultaneously machine playable and this piece brought them all together for the first time.

Releasing and having music played in a wider context (for example, pieces from this album were played on BBC Radio 3's Late Junction[71], Resonance FM[72], NTS[73] and The Quietus[74]) provides a distinct way of removing oneself from the process of instrument making. Focus is instead shifted towards listening to the outcomes in the context of the music of others. This often leads to moments of reflection and realisations that are hard to encounter through other means. On occasion, these are quite significant in determining the path of a project as occurred when my piece *Ell* was played on Late Junction, followed by John Francis Flynn's *Tralee Gaol.* I was left questioning my grand aims at the time. Until this point, I had in some way hoped that a concentrated period of research might allow me to create a machine capable of playing an aerophone with human-like articulation and nuance. Having researched such machines and even dabbled in their making, I had no illusions that this was anything other than a deeply challenging task, but on hearing the contrast between our pieces I resolved that it would

71 "BBC Radio 3 - Late Junction, the Strangeness of Dub," 27th August, 2021, accessed 16th October, 2024. https://www.bbc.co.uk/programmes/m000z1ls

72 Benjamin Tassie. "Future Classical", 31st May, 2022, accessed 16th October, 2024. https://www.mixcloud.com/Resonance/future-classical-31-may-2022-sam-underwood/

73 NTS Radio. "Fractal Meat on a Spongy Bone", accessed 16th October, 2024. https://www.nts.live/shows/fractalmeat

74 The Quietus. "Puffer, Tapper, Blower: MrUnderwood's Acoustic Modular Synth", 7th September, 2021, accessed 16th October, 2024. https://thequietus.com/interviews/sam-underwood-ams-interview/

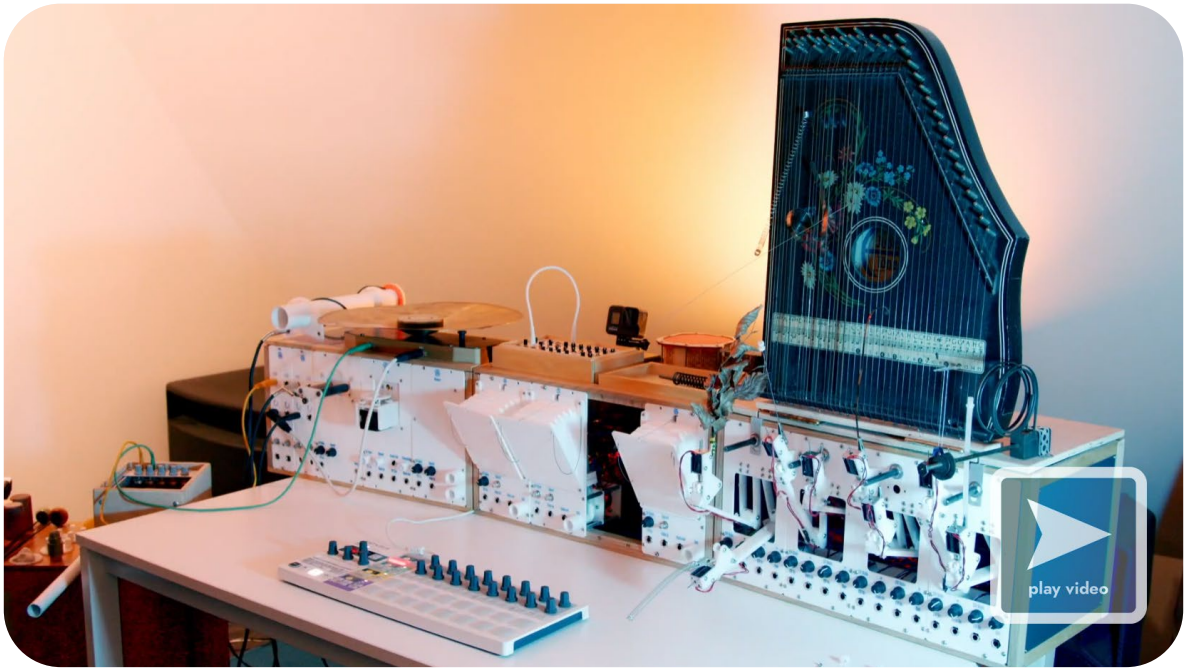
ultimately be fruitless, at least in terms which held interest for me. At this point, I committed to playing to the machinic strengths, and weaknesses, of *ams*, where alternative, novel methods of articulation are possible with complexity and depth of expression stemming from a system made up of individually (relatively) simplistic modules, rather than seeking to make a single highly complex machine towards a narrower end result.

It was interesting to hear Sarah Angliss speak about recorder playing many months thereafter, as part of her show & tell at *Soundings* (01:29), where she touched upon the subtly and nuance involved in its expressive playing, comparing and contrasting it with *ams'* method of articulation and pipe playing capabilities. This served to reinforce the position I had taken on hearing Flynn's piece.

II

Augmented Instrument Lab

Debut *ams* solo performance (online), November 2021 - **13:15**



This performance piece took place during the Covid era and was therefore delivered virtually, as part of an event organised by Lia Mice, during her time at the Augmented Instruments Laboratory. It was the first time people had seen and heard *ams* in a performance setting and I presented a single ~13 minute semi-improvised piece. At this stage in *ams'* development, I felt an urge to use and demonstrate *all* of its capabilities and these were gradually added to create a dense textural noise and drone piece that would eventually be cut off through the pulling out of the mains plug.

I felt *ams* had by that point become a playable and expressive musical instrument system, broadly functioning well as a collaborator in a human-machine setting. This was something I was unsure of until I presented it in a performance context. I also felt that *ams* was starting to make its music known to me, or at least the music I would make with it.

Staging a live performance led to the anticipated and desired scrutiny. Rehearsing and performing with *ams* highlighted what capabilities I felt were still lacking. For example, gradating the two outputs of the Blower—at this stage it could only fully switch between the two outputs on receipt of a Gate signal—and creating multiple Blower modules was clearly necessary to create the denser and more nuanced drones I sought. Something a single Blower module could not muster.

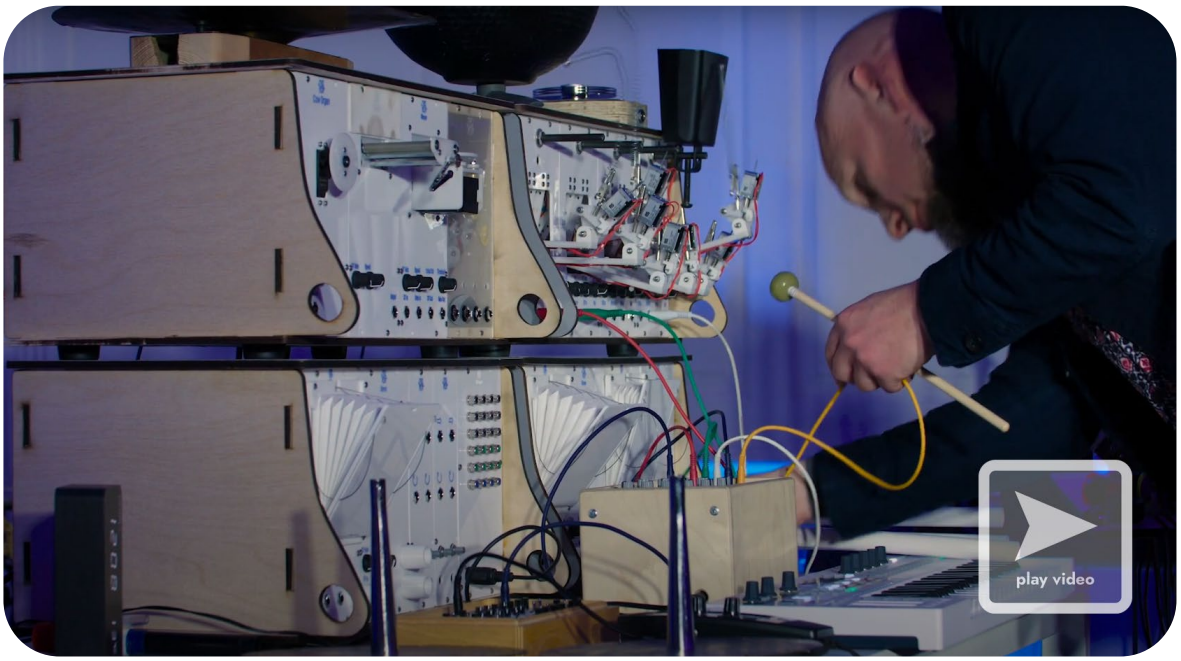
The way in which the audience encountered this performance wasn't as I would've liked, as *ams* is intended for close quarters acoustic performances. That said, the use of multiple cameras and microphones did provide food for thought, as it opened the system up in ways that were distinct from my innate live performance approach and were well suited to an online video performance.

The full online event can be viewed here.

III

Soundings #2

Debut *ams* solo live performance, November 2022 - **29:47**



This semi-improvised performance, preceded by a show & tell, was the first time *ams* had been experienced ‘in a room’ by an audience. It also included all the core modules that make up *ams* today.

This ~30 minute piece slowly morphed and built throughout, finishing on a more rhythmically driven section, which again featured an awkward under-table drum rig, akin to that used on the piece *Nder* from the debut *ams* album. This broad performance trajectory is common in *ams* performances to date.

With many new modules built—including the three Blower modules with gradated outputs mentioned previously—the creation of the music I had envisaged for *ams* was now broadly possible*,* through a system that felt replete with sound making opportunities. Naturally, I would go on to build more (sub) modules and, crucially, to learn to use *ams* more fluently and instinctively. I think at this stage not having such an in-depth knowledge of and confidence around *ams* led to a less focussed outcome than that to which I am now accustomed. This was exacerbated by the solo nature of the performance, and to some degree that I was responsible for the wider event logistics and hosting. This said, I felt happy with the performance and the state of *ams*. Most notably, it was creating the morphing drone and textural noise sounds I had designed for and I felt wider uses were making themselves known and would become usable with practice. This was also when I committed to building the Windchest sub-module to provide a different form of air control.

One of the main points of learning was to do with the scale of the venue, and the fact that, especially with *ams* on a stage, my presence would obscure what was going on for some audience members. This was the moment at which the decision was taken to accentuate the close quarters, deep listening nature of *ams* in a performance context. In most cases, future performances would take place in-the-round.

IV

Ly

Improv piece on Goliard Recordings tape compilation, March 2023 – 06:44



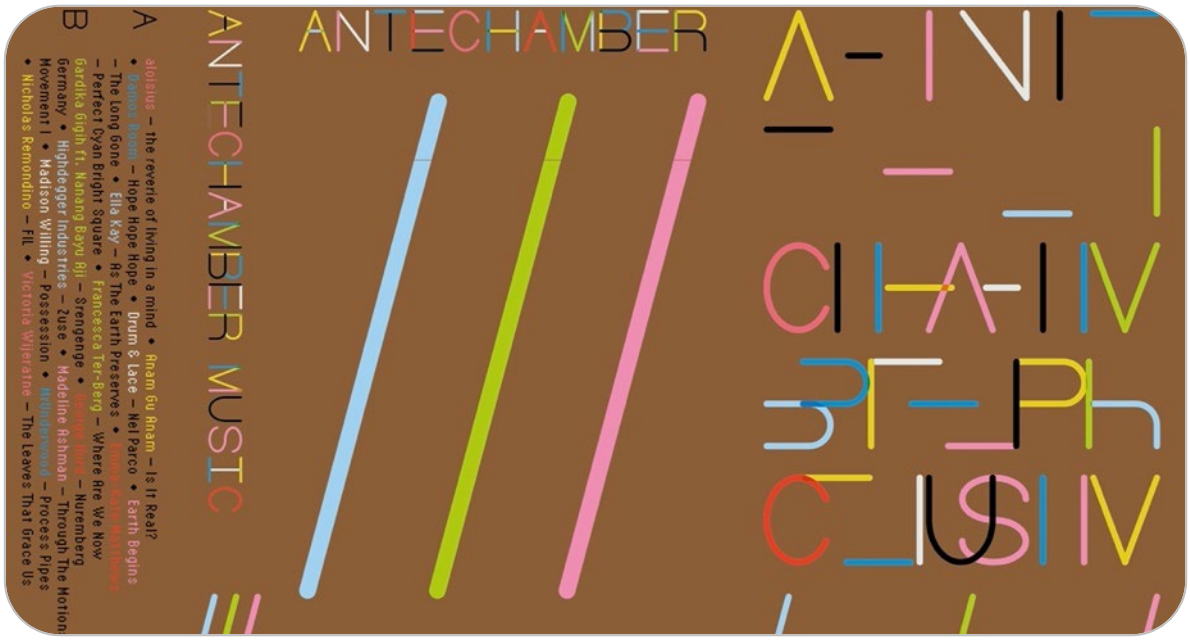
Click above image to listen on Google Drive

This piece, released on a tape compilation by Goliard Recordings, represents a growing confidence in my use of *ams*. I had set *ams* up in a state that meant it would function chaotically across all modules when it received a single control signal. The intensity grows and then subsides again, accompanied by my vocal harmonisations. By this stage *ams* had started to make its music known to me and I had relaxed into the ebb and flow of agency between human and machine. This piece was semi-improvised and recorded in one take. I include it here to show progression. It both highlights *ams* being utilised as a full-system and is a rare example of the human in the machine contributing sounds to the mix.

V

Process Pipes

First MIDI piece, released on Accidental Editions, August 2024[75] - **05:13**



Click above image to listen on Google Drive

This piece, released on Accidental's Antichamber compilation, represents a significant probe into an entirely different approach to controlling *ams*. I use the term 'controlling' here, as opposed to 'playing' or 'performing', because, unusually, this piece was pre-sequenced and *ams* was then set to run, without any real-time human intervention. Due to an upcoming collaboration with hellocatfood (included below), I had worked to create a means of MIDI controlling *ams*. hellocatfood would do so using live code but for this

75 Recorded March 2023

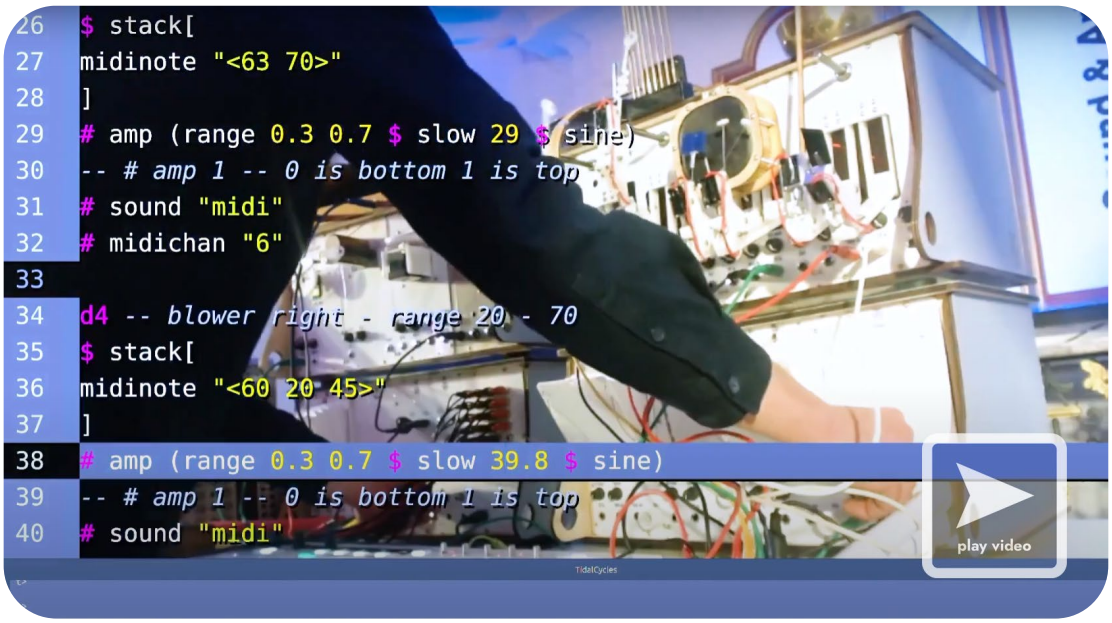
piece I turned to Cubase to explore tight and complex control, to create a process piece using pitched pipes on the Windchest sub-module.

This piece enabled the exploration of more structured and complex playing, without the intervention of a human player in the role of sound shaper or disrupter. Whilst this way of working opened some opportunities in a studio setting, I found it strengthened my commitment to a human-in-the-machine when considering *ams* as a live performance instrument. Although I was able to create greater rhythmical complexity and exploit some interesting sonic effects through the pre-sequencing of *ams,* I consider this would significantly limit opportunities for reflexion and happenstance in a live setting. These are core performativity traits in *ams* and form part of the invitation to be there, at an *ams* performance. Though as covered when analysing the *ams x hellocatfood* performance below, there is a route to rich, complex and reflexive sequencing alongside similarly focused and responsive sound shaping and disruption, by splitting the tasks of sequencing and sonic manipulation between two performers.

VI

ams x hellocatfood

Live coded *ams* at *Soundings* #4, May 2023 – 31:56



This performance was a deep probe into task-sharing. hellocatfood (Antonio Roberts) was entirely in charge of the actuation of *ams*. My role was to respond to this impetus in real-time, shaping the sonic outcomes of these actions. Oftentimes, aspects would lie beyond the detailed control of either of us.

As well as hellocatfood typing and me tweaking, the live code and footage of *ams* were displayed on a large screen, stage left. With the added intrigue of seeing the code, I felt the screen complimented our aesthetic aims better than if I had been playing solo. That

is to say that in a solo *ams* performance I would prefer the audience to encounter *ams* at close quarters, rather than remotely, even if a screen was used to 'bring them in'.

This performance was similar in musical form to my debut in-person *ams* performance at *Soundings #2*, building from textural noise to more structured rhythmical outcomes, but it felt more controlled. More fun, even. Something which people who attended both performances fed back to me afterwards.

I had it reaffirmed that this form of collaborative live music making could be very fruitful. This is something I have done in duo performances before, where I was responsible for real-time effects processing in response to audio generated by someone else. As with that project, not having to consider all aspects myself was freeing and led to a deeper engagement with the detailed work of shaping *ams'* mechanical and sonic outcomes. Until this performance, I hadn't considered how such a way of working serves to maximise interferability by creating enough headspace for me to engage in this more deeply. It felt like the best *ams* live performance to that point and is an approach I went on to explore further with hellocatfood and other live-coders[76], as well as through my ongoing collaboration with Graham Dunning (below) that saw our machines controlling each other, resulting in a similar task sharing approach. Beyond these examples, *ams* would be well suited to a range of other collaborative settings, such as forming part of a large improvising ensemble, playing with electronic modular rigs, or even as a single-module-relentless-mechanical-noise source for longform pieces.

76 Most notably a live performance with Eye Measure at Pattern Club in Sheffield on the 29th Sept 2023

VII

Beaux Timbres

Album released on Paradise Records (June ‘23) and Accidental Editions (October ‘24)



Click above image to listen on Google Drive

Rôtation Côsmik	*03:10*
Les Yeux Avides	*04:18*
Pest Modern +	*03:12*
Ecusson	*05:59*
Biscuit and Milk	*01:41*
Beaux Timbres	*03:35*
Air	*05:40*
Prix Libre	*03:42*
Machines A Musique	*04:37*

This release was as part of an artist residency in Nantes, in June 2023, where Graham Dunning and I worked to explore areas of interest, overlap and contrast between our musical instrument systems. I would use three cases of *ams* modules and Graham his extended turntable system, which uses a Technics 1210 record deck as a motor for an elaborate and idiosyncratic rotary sequencer system. Graham had already started to extend his system further, to include some early work towards his own PhD research and this meeting of machines would drive both of us to develop many further opportunities for interaction between our systems, culminating in our performance at Line Up Festival (below).

Working to a relatively short timeframe within a semi-improvised musical framework served to expose many of the nuances, capabilities and limitations of each system. These included the quiet and chaotic tendencies of *ams* set against the loop-based and electronic music sounds of Graham's extended turntable system. These recordings were initially released as a super-limited edition on Paradise Records before a follow-up release on Accidental Editions.

Though it is more common for us to create a single longform piece, exploring a variety of styles and approaches, when we perform together, we chose to split this into individual tracks. This reflected how we had worked together during the residency and allowed for reconfiguring our systems to create discreet setups for each piece. We would then improvise and allow the music to unfold within each loosely defined framework. Sometimes *ams* would exert greater control, such as using the Shaper module to provide us both with a modulation source based on a gently fluctuating piece

of plasticine (Ecusson). Other times Graham's system would provide a rhythmical pattern to control *ams'* various actuators (Machines A Musique). At all times, we were both humans in the machine, disrupting and adapting outcomes.

This residency also included the ongoing development and adaption of *ams*; creating music in and of Nantes. Influenced by a mixture of the things we encountered locally and also directly using items that were scavenged, such as flexible beaters and random detritus.

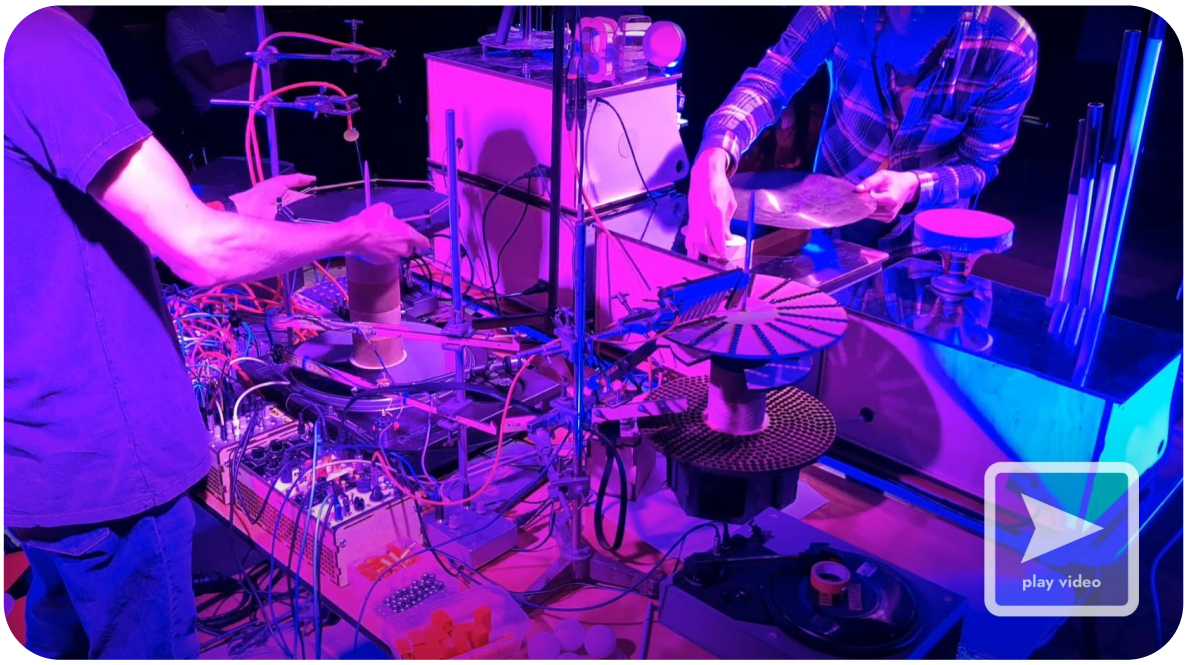
ams' modularity and reconfigurability was exploited in this instance as only three cases of modules would fit on the Eurostar. I was able to select the mixture of devices best suited to our collaboration.

We delivered two performances during this residency, but I have chosen to include our most recent collaborative performance (below) as this comes after a gestation period following on from this initial meeting of machines, during which our systems have developed significantly to create wider opportunities for interplay. I use the performance at Line Up Festival in Malvern (August 2024) to reflect on the status of *ams* near the point of submission of this research, and in the terms set out by it.

VII

ams x extended turntable

Live performance at Line Up Festival, 24th August 2024 – 53:54



In the context of this research, this performance with Graham Dunning and his machines represented a bookending, a coming of age even, of my work with *ams* to date. I relaxed into *ams* and the shared process of music making in a way that stemmed from a contentment with its capabilities and my fluency as part of the system. As discussed previously, this task sharing approach is one I have engaged in and found fruitful before, but having both developed our systems to shape their affordances in ways that increased their hybridisation, we were able to exploit this throughout. As with

the recording of our album *Beaux Timbres*, each party (human and machine) exerted varying degrees of control over the structure and music of this performance, but these new expressive opportunities resulted in the most satisfying *ams* performance I have delivered to date.

The set started with the *ams* Winchest controlled by Dunning's rotary MIDI sequencer. This uses ball bearings to trigger switches, which output MIDI notes within a range Dunning can vary through a module of his design. We used this to create an additive process piece, accompanied by a building textural noise bed and rhythms created by both systems. At some point (from around 17:30) the Piezo (prototype), Shaper and Piezo Feedbacker modules of *ams* are used to create a chaotic rotary platter sequence that is amplified and then used as CV to control Dunning's synths. Drones and noises are layered on top of this before more rhythmical patterns start to reemerge around the 36 minute mark. This ultimately culminates in a driven, yet decidedly wonky, finale, with Dunning's system firmly back at the helm. The broad range of music and performative exchanges, indicate a maturing of *ams* and Dunning's extended turntable set up. It was clear from how we both relaxed into what we were doing (we played 20 minutes longer than billed) that there was a contentment and confidence in our systems and approaches.

When considering this performance with reference to notions of agency and expressivity, one can see and hear how embedded the broken machine aesthetic is in both of our practices. Each of us employing difficult to use systems that are created to

include and embrace imprecision and fallibility. When conjoined, agency ebbs and flows between all the parties involved, human or otherwise.

This collaboration is clearly situated in the long shadow of electronic music. The system Dunning uses here stems from his *Mechanical Techno* project, which he employs to create "slightly off-kilter dance music"[77]. This tends towards looping, pattern-based outcomes, which were expressed across both systems. Graham's use of electronic synth and drum sounds—played in this case through tabletop speakers at a volume allowing for mixing with *ams'* acoustic sounds—also adds a more obvious electronic music influence to the live 'found sounds' of *ams.* Though it is in a broader, foundational sense that both of our practices draw on electronic music here. One that stems from asking similar questions about live electronic music performances we have encountered and our shared interest in action-sound coupling and liveness.

To this end, we both employ approaches that place visible physical systems in front of people, with us both playing in-the-round in this collaboration. The action-sound coupling is strong. Inescapable, even. Ranging from grand systemic features, such as Graham loading up his Technics 1210 powered rotary sequencer, to micro-gestures such as me subtly tweaking the length of an organ pipe to alter a sequenced pattern being created by Graham's system. As a performer, such live tweakability is often very satisfying and I got lost in it at times during this set.

77 Graham Dunning. 2024. *Ironing In The Creases*. https://doi.org/10.5281/zenodo.13904840

Following a period in which we both worked to develop our systems, with some emphasis on how they can integrate better in a live setting, this performance felt like an exciting and invigorating coming together. I very much look forward to our systems encountering each other in future.

Moving air

in conclusion

The work presented above charts the development of *ams* as a musical instrument system. A development that saw machine and music inexorably linked: repeatedly challenged and progressed. From the somewhat tentative debut album *Umber Ne*, and the throw-everything-at-it *Augmented Instruments Lab* online debut, things progressed to arrive at the collaborative performances with hellocatfood and Graham Dunning, where the system—including the human in it—had reached a point where its capabilities and ease of expression were significantly better established.

Beyond this broad progression it is interesting to reflect on the differences between the outcomes when *ams* is used in a recorded or live setting. In a studio environment each piece can be crafted in a way that involves setting up the varied—and collectively complex—systems that make up *ams* to achieve certain aesthetic aims. In a live setting, pieces tend to morph more slowly and lack such distinct shifts in style, as the process of reconfiguring *ams* dictates. This serves as a good example of how a musical instrument's design affects its use and outcomes, and that the affordances can themselves vary according to the setting.

The collaborative tendencies of *ams,* and its operator, have provided the most fruitful explorations to date. The task sharing not only between human and machine but with others controlling, or at least cajoling, *ams* opened the system up to more detailed

exploration on the sound making and shaping side. Something I considered extremely fruitful.

There is a great deal more music to be created with *ams,* which will explore other ways of engaging with it. I'd also like to hand it over to others to work with, which is bound to create bold changes in direction and use. Some might wish to explore it through the creation of super longform static pieces that take advantage of its machinic stamina, whilst others may go deep on the chance operations of chaotic sequencing, or some may simply decide to make wonky acoustic techno. The openness, adaptability and control scheme of *ams* creates a basis for all these approaches and many more.

Together, these outcomes show a system and performance practice in flux. Charting a gradual but inexorable progress, in response to repeated experimentation, development and scrutiny. Presented as they are in this chapter, these pieces also serve to mask much of the messiness, failure and uncertainty that accompanies such research. Plus, under the pressure of time, not everything you'd like to develop can get your full, immediate attention. The next chapter explores some of these tensions.

A moment in time

what next?

As with any PhD, the research covered in this thesis represents a moment in time. It can be viewed in the context of my wider work as both a continuation, and an intense period of deep study. Given my broad ranging and deeply inquisitive practice it has been difficult to define the boundaries of what to present, as even within the development of *ams* much has been omitted or only exists as green shoots at this stage. This includes findings arising from the use of *ams* as recently as the collaborative performance with Graham Dunning some weeks prior to me writing this sentence. This research is both built on my work that preceded it and represents a step change in terms of the depth and rigour of it, resulting in this (cherished) opportunity to create a new musical instrument system and investigate its affordances. An exploration that has begun in earnest but that has much ahead of it still.

The research outlined herein can be thought of as a node in a sprawling network of possibilities. Encountering the same stimuli again, I would have ended up in a different place. That is the nature of such working practices, where unpredictable moments of inspiration occasionally speak, making themselves heard above the background noise. As such, this PhD is a snapshot in time from which it is hard to state in detail where my

research will take me next, other than, to use the motto of the fine city of my institution, the Royal Birmingham Conservatoire: 'Forward'.

It is worth reflecting that this research and my work in this field also impacts the work of others, and where this takes their work is also yet to be uncovered. During this period of research, I have worked directly with many artists and practitioners, such as Graham Dunning, hellocatfood, Eye Measure, Benjamin Tassie, Zubin Kanga and of course Richard Sewell, as well as engaging with all the artists who presented their work at *Soundings*. I have also sought to publicise my research widely. Alongside live performances and recordings, I have been interviewed about *ams* by Jennifer Lucy Allan for The Quietus[78], Benjamin Tassie for his Resonance FM show[79], had pieces played on BBC Radio 3's Late Junction[80] and NTS[81], and set up a YouTube channel[82] which has been picked up and shared widely. The *Mammoth Beat Organ* was even included in an exhibition on musical instrument design at the Science Museum[83].

Throughout this process, I have developed and used *ams* in a variety of settings. I have also identified several findings and contributions that have shown themselves to be worthy of further interrogation. These are covered in the section *further exploration* below, and no doubt some of these will end up answering the query: *what next?*

78 The Quietus. "Puffer, Tapper, Blower: MrUnderwood's Acoustic Modular Synth", 7th September, 2021, accessed 16th October, 2024. https://thequietus.com/interviews/sam-underwood-ams-interview/

79 Benjamin Tassie. "Future Classical", 31st May, 2022, accessed 16th October, 2024. https://www.mixcloud.com/Resonance/future-classical-31-may-2022-sam-underwood/

80 "BBC Radio 3 - Late Junction, the Strangeness of Dub," 27th August, 2021, accessed 16th October, 2024. https://www.bbc.co.uk/programmes/m000z1ls

81 NTS Radio. "Fractal Meat on a Spongy Bone", accessed 16th October, 2024. https://www.nts.live/shows/fractalmeat

82 Sam Underwood. "Parp Clink Bonk", YouTube, accessed 16th October, 2024. https://www.youtube.com/@ParpClinkBonk

83 Science Museum. "Turn It Up: The Power Of Music", accessed 16th October, 2024. https://www.sciencemuseum.org.uk/what-was-on/turn-it-up

further exploration

As a highly inquisitive and determined reflective practitioner, it can be difficult to constrain my research, to separate distractions from areas worthy of further exploration, especially as this distinction is not always clear upon initial investigation. As such, I have chosen to cover the areas that have made themselves apparent as *key* to further investigation in this section. Some interesting technical approaches and findings, representing broad areas for further exploration by myself and others, are included in the accompanying appendix.

Controlling and sequencing

In modular synth and electronic music realms, musical outcomes are shaped, often defined, by the chosen controllers and sequencers. More often than not, the sound modules themselves just obey incoming control signals, so how one initiates this control is key. To date I have used a mixture of loop-based and chaotic sequencers, which create outcomes at either end of a spectrum. One is reminded of the discussion relating to the first *Soundings* event, of the Tuuri, Parvianen, and Pirhonen paper[84] contrasting 'control over' and 'indwelling', as it provides a good analogue for the distinction between these diverse ways of controlling *ams*. The former being *ams* when controlled by a rigid

84 Tuuri, Kai, Jaana Parviainen, and Antti Pirhonen. 2017. *Who Controls Who? Embodied Control Within Human–Technology Choreographies†*. https://doi.org/10.1093/iwc/iww040

step sequencer and the latter when the Shaper's chaotic platter sequencer forms part of a complex system with no strictly defined control structure. Due to *ams'* adherence to modular control standards, there are many options to explore here, both in terms of existing modules for purchase and any I may choose to build. As part of this exploration, additional study of chaotic (especially magnetic platter) sequencers will be undertaken to further investigate issues of agency and chance in the design of musical machines. One original goal included building enough control and sequencing into *ams* to make it possible for it to be self-contained, and that is still an attractive avenue.

Flexures

A related area that warrants further investigation is that of laser cut flexures. As discussed in ***Design, make, experiment, repeat***, through the use of these one can derive complex outcomes, such as polyrhythms from straight pulses or more general variability and richness that doesn't apply in more rigid systems. While my study of these to date has involved creating a range of flexure designs and testing them in use, they have shown themselves to be worthy of more strategic study, as laser cutting allows for reliable changing of variables such as flex and loading. Therefore, a structured process to assess these in a variety of materials and designs is a logical next step. If accompanied by a set of machine-movable percussion instruments, these could add great richness and adaptability in terms of my *reflexive machine* research.

Feedback instruments

Feedback instruments and systems have shown themselves to be very promising in terms of my *reflexive machine* aims and the wider aims and aesthetics of *ams*. They are visually stimulating, with a strong action-sound coupling and they create astable, difficult to control outcomes, which are exciting from a performance perspective. This is a rich area of exploration[85] and one I have embraced more widely in my work over the years. The next stages of this in terms of *ams* would include a formal study of the effects of the form and loading of feedback surface instruments, and the development of a prototype instrument that is constrained using electromagnets above (not touching) the surface.

Machine playable pitched instruments

Latex and pitched pipe instruments within *ams* offer machine playability and variation of frequency. To date, my exploration has mostly been restricted to sub-instruments with only loosely controllable pitch outcomes, or instruments where the pitch can be controlled more reliably but only by the human player. I have developed designs for a variety of latex, pipe and stringed instruments with more tightly controllable frequency variation, such as a slit pipe that is tuned by rotating a close-fitting outer pipe featuring a helical slit. It is hard to predict the extent to which my research will extend into this area, as my focus is not on tightly controlled pitch outcomes, but as each element is modular, any such instrument would be open to disruption by the human-in-the-machine.

85 "Participants" Feedback Musicianship Network, 4th May 2021, accessed 16th October, 2024. https://feedback-musicianship.pubpub.org/pub/z8z983sj/release/16

Other humans-in-the-machine

Speaking of the human-in-the-machine, I hope to extend the investigation of *ams* beyond my use of it by offering it for loan to other artists and performers. Such an open and collaborative approach should throw up some interesting findings, that necessarily fall beyond those that would be encountered through my continued use of *ams*.

Collaborative live performances

Further collaborations on the performance side of my practice will also be sought. Having explored collaboration in this research as a fruitful and engaging approach to music (and instrument) making, this has transformed my work with *ams* and is worthy of deeper investigation. It has been seen to be particularly fruitful collaborating in a live setting, with the tasks of controlling and shaping the sonic output of *ams* separated. There are many more approaches to explore here, such as working with electronic modular artists, artists working with algorithmic patterns, or seeking out those with similarly wonky systems to *ams*.

Playing (as part of) *ams*...more

Beyond the many findings, ideas, developments, and outcomes outlined above, learning to play (indwell in) *ams* is a key next step. As with any musical instrument this includes a mixture of technical mastery and self-expression. I relish these next steps.

(Re)solution

conclusions and contributions

Where some experimental musical practices seek to explore the boundaries of existing instruments and compositional approaches, my research—through the creation and investigation of *ams*—harnessed a never-before-encountered musical instrument system, resulting in an open exploration that sidestepped many inherent associations and formulas. I would contend that experimental musical instrument makers necessarily find themselves somewhere on a spectrum between two broad camps. Those who design instruments to fulfil specific aesthetic and musical intentions that are not catered for by existing instrumentation (such as Luigi Russolo embracing noise and Harry Parch microtonality) and those for whom a new instrument is a starting point for a wide-ranging sonic exploration (such as the Bachet Brothers' many experimental designs and Bart Hopkin's diverse Instrumentarium). Clearly, a blend of these concerns is often present but *ams* certainly falls more into the second camp, with the ongoing development driven by a series of experiments and an iterative design process. In fact, it is designed in modular form in part to easily respond to findings which demand further probing, adaption or expansion, to add new sonic or control capabilities. This research is grounded in this exploration, in order to uncover the unique affordances of such an approach and system. The live playing of *ams* itself forms part of this ongoing exploration, through an assessment of the encounters that occur between human and machine, in the moment.

Whilst many of the aesthetic bents of *ams*, such as textural noise, chance operations and drone are long established in experimental and wider music making practices, the creation of a wholly new system, with fresh control and sound making capabilities, necessarily results in new musical and live performance affordances.

As such, *ams* itself is a primary contribution of this research and below I seek to unpack these affordances by referring to each of my research aims in turn.

Probe the affordances and creative opportunities presented by *ams* as a new human-machine musical instrument system

Many novel music making and performance opportunities have been established through the development and use of *ams*, and many more will be uncovered through its continued use. The fundamental decisions underlying the design approach are key in shaping these. I would contend that the following principles are central in determining the affordances of *ams* and represent primary contributions of this research:

Embedding a human player in the machine

The collaboration between human and machine in *ams* shapes its affordances most fundamentally. Its physical, acoustic nature embeds a messiness in the system that adds colour and complexity to the sonic outcomes, through a sharing of agency between the human and the non-human. This collaboration combines many of the strengths of machine music, such as multitasking and hyper-virtuosity, with the abilities of a human performer, such as listening and reflexivity.

The design of *ams* is fundamentally shaped by the decision to embed a human player. This leads to its inside-outness and to its striving for *Maximum Interferability*. These principles define *ams'* playability and performance affordances, and in turn the music

one makes with it. When coupled with the sonic aesthetic decisions that underpin *ams*, such as a focus on timbre and textural sounds, the eschewing of 12-tone equal temperament and the acceptance of machine noise, new and unusual sound worlds are created.

Acousticness and quietness

These attributes create a distinctive invitation to audiences experiencing *ams*. I especially consider its quietness a radical and provocative act, for performer and audience alike. It demands and rewards close attention to the sounds created and the acts which elicit them.

ams starts by posing more questions than it answers, opening up ways of using and encountering it. Its distinctive combination, encompassing familiar structural and control formats, alongside a radical looking and sounding physical system commands attention and creates distinctive performative opportunities.

From a sound and instrument design perspective, my interest is in exploring the fine detail and messiness of acoustic sound creation and shaping, and the direct means by which this can be altered. For example, when a physical, mechanical process is not functioning as you might like, the cause and remedy are generally open and obvious. I found this not to be the case in the past when designing electronic synths that relied on changes to analogue circuitry.

This direct coupling between action and sound is also true for audiences experiencing such instruments, rather than being hidden away in hard to decipher black boxes. In the

words of Magnusson, “Unlike electronic or digital instruments, acoustic instruments do not come with a manual, they are manual.”[86] *ams* foregrounds this through its radical presentation as a ‘very quiet acoustic musical instrument’.

It must also be acknowledged that this decision imposes restrictions on *ams* and how it can be encountered. There is no firm rule stating that it can’t have overhead microphones and amplification, which may be worthy of exploration at some point, but I abandoned this way of thinking about *ams* during its development, in favour of this more radical position.

Modularity

When creating a musical instrument *system*, modular thinking is not uncommon. One might even characterise a string quartet as four acoustic modules, each fulfilling a given role. Other, more closely aligned modular approaches, such as Logos Foundation’s Robot Orchestra[87], exploit their modularity to create a flexible and novel ensemble. Through the adoption of a (fractally) modular design approach *ams* places these traits at its core, which has seen its capabilities significantly expanded and adapted over time. Modules can ‘simply’ be created or adjusted to increase or alter *ams’* scope. Additionally, by situating it in such a buoyant field, where expansion possibilities are plentiful—through modules that can be purchased—*ams* is open to development beyond its acoustic and mechanical beginnings.

86 Magnusson, Thor. 2019. *Sonic Writing: Technologies of Material, Symbolic, and Signal Inscriptions.* https://doi.org/10.5040/9781501313899

87 Logos Foundation. “The World’s Largest Robot Orchestra”, accessed 16th October, 2024. https://www.logosfoundation.org/mnm/index.html

This modular approach also leads to a flexible system capable of performing many sound-making tasks at once. Where such capabilities may be commonplace in electronic music systems, they are rare in the acoustic musical instrument realm, especially in playable instruments, as opposed to reproductive instruments, such as fairground organs.

Fractal Modularity

In developing *ams*, I have interrogated the possibilities of modularity-to-the-nth-degree, throughout its design. I propose that this is linked to the principle of *Maximum Interferability* as it opens each layer of the instrument up to alteration, by modularising it. For example, when the Blower module is plumbed into the Windchest sub-module, sounding pipes can be swapped in real-time and I even created a set of modular organ pipes where different pipe lengths can be dropped onto the foot/mouth sections, on the fly, to quickly alter the frequency and voicing. This expansive form of modularity results in a highly adaptable system, that allows for live and visible alterations, and for an open-ended design process. This creates a depth of flexibility and scope for adaption beyond a system whose modularity ceases at the module front.

Play

People often use the word ‘whimsy’ to describe their experience of encountering *ams*. My live performance and musical instrument making practices have always embraced such outcomes, based on a healthy background principle of not taking oneself too seriously. This opens the door to the creation of instruments that look and sound somewhat outlandish, or even, at times, ridiculous. *ams* can be both of those things and I welcome opportunities to explore this in design and performance settings. I would also contend that this helps to lower barriers for some people encountering *ams*, as either audience members or users, with children seemingly treating it as some sort of sonic playground.

Novel mechanical design principles

The adoption of three core and unusual mechanical design principles in the development of *ams* has shaped its affordances and I propose these as interesting principles to explore whenever creating such a system. As follows:

- Maximum Interferability

  This principle leads to designs that are as open and forgiving of human intervention as possible. This has fundamental implications for any design and expands the potential sonic and performance affordances. For example, the poseable arms and hot-swappable beaters of *ams’* drum modules offer much greater adaptability than a robotic drum machine with fixed actuators.

- Welcoming of side effects

  I am happy to consider many of the side effects of *ams*' mechanical systems such as motors whirring, solenoids clicking and non-linear outcomes, as part of its aesthetic. They are bonus sounds and actions. Adopting an open and pragmatic approach to these has many benefits. It creates richer and more complex outcomes and doesn't draw focus from the creative exploration through lengthy and difficult efforts to counteract these features. In some cases, it even allows for creative exploration of these side effects in their own right, such as using the Shaper's stepper motor to create sequences of frequencies, for example.

- A reflexive machine

  Striving to create and embracing a system that responds reflexively to its physical environment is one of the richest areas encountered through this research. This has included formal exploration of these attributes, such as the design of flexure beaters, or pure happenstance, such as the first time realising the Shaper module could be used as a chaotic platter sequencer. Both are now central to *ams'* capabilities and give the system agency in a way that a more rigid approach would not.

  These design principles could be broadly grouped under the heading 'abandoning control'. Richard Sewell describes this as "my biggest learning from *ams*, the acceptance of side effects and ill-controlled mechanisms as contributors to the richness of performance. Quite a culture shock from an engineering point of view.".

Adherence to modular design/control standards

An open and expansive system is created through the embedding of modular synth control and format standards at the heart of *ams.* This creates a variety of affordances which are again relatively familiar in electronic music but less so in acoustic instrument designs. These include:

- Expansion and adaption opportunities

  These stem from an ability to purchase and incorporate entirely new sound-making and control modules. Though the use of third-party electronic sound-making modules feels less in keeping with my exploration of *ams* to date, the chosen control method has been shown to be fundamental to the music *ams* creates, and its standardised method of control opens the door to many options for doing so. For example, outcomes vary significantly if using a dance music-oriented sequencer such as Arturia's KeyStep Pro, or the Shaper as a chaotic platter sequencer, or a shop bought aleatoric CV sequencer module. This adds great flexibility and opportunity for extending *ams* with many new and often very specific modules being created, allowing for an ever-evolving system, whilst still maintaining the openness and messiness of acoustic sound-making at its core.

- Collaboration

  Another key aspect unlocked by *ams'* adherence to modular control standards is the ability of systems to control, or be controlled by, *ams*. This has proved fruitful in a variety of collaborative performances, including having *ams* controlled through live-coding, electronic modular systems and even physical controllers such as Graham Dunning's expanded turntable sequencers. In the latter case *ams* was also used as a control source.

Explore how modular design approaches can deliver more bespoke and reflexive acoustic musical instruments.

As touched upon above when considering the affordances of *ams,* modularity is a key feature, both in the way it creates a flexible instrument design basis and in the technical sense of adhering to modular synth standards. I would contend that this is a very effective means of creating an instrument system that can be shaped to the aesthetic aims of the performer. This occurred on many occasions during the development of *ams,* for example: responding to a sense that the system lacked certain capabilities, such as adding new sound and control modules; tweaking existing modules, such as blending the Blower module outputs in order to create beat frequencies; and duplicating existing modules to create wider sound-making capabilities, such as adding multiple Puffer modules to create chords. In this sense, *ams* is both bespoke and reflexive in its design.

The principle of *Fractal Modularity* in *ams* acts both as a means for further instrument customisation and for real-time adaption and reflexion by the human player. During a performance this is exploited by the human-in-the-machine to shape the sonic outcomes, through direct physical manipulation. What my approach also strives to do is create a system that responds reflexively to its physical environment. What I term a *Reflexive Machine*. This is really just a case of designing in properties that mean the physics of the situation affects outcomes more significantly than would be the case if

using a more rigid system. Another way to approach extending *ams'* reflexiveness would be to develop modules that are responsive to external controls. To some extent this is the case with the proximity sensor in the Shaper module, but it could potentially include more in its design to respond to inputs, such as 'listening and harmonising' using fast Fourier transform (FFT) or AI.

Modularity and *Fractal Modularity*, lead to systems with complex pathways that can be harnessed in a variety of configurations to different musical ends. As demonstrated in the videos herein, this can range from chaotic textural noise pieces to rigidly structured compositions. The *ams* modules and sound making capabilities also mean that when it is harnessed as a system it can be considered a complete performance instrument, in a way that individual instruments tend not to be.

A modular approach in acoustic musical instrument design could look very different to how it applies in *ams* and is something I would encourage wider exploration of, in the pursuit of more customisable and reflexive instruments. As it is used in *ams*, modularity has several interesting properties. It brings both openness and constraint. In terms of openness, it means that new modules can be added when new ideas appear, and modules can be duplicated when more of a certain kind of work needs to be done. It also means that modules can be combined very richly, both electrically (via the CV and Gate control scheme), pneumatically (either of the *ams* air sources, external bellows/chambers, or the performer's lungs can be connected to any of the aerophones), and mechanically (one module can literally be used to strike or foul nearby

modules). This gives the performer a huge range of possibilities. Though these shared interfaces and modularity also impose constraints. For example, no part of the system is committed to producing any particular range of frequencies. Modules are also generally monophonic or duophonic, for those which can even be considered in those terms at all. The chosen module size—despite opting for the larger 5U/MU size over the much smaller and more widely used Eurorack format—also imposes major constraints. For example, the Puffer modules cannot drive large aerophones because the maximum practical bellows size is still quite small. Also, despite experimenting with stringed instrument modules—including using a special metal impregnated rubber string to create lower frequencies at shorter lengths—a finalised design was never (yet) reached, due to the short scale restriction imposed by the module size. There are many other such examples.

Naturally, much was explored in terms of what *could* be done at this size, such as developing the latex instruments, which create lower frequencies at a smaller scale, and making compliant beaters to add a *flick*, thus increasing strike strength. Again, there are many such examples included in *ams* many of the most novel findings were driven by the size constraint itself.

One area in which this constraint doesn't apply so much, is in the *ams* sub-modules, which break out of the module format and have opened the system up to many additional affordances.

If I had chosen a different size, or an entirely different version of modularity in acoustic musical instrument design, inevitably a very different system would have emerged as other instruments and approaches would have been practical. These are the fundamental design decisions that go on to determine the idiosyncrasies of any musical instrument. As we experienced with the *Mammoth Beat Organ*, these can be the source of some tension, but I would contend that in both cases, the modular design approach has added flexibility and delivered more bespoke and reflexive instruments.

Examine the interrelations between *ams* and electronic music to inform a post-electronic, post-speaker soundscape.

During my research these topics were frequently touched upon, oftentimes as part of a foundational discourse describing why artists choose to work in a certain way. This was especially prevalent amongst the artists that presented their work as part of the *Soundings* event series, where themes repeatedly emerged exploring concepts of the open and coupled nature of acoustic musical instruments, and in many senses what it means to perform at all. Whether it was Kenchington describing the opportunities presented by task-sharing with mechanical instruments and a longing to ‘keep it real’, or Angliss speaking of the richness of a physical acoustic system (the stuff you get 'for free’) coupled with computer control, these were compelling arguments presented in support of the use and combination of electronic and mechanical systems with acoustic instruments, in a performance landscape informed by electronic music.

My research, in the form of *ams*, is a very direct manifestation of this approach. One that stems from many of the same concerns and seeks to exploit and combine the opportunities presented by new technologies (on the control and manufacturing sides), materials and the messy complexity of acoustics. My iterative and experimental process of developing and using *ams* has done much to interrogate the interrelation between

acoustic instruments and electronic music, and with the system now in place this exploration is ongoing.

Regarding post-electronic and post-speaker soundscapes, as described by Wilson[88] and Bradley[89] respectively, much of my work and many of the ways of creating and harnessing sounds within *ams* uses the physical, acoustic, mechanical and feedback systems, they describe. Exploiting the richness, complexity and happenstance of such sound making. In the case of *ams* though, I consider its ability to integrate with widely available electronic music equipment as adding another sense in which it creates post-electronic music. This can be in the form of synths, controllers and sequencers, as well as other pattern-based controllers such as Tidal Cycles—the programming environment used by hellocatfood at *Soundings*—and Graham Dunning's physical rotary sequencers. Such capabilities allow for the use of systems and approaches which stem directly from electronic music. Indeed, I often use *ams* to create music heavily influenced by electronic music, and even dance music, but I attempt to maintain the embodied live aspect and much of the richness and complexity that Wilson describes and harnesses in his own work.

One area I hoped to explore further through *ams* by this point is that of the creation of 'electronic music sounds' through acoustic means. This may be a somewhat vague goal—and possibly somewhat perverse, given that many synth sounds were originally

88 Wilson, Daniel. 2012. Miraculous Agitations: On the Uses of Chaotic, Non-Linear and Emergent Behavior in Acoustic Vibrating Physical Systems.

89 Bradley, Fari. 2021. A New Materiality Post-Speaker Sound Art.

modelled on acoustic sounds—but some of my findings certainly touched on this, such as the feedback pipe beat frequencies and the bell sounds of the clock chimes. Nonetheless, I had aimed to address this goal through a more rigorous, structured exploration that identified, sought to mimic, and catalogued some signature synthesiser sounds. Something to explore when using *ams* in future.

Explore how visual and sonic 'coupling' in such instruments can create embodied live performances.

As was established through the presentations and performances at *Soundings*, visual and sonic coupling, and the experiencing of embodied acoustic sounds, in a space, is central to much of the work in the field. With one modest statement, Bastien summed this coupling up beautifully at the third *Soundings* event. When asked to talk about his work, he simply stated, “I don’t have much to say about the little machine you see behind me because rapidly you will understand everything.”.

By performing in-the-round and acoustically, *ams* seeks to reward deep listening and close viewing, maximising the ability of audience members to witness cause and effect. This has led to audible gasps, laughter and muttering from audience members, which is often further prompted by the use of deliberately flamboyant or gestural approaches, such as precarious objects placed on top of the feedback surface instruments, hot-swappable organ pipes, and poseable drum beater arms. In an *ams* performance, I consider the visual and sonic aspects to be of similar importance and *ams’* design is effective in foregrounding this. The one exception is my tendency to block the view of audience members at times, but I have been working on ways of avoiding this in recent performances, such as placing the module cases across a wide table, so a smaller section is obscured at any given time.

Lastly, this coupling of the sonic and visual is also important when encountering *ams* as the human-in-the-machine, leading to a direct and reflexive playability, with most methods of adding, adapting, or removing sounds being inherently obvious.

the end (the beginning)

And so, we reach the end. Only, due to the nature of my working methods, it too is a beginning, with much yet to explore and develop through the use of *ams*; by myself and others. The research presented here is one version of the outcomes of this interrogation. One that charted a path based on moments of inspiration and happenstance, within an experimental and inquisitive framework. An entirely different path could have emerged, even within the bounds of this project.

In this next phase I plan to continue using and developing *ams,* in collaboration with Richard Sewell on the design side, and others in a performance setting. I also plan to loan *ams* to other artists in order that they might engage with it and become fluent in its foibles. I am sure it will be fascinating and informative to watch and document this process, and to see what is similar or dissimilar from my engagement with it.

I hope that this research demonstrates the effectiveness of engaging in new musical instrument design as a route to novel musical and performance outcomes. I have sought to showcase this throughout the four years of my research and via this thesis. All in the hope that it will inspire others to adopt a similar approach. Someone else's beginning…

Appendix

richard sewell

Richard Sewell's work on *ams* was pivotal to its creation. Richard is a creative technologist, employed by me to help realise my vision of *ams* as a musical instrument system. Unlike some outsourced specialists though, Richard isn't a passive manufacturer. He has a broad skillset and an insatiable imagination, allowing him to riff off initial ideas to develop them, before and during all stages of design and development. There were many aspects of *ams* that I couldn't have developed in-house and the depth of *ams*' capabilities as a system relies on Richard's input and development.

With the initial modules in place, experimentation, interrogation and further development fell mostly in my realm, though some aspects were referred back to Richard when necessary. Crucially, he was always there to discuss options and dilemmas as they arose, which helped to give the project forward momentum.

In a nutshell, every project would benefit from a Richard Sewell.

technical titbits

Whilst a full blueprint for the wholesale reproduction of *ams* modules doesn't seem fitting within the spirit of this research, there are several working methods, materials and techniques that I wanted to detail, in case they are of use to other instrument makers.

System wide

As much as possible, *ams* modules are made with a combination of laser cut and 3D printed parts. Front panels are 3mm thick white acrylic, engraved and paint-filled (with artists' acrylic paint). Mechanical components are generally 3mm thick white acetal, which laser cuts well and is very strong. 3D printing is generally used to create parts where greater depth is required.

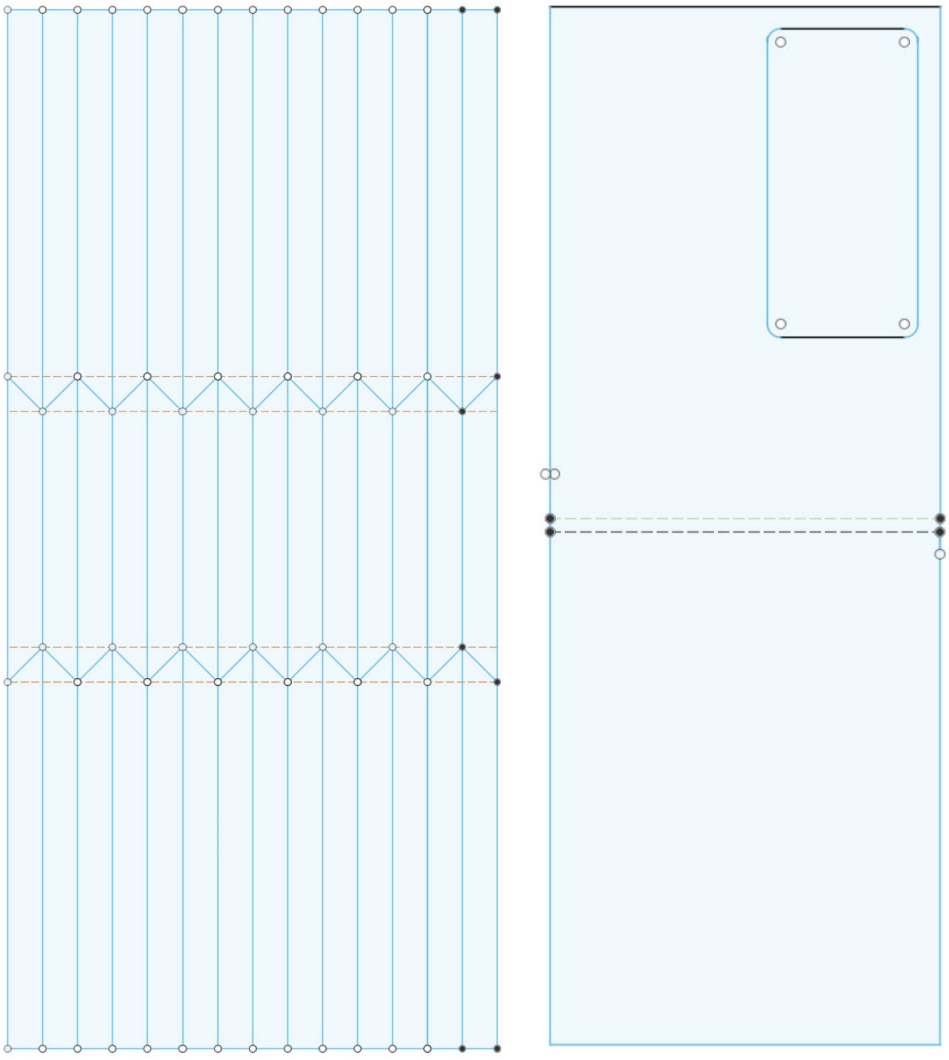
Most modules include an Arduino Nano. They are cheap, robust, likely to be available for a very long time, and have plenty of processing power for *ams*' needs. Circuits are on hand-wired matrix board.

CV and gate signals are all in the 0 to 5V range. The Nano's ADCs will read that directly. For CV outputs, PWM is used on a digital pin and an RC network. This is not the fanciest or most precise approach but it's more than enough for these purposes.

Stepper motor drivers are all SilentStepStick modules.

Puffer

The Puffer's bellows are made from Tyvek (105 GSM, bought as a pack of A4 sheets). Tyvek is a kind of synthetic paper made of spunbonded polyethylene. There are two parts, folded and glued together (with Colall, a PVA glue), then glued to acrylic front and back plates. A laser cut template was used to add pencil marks to the Tyvek sheet for folding, though if producing more a 3D printed template to press fold marks into the sheet would've been produced.



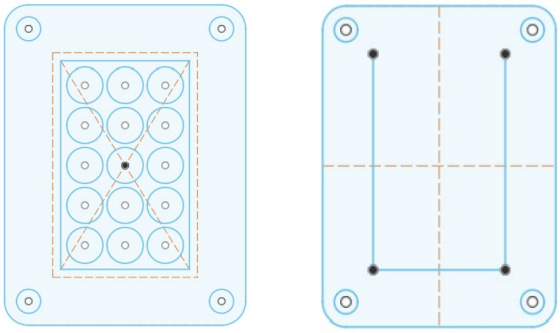
The bellows has no separate hinge, the Tyvek provides that. The return spring that opens the bellows is hand-made from piano wire. As piano wire is highly resonant, these do add some noise, especially if stridulated by the acrylic slot they pass through. Felt has been used to partially damp this.

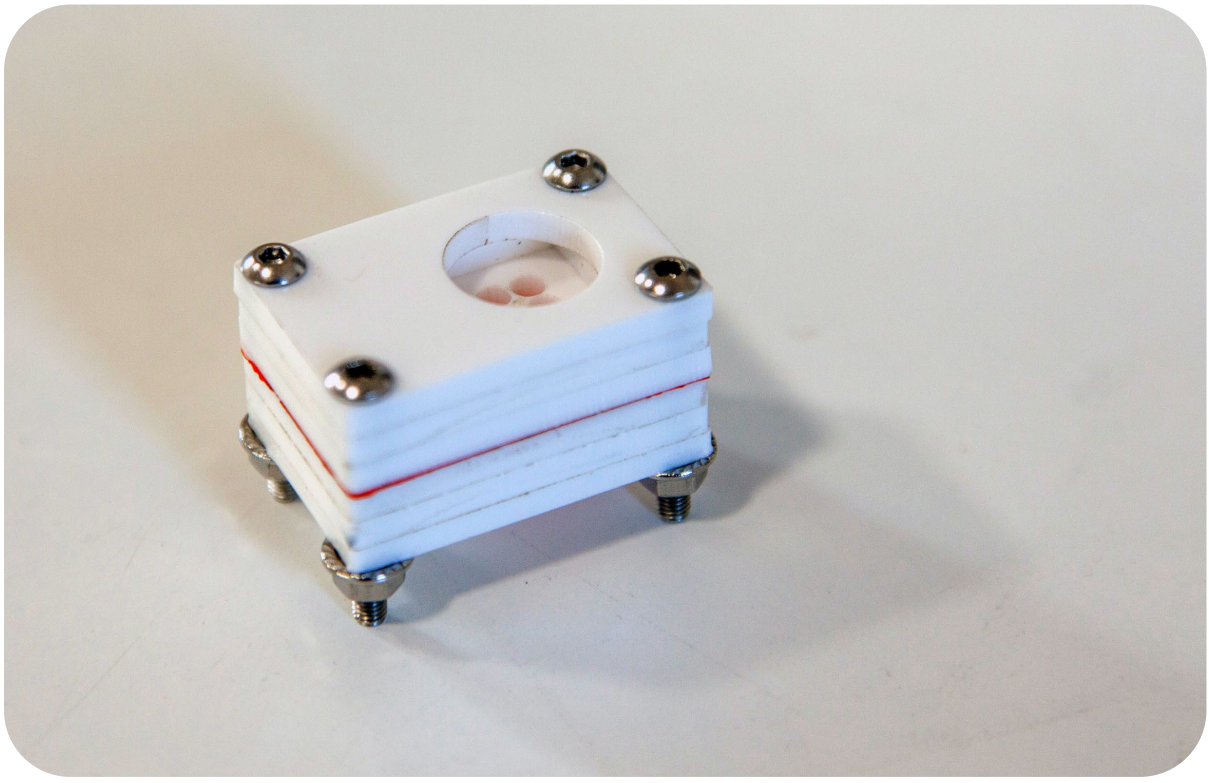
The top folded portion of the bellows tended to pop out at the highest pressures, so Tyvek strips were glued into the valleys at the top.



Puffer - pleated bellows

A bellows needs non-return valves on its inlet and exit. These were made with laser cut 0.5mm polypropylene sheet for a reed and perforated acrylic sheet for a backplate. They are integrated into the plate at the back of the bellows and inline on the Puffer's output piping.

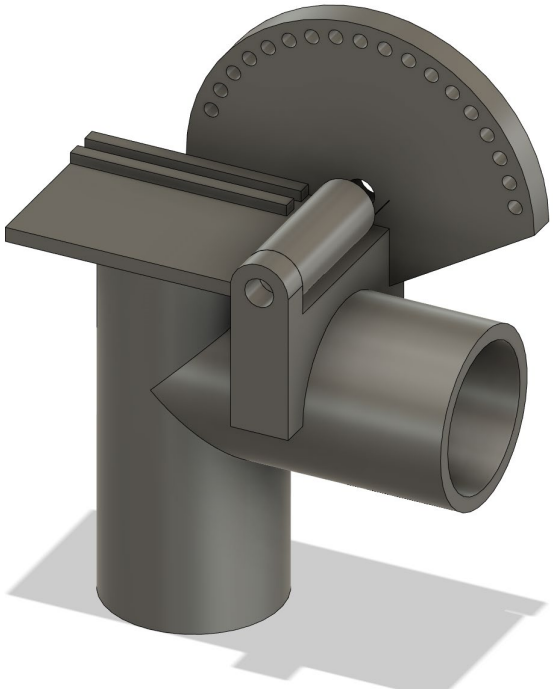


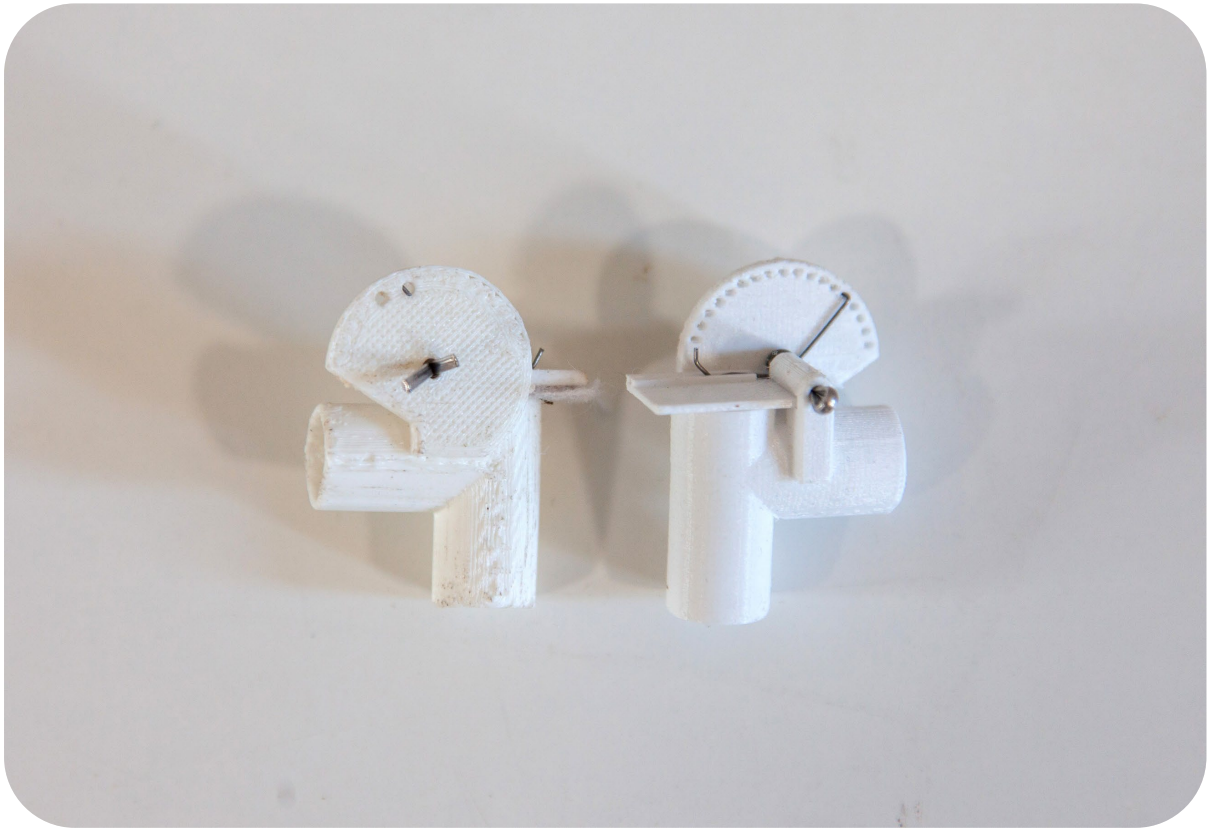


Puffer – non-return valve

This design scales extremely well to other pipe / air system sizes. Fine tuning may be required to prevent the reed from coming into resonance and sounding during airflow.

A pressure relief valve is also required, otherwise the bellows is overstressed if the output is ever blocked. This is 3D printed, with a wire spring, and inserted into the output tube.





Puffer – pressure relief valve

The bellows is driven by a stepper motor, which is running a loop of toothed belt. That has an attached cord to pull the bellows shut. The flexibility of the cord allows the performer to push the bellows by hand for additional toots.

Two microswitches act as limit switches for the toothed belt position.

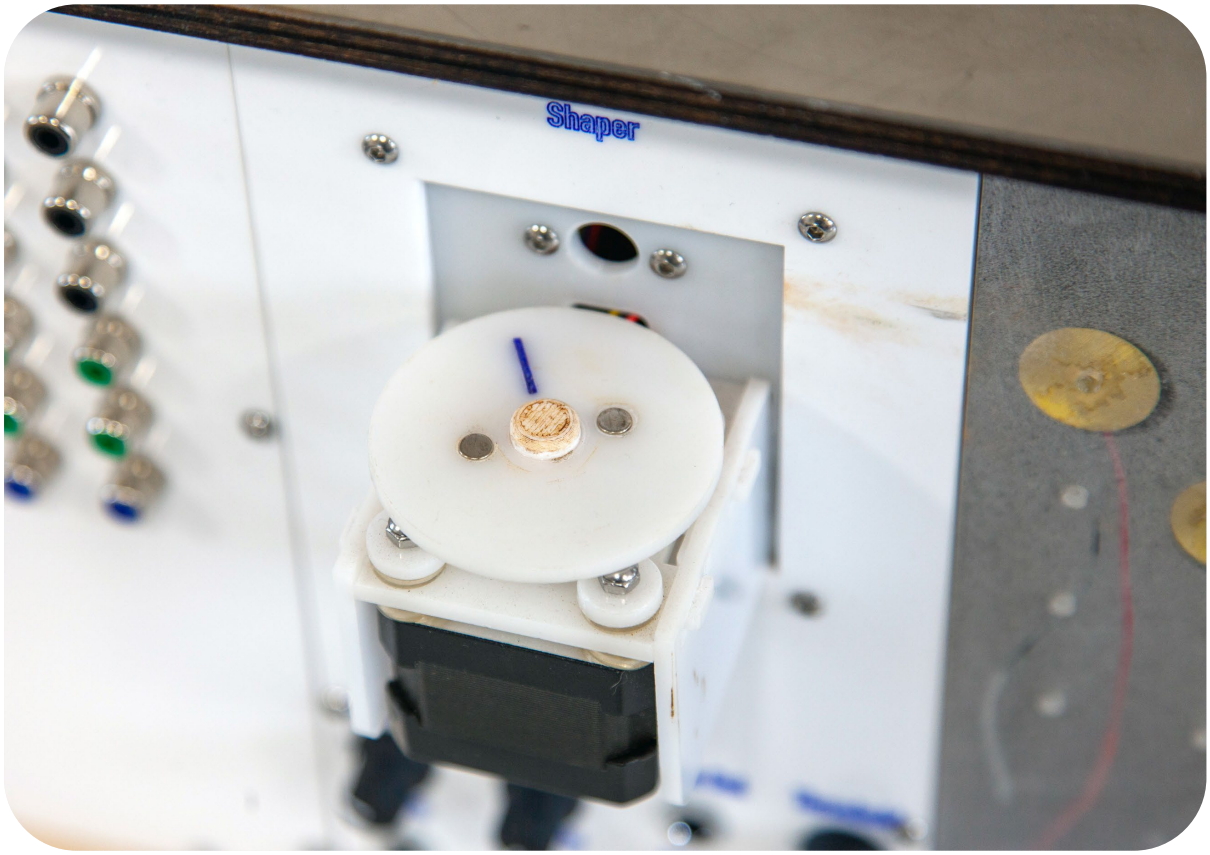
Air output is provided via a 3D printed socket in the front panel, to fit a 14mm OD silicone hose. The usual solution for this is a spigot which fits inside the hose, but after some experimentation a tapered socket was found to be easier for the performer. With a spigot, the removal force is much more than the insertion force, whereas with a socket the two forces are more similar.

Shaper

The Shaper has a stepper-motor-powered turntable, and a VL53L0X rangefinder looking across the top of the turntable to detect the range of objects. The rangefinder's sample rate was only just adequate for this. If doing it again a faster rangefinder would be sought.

The stepper motor is rubber-mounted to keep the noise down.

A 3D printed hub provides a central spigot and there is a glued-on fixed baseplate. This is laser cut from acetal and has two 5mm diameter magnets press-fitted into holes on either side. The magnets have opposite polarities.

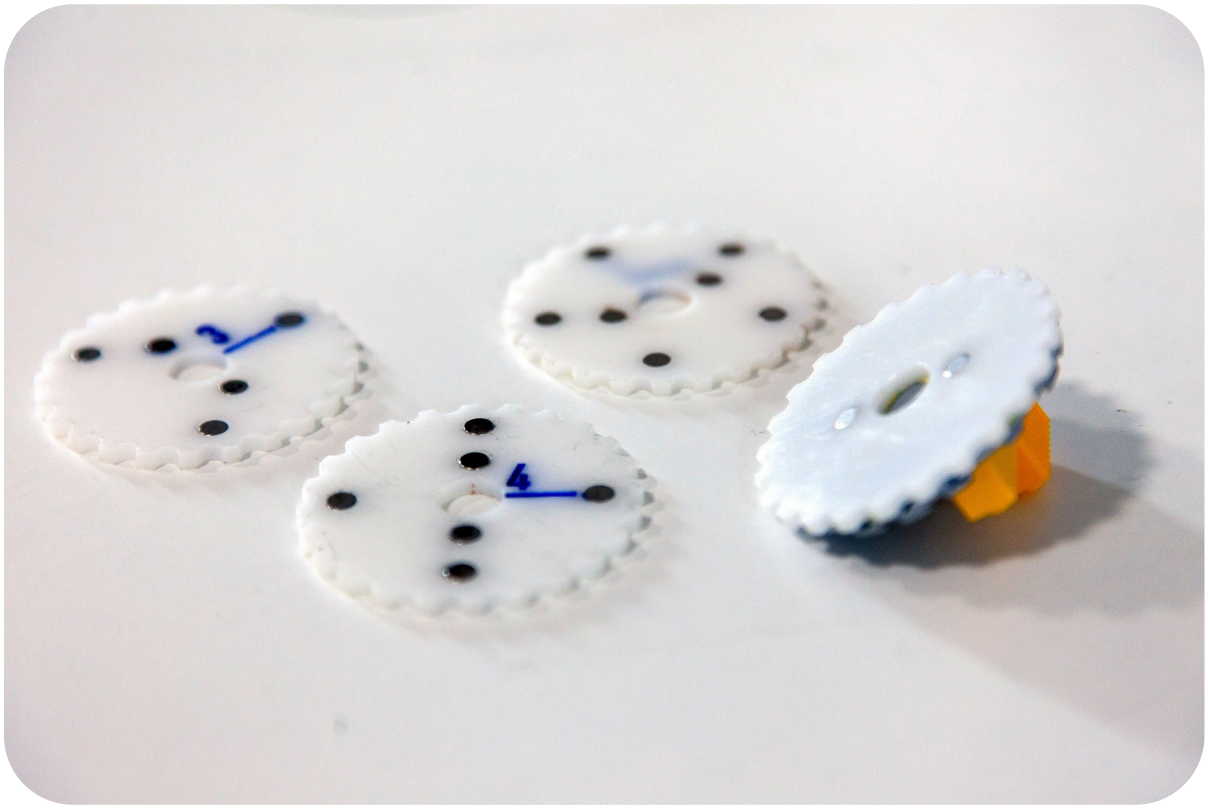


Shaper – platter

The swappable plates have matching press-fit magnets and a hole to align to the central spigot, so they will always locate precisely and in phase.

There's a Hall effect switch under the baseplate to act as an index sensor.

Some of the swappable plates have more magnets pressed in at a larger radius, used to locate magnetic pegs. These come with various numbers of magnets, giving three to seven peg locations per rotation. They can also be used to hold any other magnetic materials.



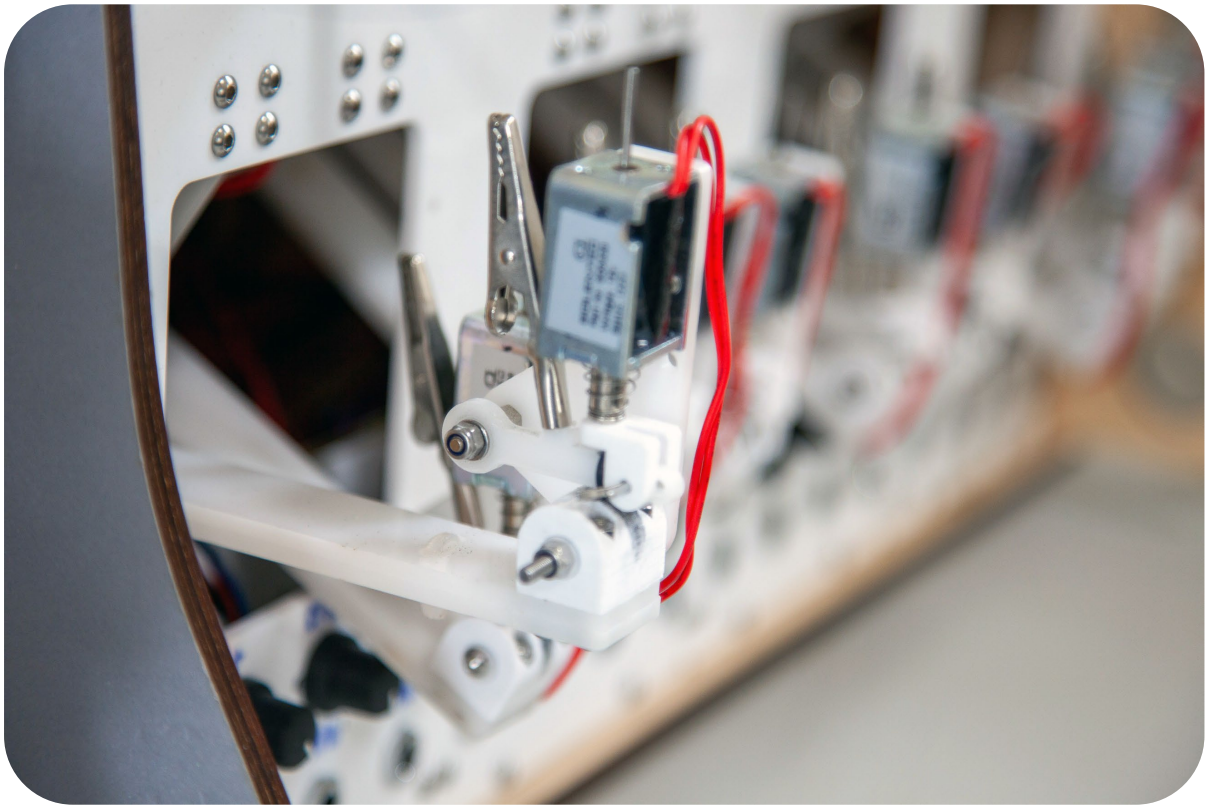
Shaper – plates

There are also plates with Lego tops and textured tops intended to be used with blobs of Plasticine.

Tapper

The Tapper has adjustable arms, made from acetal strips and 3D printed blocks. The key to making a joint with controlled friction like this is to use a spring of some sort, so the clamping force stays roughly constant. The Tapper used M3 crinkle washers to provide this spring.

An acetal linkage converts the short linear stroke of the solenoids into angular motion.



Tapper – solenoid linkage

A crocodile clip was fitted to the linkage to provide a flexible way to attach beaters of many kinds.

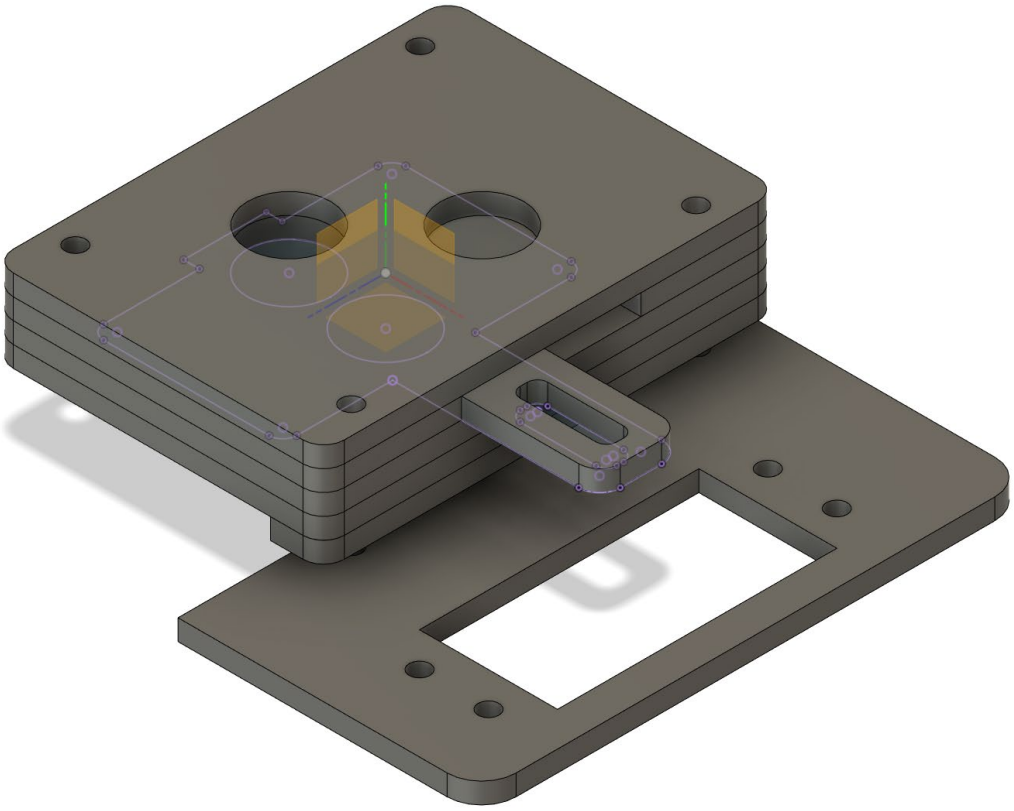
For the first solenoid, always used to hit things, it was important to drive it with short pulses, so the beater is propelled towards the struck item and is then allowed to bounce. In other words, the pulse must have stopped by the time the beater arrives.

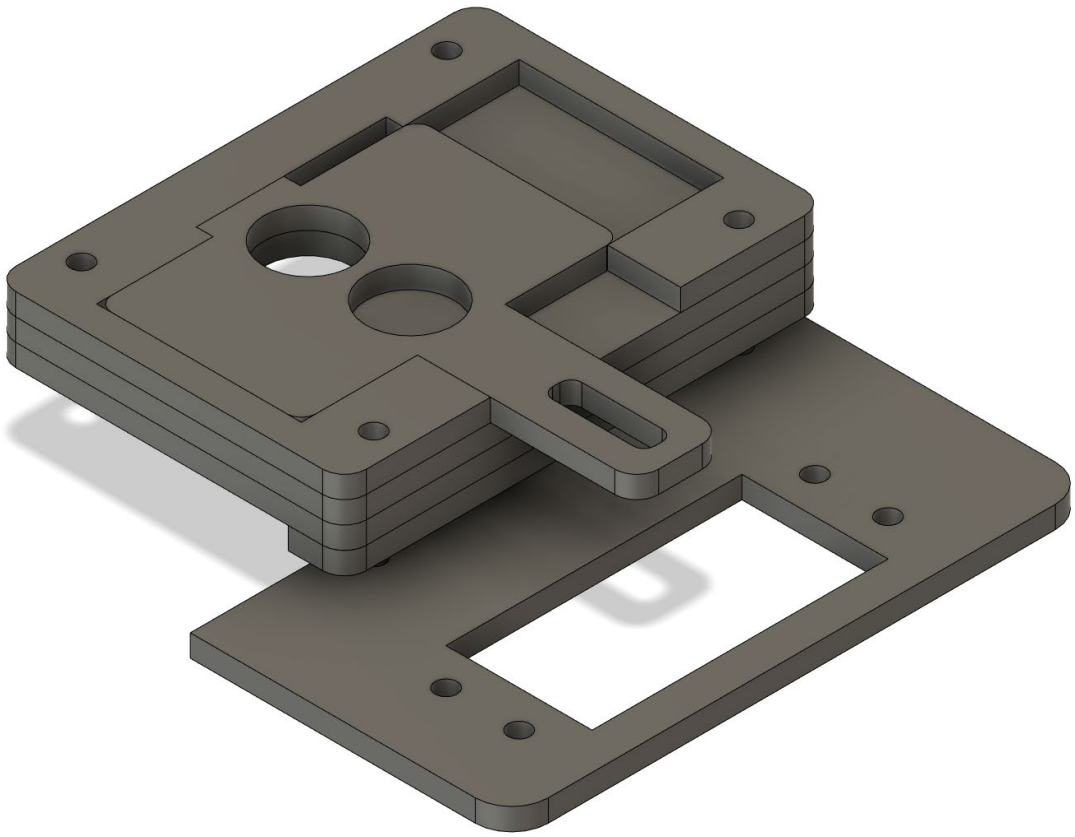
The solenoid was driven with a PWM signal (derived from CV and knob inputs) to adjust the energy of the hit for a fixed 32ms duration.

The second solenoid is used to provide a force, not a hit, so it is driven continuously with a PWM signal. Solenoids have a very nonlinear force curve, with much more force near the end of their travel, so the travel of this solenoid was restricted by putting a couple of tiny O-rings over the armature end to keep it out of the high-force region.

Blower

The Blower switches between its two outputs using a slide valve, which is made from a stack of laser cut acrylic parts. The stack is bolted together.





The sliding part is made of acetal, which is used as a bearing material, in an attempt to reduce friction. This part needs a tiny bit of clearance so it can move freely. This is cheaply provided by making the corresponding layer in the stack a tiny bit thicker. You can do this with a layer of tape, or (even more cheaply) by not peeling off the peel-off film on that layer.

The valve is actuated with an RC servo. These are very easy to drive directly from an Arduino, and they are very cheap. The major downside is the noise they make when they move, though in the Blower that is mostly lost in the blower noise.

The blower itself is a centrifugal electronics cooling blower. These are available in a wide variety of flow rates and pressures, and the one used here was chosen for a high static pressure.

Spigots for hoses are 3D printed parts with bevelled ends, which fit into countersunk holes in the stack of laser cut parts. They need to be retained by a second un-bevelled plate.



Tumbler

The Tumbler uses a stepper motor directly connected to a roller (a length of silver steel rod) running in bearing races. The races are pressed into laser cut acetal plates. Silicone tube is pushed over the rod to provide more drive friction.



Tapper – solenoid linkage

beyond the module fronts

Feedback plate

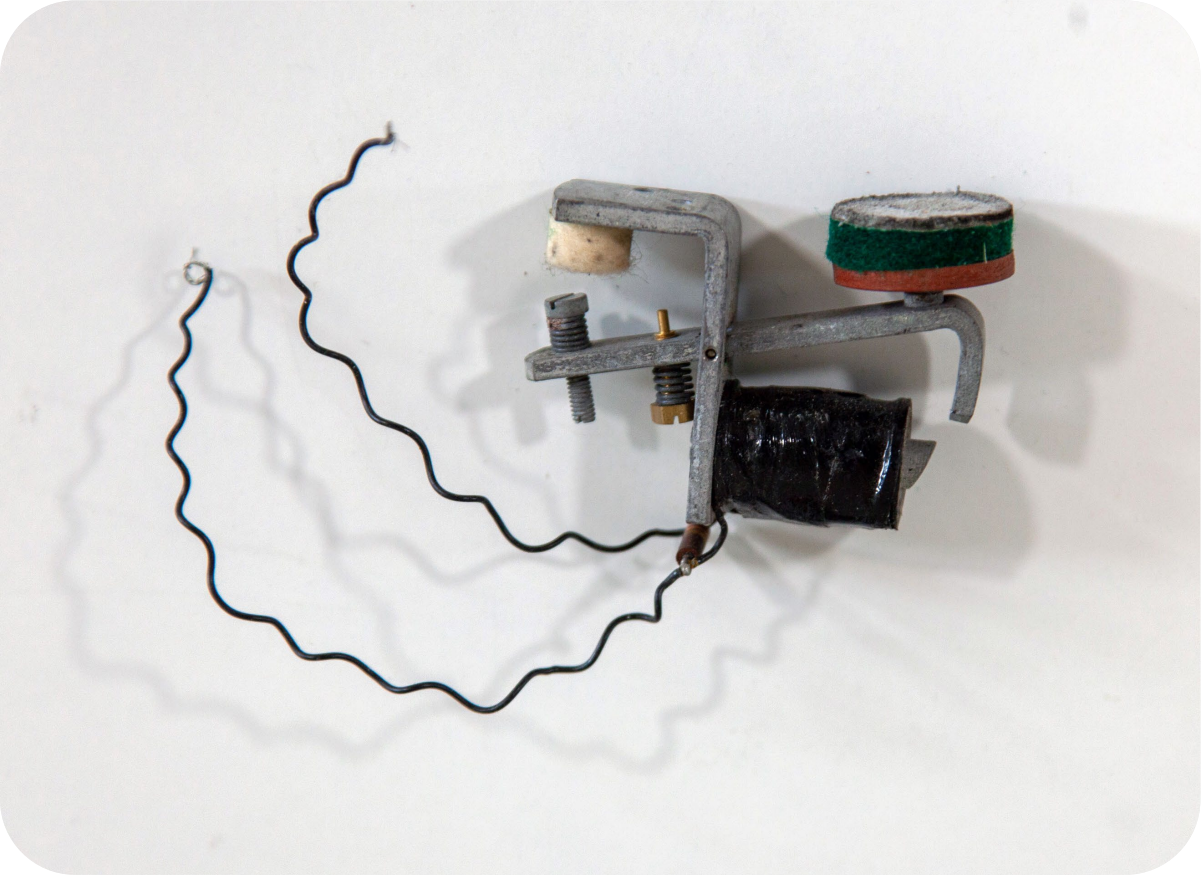
The Feedback plate instrument uses a bare ceramic wafer piezoelectric element as a contact microphone. This is glued to the underside of the magnetic steel plate using epoxy resin. The driver used is a Sparkfun Surface Transducer (Large), which is coupled using a bolt threaded into the hole on top of the driver (normally used to attach the vibration pad) and rubber rivnut. The nature of this attachment, in terms of its position on the plate and coupling method, have a fundamental effect on its behaviour with respect to resonance and noise. In this case, the softer coupling provided by the rubber rivnut helped to prevent more shrill feedback frequencies from dominating.



Feedback plate – rubber rivenut detail

Windchest design

The Windchest sub-module is an airtight box with an air inlet and holes on top, through which air is released using pallet magnets on receipt of DC current. Pallet magnets are electromagnetic valves commonly used to vent air in organs. Their action is mechanically useful for the task they fulfil and they operate quietly. They feature a flat section (the pallet) covered in leather or felt, that presses against the underside of the windchest. On activation it pulls the pallet away from the hole, allowing the air to flow out. Each pallet magnet is wired to a different phono socket on the side of the module.



Pallet magnet – single, unattached

Phono sockets and cables are used for attaching to the Octopus module due to their ubiquity and relatively high current rating.

Leather and felt are used to create soft and quiet air seals and gaskets in the Windchest sub-module as these materials are easily laser cut and glued, to create accurate, airtight seals.

The top of the Windchest features sixteen of the 3D printed tapered sockets used on the Blower module front, for coupling and decoupling of pipes during performances.

Flexures

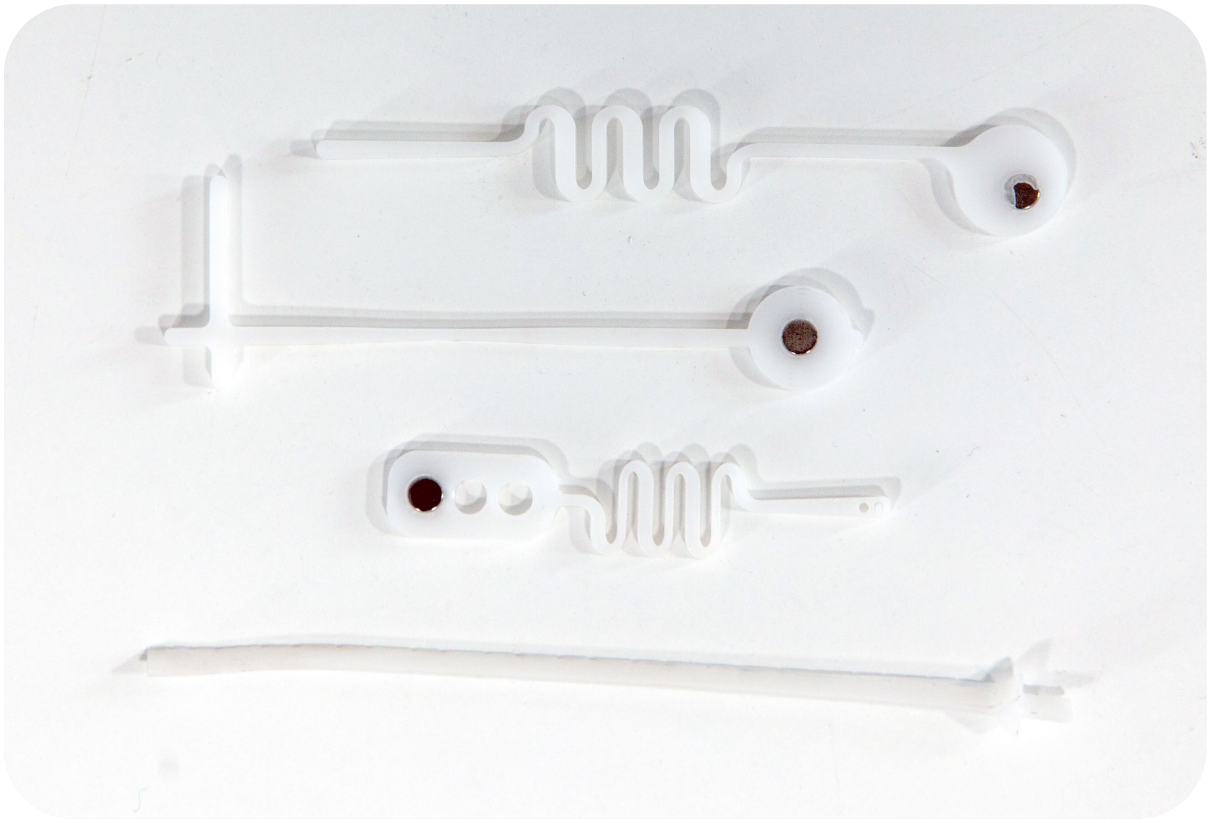
A fascination with flexures and compliant mechanisms, and a chance happening when a 3mm ply living hinge snapped and found its way onto one of *ams*' drum modules, led to an exploration of living hinges to add flexibility to *ams* in various ways. Living hinges are a flexible section, generally joining two rigid sections, which are most often created by cutting or thinning sheet material. When cut from acetal, these produce a flexible section that can stand being bent for thousands of cycles without breaking. Acetal has high tensile and flexural strength, stiffness, and fatigue endurance, making it less likely than acrylic or plywood to shear in this setting.



Flexure beaters – living hinge designs

The benefit of working with living hinges in this way is that they are highly adaptable. More, less, or different flex can be designed in with a reasonably high degree of precision and repeatability, through changes to the form and spacing of the cuts made to create the hinge.

Other approaches to flexure design were also used, such as adding flex *along* (rather than across) the material, by cutting thinner or spring forms along the length of the beater.



Flexure beaters – spring shaft designs

In some flexure beater designs press-fit magnets were again used in the beater head, to allow for the adding of mass on the fly.

roads not taken

There were a few delightful technical avenues that were not pursued in full but may hold some interesting findings and approaches.

Magnetic rubber string

As part of an attempt to make a tunable string instrument and to create bass at the small scale of an *ams* module, we experimented with magnetic o-ring cord.

This is a rubber cord with magnetic particles embedded in it. It is used in food preparation machinery, the idea is that if a bit of o-ring breaks off and is included in the food it can be detected with a metal detector at the end of the production line. It's sold as (e.g.) 'metal detectable o-ring cord'.

It is magnetic enough to be picked up with a guitar-pickup style coil, and perhaps to be driven with a coil as well. It is stretchy and heavy, so even a short length can be used as a bass string.

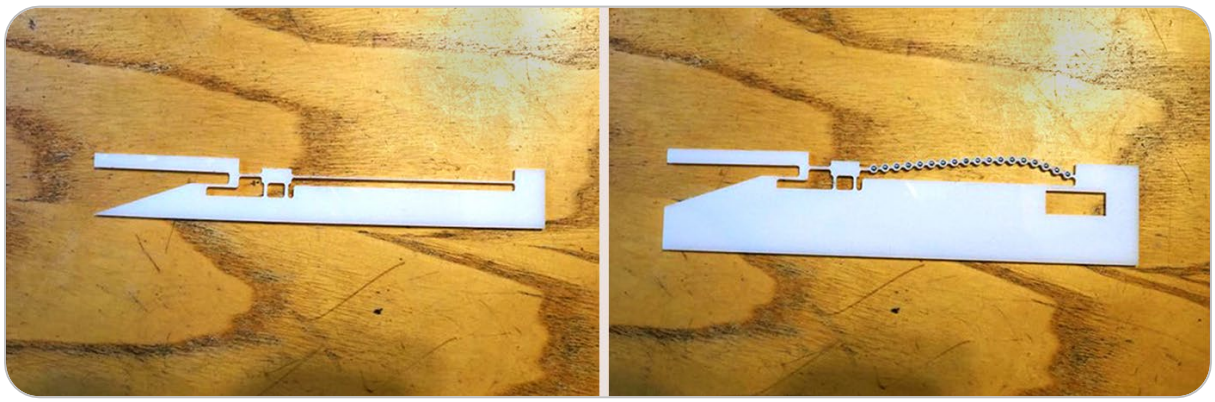
Cam-driven rumblers

This is a simple mechanism in which a DC gearmotor is used to drive a lobed wheel. A ball race follower runs on the outside of the wheel and is supported by a sound board or resonator. The speed and number of lobes on the outside of the wheel determine the frequency of the sound produced.

This gets you a range of low notes at reasonable volume, albeit with terrible pitch control and a fairly unforgiving timbre. It would be practical to use a motor with an encoder and so get pitch control too.

Flexure violin

Lastly, there was some experimentation with making string instruments from laser cut acetal flexures, some of them weighted with ball bearings for lower frequencies.



Flexure violin – prototype designs

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