Drum Modal Feedback: Concept Design of an Augmented Percussion Instrument

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Abstract

We here outline the concept design of an augmented percussion instrument, conceived for and used as part of a variety of distinct performances and compositions. Throughout the curation of this project, each creative act has enabled us to contextualise, examine and reflect upon the design of this augmented instrument. In accordance with Stolterman and Wiberg's concept driven design methodology, we do not present a singular instrument design, but instead an overarching design concept alongside its developmental and evaluative narrative. This augmentation centres upon the use of a drum trigger and a tactile transducer, which when coupled together can be used to feedback or resonate a drum. The resultant soundworld develops upon the idiomatic sonority of a drum, and allows for the duration and timbre of a drum strike to be continuously manipulated and shaped throughout a performance. In exploring the soundworld which results from this approach, we have experimented with numerous configurations of these pieces of hardware, and have also employed various pieces of software to parametrise the sonic subtleties that this approach engenders. Most prominently, we have developed a bespoke piece of software which analyses the modes of a drum prior to performance, and uses this modal analysis to shape the overall feedback and resonance. Throughout this design process, we have consistently been met with new creative criteria that challenge our approach and ideas, in response to the particularities of the musicians we are working alongside, as well as the performative and aesthetic environments we are working within.

Keywords

augmented percussion instruments, concept design, practice based reasearch

1 Introduction

It is often the case that in artistic practice, a simple concept is woven into a series of distinct projects and activities. In such cases, the form of that concept may extend beyond just its inclusion amongst those projects and activities, and pertain to a sentiment of its own accord. What is at first conceived as a means to achieve a particular, contextualised aesthetic quality, may then come to emblematise the expression of such a quality within new and unfolding contexts. During the preparations for a recording session, we had the initial conception to attach both a drum trigger and a tactile transducer to an acoustic percussion instrument, so as to enable this instrument's sound to be performatively distorted using feedback and resonance. Although previous works employing the resonant feedback of drums [5, 13, 20, 25] comprise a significant precedent, our own explorations of this concept have manifested into a detailed exemplification of its constituent soundworld, engendered through a malleable and variable technological approach. In many senses this project still remains in flux, as it serves to lay the foundation for the continued creative application and interpretation of this concept.

Building upon Stolterman and Wiberg's [42] concept driven design methodology, we here outline the concept design of an augmented percussion instrument, the development of which centres upon our exploration of this technology amidst our creative practices. Such a concept design is comprised of two parts - a technological concept, which constitutes the instrument's form and interactivity, and a sonic concept, which is the soundworld that this instrument engenders. As such, we here examine many of this instrument's technological intricacies, as well as document the musical affordances and constraints that this technology envelops. Alongside our use of hardware devices, we have developed and experimented with a variety of software tools that have enabled us to carve out an idiomatic and performative soundworld, building upon the acoustic properties of the percussion instruments we are augmenting. Our practice led design process has provoked us to consistently reconfigure our design criteria, and define a concept that supports the implementation of an augmented percussion instrument applicable to a variety of aesthetic contexts.

2 Design Methodology

Stolterman and Wiberg's [42] term *concept design* is used to refer to the process through which a concept is defined, detailed and developed. Such a concept may be grounded in tangibility, i.e a proof of concept, but the concept itself is not necessarily a particular artefact. In this sense, a concept is a form of abstraction [15], which can then be used in the design of more complex, situated instantiations. To recontextualise this notion, our work and research elucidates the concept of an augmented percussion instrument, however the product of this research is not the creation of an augmented percussion instrument in particular. Instead, we have produced a collection of implementations and reflections that exhibit this concept, portrayed through a series of practical and experiential manifestations.

> " [T]he design researcher must go beyond the initial idea and explore the unknown. Usually, this means

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> working hands-on with materials; creating models and prototypes; and experimenting with unusual materials, forms, and content in the exploration of new design spaces. Concept design is about opening up and exploring new design spaces or finding unseen parts of already known spaces." [42, p.110]

In curating both our research and our presentation of it, we aim for this work to provide a foundation from which augmented percussion instruments may be further explored, within either research driven or practice driven contexts.

In conducting this design research, we have been consistently driven by our artistic practices, and it has been these practice led endeavours which shaped the formulation of our resultant concept. We similarly present this work largely as an annotated portfolio [2, 11], with each creative act serving to exemplify and rationalise certain facets and constraints relating to our concept. This style of presentation was chosen primarily due to the practice led nature of our research, for it is undoubtedly an example of 'research through art' [10], and such a mode of presentation emphasises this theme [2]. This practice led methodology also entertains an explicit contradiction to the idea of user-centred design, within which a design is assessed based on a functional relationship to its users, rather than its aesthetic or artistic affordances. User-centred design tends to impose subtle restrictions surrounding the openness of a design concept, by curating not only the design of a particular system, but also the subsistent design of its context - "A 'user' is something that designers create." [35, p.129] This contradiction serves to alleviate some of the well-documented pitfalls encountered during the user-centred design of musical instruments [38]. We uphold that such adherence to a prescribed functional relationship with a user obfuscates the intricacies of aesthetic sentiment that may be engendered through difficult and explorative playing techniques [32, 46] or a misuse of said functionality altogether. And in focusing our inquiries towards practice, we allow for the emergence [12] of aesthetic design criteria over functional ones, and embrace failure [16] and difficulty as an integral part to our reflective and reciprocal process.

Throughout this project, it has often felt that its discoveries and understandings were formed naturally through the inquiries born of a creative process. At many junctures, the questions regarding our concept design arose not in service of the concept itself, but to *serve the music*. The benefits of resolutely *serving the music* is that the concept in question must be able to withstand all of the scrutiny directed towards it by those who work with complete conviction and dedication towards achieving their anterior creative pursuits. Such a framing serves to elevate the authenticity of artistic practice, so as to not overshadow its motives with an extra-musical research agenda. As such, the goal for this work was not simply to produce technical knowledge, but to align our epistemic inquiries with the artistic pursuits that surround them - to simultaneously embrace "the Picasso philosophy" [10, p.5].

> "The notion of simultaneity is useful here because the most enticing design artists are utterly flexible regarding the role they play, being content to work as designers and as artists at different times, although not always in the role or circumstances in which they would be expected to do so." [4, pp.14-15]

Serving the music in this sense is a contestable means of conducting academic research [10]. The challenges which arise through aesthetic pursuits may perhaps only be relevant within those aesthetic contexts. The knowledge produced through such pursuits may be esoteric or embodied [1], unspeakable once removed of its original context. However, a particular exemplification of a concept is always contextualised, a notion which is encapsulated by Stolterman's use of the term *ultimate particular*.

> "In design practice, the goal is all about creating something *non-universal*. It is about creating something in the world with a *specific* purpose, for a *specific* situation, for a *specific* client and user, with *specific* functions and characteristics [. . .] Design is about the unique, the particular, or even the *ultimate particular*." [41, p.59]

In accordance, the form of aesthetic knowledge being discussed here is both subjective and intersubjective [24]. It is influenced by the aesthetic sentiments of its practitioners, but it is also shared experientially. Through successive implementations and reflections, the knowledge which surrounds a concept's foundation - the intersubjective knowledge which can transcend a subjective context - innately becomes clearer. And via this process of presenting our concept, we attempt to translate some of these aesthetic understandings into a co-constructed form that is applicable to contexts beyond our own.

3 Practical Background

Throughout this work, we have drawn a number of references from musicians and designers who have previously explored adjacent soundworlds and instrument augmentations. Primarily, we have paid close attention to the many designers who have used resonance and feedback in their work [7, 21], as this sonic idiom has become a prevalent trend amongst recent augmented instrument designs. Where augmented percussion instruments are concerned, many designers have demonstrated a variety of hardware approaches towards resonance, utilising either electromagnets [3, 13, 19, 34], loudspeakers [20, 25, 29, 45, 47, 48], or tactile transducers [5, 18]. Similarly, there are also many examples of designers creating feedback with their percussion instruments using traditional microphones [5, 48], contact microphones [13, 20, 45] or drum triggers [25] to amplify their instrument's sound, alongside the use of audio effects to manipulate this signal [5, 25]. Many of these designs share traits with our own work, as our personal hardware configuration sought to combine aspects from many of these previous approaches, whilst simultaneously extending upon the use of performative software surrounding this concept. In accordance with our design methodology, many of these previous approaches afford particular functionalities and aesthetic qualities with regards to the practitioners involved and the creative contexts within which they were working.

Often the soundworlds produced through these methods are extremely varied, with many of the aforementioned instruments spanning a wide range of colours from absolute noise to articulated and textural tones. This soundworld has a long history in modern music practice, with works by Karlheinz Stockhausen [40] and Tony Oxley [30] being some of the earliest works to first demonstrate the sonic possibilities of amplified percussion. More recently, in many of the works by Rodrigo Constanzo [5] and Christos Michalakos [26–28], the use of augmented percussion has been explored through an experimental approach to solo percussion performance. Both Constanzo and Michalakos have previously combined drum triggers, transducers/loudspeakers,

and a software driven approach to create resonant feedback, allowing for a large breadth of sonic versatility and colour that is evocative of numerous aesthetic sensibilities. Elsewhere, augmented percussion instruments have been used in installations, as can be seen in the work of Jeff Gregorio [13]. Here Gregorio uses electromagnets to produce modal resonances of multiple drums in consort. By applying this method to many concurrent drums, Gregorio is able to curate a sonorous and textural palette that unfolds throughout his installation. And within a more traditional concert hall environment, resonant feedback of an orchestral bass drum has been used extensively by the composer Michelangelo Lupone [20], being a focal point in works such as *Gran Cassa* and *Chant de la Matière*. Here, as the augmented drum is so large, its resonant feedback creates a dynamic dialectic between the performer and their instrument, as they employ various techniques to explore and shape the instrument's ensuing resonance.

Where non-percussive instruments are concerned, we have also paid close attention to the colours produced by the *magnetic resonator piano* [22], and particularly the sonic versatility that its many performers are capable of commanding [31]. One of the more poignant lessons we learnt from the magnetic resonator piano was its ability to leverage its performer's pre-existing musical strengths to produce new sonic landscapes, despite the change in performative context they subsequently had to undergo [23]. And perhaps one of our most striking sonic references, and one that has been repeatedly audiated and revisited throughout this project, is the feedback sounds produced by David Torn's augmented guitar [43]. In many of his performances, Torn has utilised the sound of feedback with a striking versatility, being capable of creating both melodic and textural passages using his guitar augmentation.

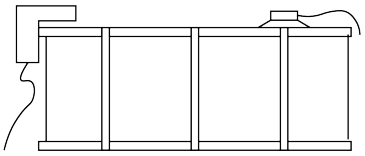
4 Concept Implementation

The implementation of our augmented percussion instrument utilises both hardware and software components to create acoustically informed modal feedback and resonance. We here outline the design considerations surrounding these hardware and software components, alongside a number of variabilities amongst them which we have encountered through our artistic practices. These variabilities serve to demarcate the possibilities of this instrument with regards to its functionality and aesthetic affordances.

4.1 Hardware

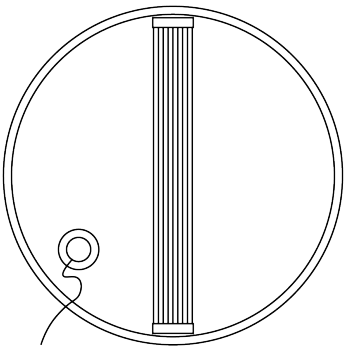
Our hardware design consists of two principal components - a drum trigger and a tactile transducer. Each of these components were connected to a laptop running our software, with the drum trigger being used as a line input, and the transducer being used as an audio output.

Throughout the implementations discussed during this paper, wherever possible we used Rodrigo Constanzo's *OP-Sensor* [6] for our drum triggers. During our development, we experimented with a variety of alternative drum triggers, and found that the OP-Sensor had the best audio quality when being used as a line input due to its low noise floor and shielded internal components. The OP-Sensor is paired with a magnetic dot placed upon the drum skin, which it uses to detect changes in the magnetic field whenever the membrane is in motion. Many other drum triggers use contact microphones with a foam wedge that rests upon the drum skin, which although works well for many other audio applications, does inhibit the natural movement of the membrane



(a) Side view of a drum, showing both drum trigger and transducer placement.

(b) Intersection of a gong drum, showing both drum trigger and transducer placement.



(c) Underside of a snare, showing transducer placement.

Figure 1: Diagram of the hardware setup for various drums.

itself. Due to their design, the audio captured using a drum trigger is not representative of the sound one naturally perceives when hearing a percussion instrument, however those that are well designed exhibit a clear tonal image of a drum's vibrating membrane. Although using drum triggers as line inputs is not their intended function, in this context it is advantageous to use them over typical microphones, as they exhibit minimal latency between the moment the drum is struck and any subsequent audio processing that follows [17].

To create both feedback and resonance, we sent audio to a drum using a tactile transducer which was mounted directly onto the drum itself. Throughout this project, we have used a variety of transducer placements, as shown in figure 1. For the best sonic relationship between the drum trigger and transducer, the transducer should be placed on the top membrane. Placing both the drum trigger and transducer on the top membrane may interfere with a performer's gestural flexibility, and so alternative placements of the transducer may be advantageous. The main concern to be aware of here is that if the drum trigger and transducer are facing each other, they will naturally create feedback of their own accord. As well, if the transducer is being placed directly onto a membrane, it is important to note the resonant shapes, or Chladni patterns, which the drum will produce when struck. These Chladni patterns demonstrate the locations of nodes and anti-nodes, each of which corresponds to a particular subset of modal frequencies. Placing the transducer on an anti-node will

effectively mute its corresponding modal frequencies, and so the placement of this transducer inherently effects the instrument's timbre. The orientation of these Chladni patterns are dictated by the orientation of the drum strike, and so in practice the position of these nodes and anti-nodes will change throughout performance. To only remove high frequency modes, the transducer should be positioned at a skewed angle from the drummer's perspective, and as close to the rim as possible [50].

4.2 Software

To explore acoustically informed modal feedback and resonance, we developed a Max patch entitled *drum-modal-feedback*[1], the design scheme for which is shown in figure 2. This patch is used to perform modal analysis on a augmented percussion instrument, so as to determine the frequency content of both a resonant filter bank and an additive synthesiser. In the case of the resonant filter bank, the audio input from the drum trigger is used to directly incite modal feedback. And in the case of the additive synthesiser, the drum trigger input is used alongside an onset detector from the *SP-Tools*[2] [44] Max package to trigger an envelope generator, which in turn independently amplifies the modes of our additive synthesiser. When designing this patch, we exposed and experimented with a multitude of parameters attached to these devices, such as the control of modal amplitudes and the shapes of our envelopes.

To analyse the frequency content of an augmented percussion instrument, we developed an API that interfaces with the *HISSTools*[3] [14] Max package using Node for Max[4] and TypeScript[5]. Before being able to perform with this software, a performer is required to analyse the frequency content of their instrument. This approach was chosen to allow for an overall flexibility between different instruments, and similarly to allow for a drum to be reanalysed after tuning or extensive playing. Our analysis uses an exponential sine sweep [8, 9] to create an SPL measurement of a drum's overall frequency content, which is a method of analysis also commonly used for capturing room responses [37]. Once the SPL measurement has been captured, we use the peak picking algorithm [36] in combination with quadratic interpolation [39] to determine the precise frequencies and amplitudes of a drum's dominant modes. Although many methods for identifying the dominant modes of an object or space exist, we chose this approach as it is both simple and intuitive [36], and has been shown to be the preferred method for analysing musical instruments [33]. Upon completing these calculations, we then made it possible to performatively manipulate our resultant modal information in real-time, utilising techniques such as limiting the frequency range of active modes, as well as limiting the logarithmic distance between these resultant frequencies. As an example of using such a parametrisation, one could specify that they only want to create feedback using modes between 220Hz and 880Hz, and that they must be separated by at least a 400 cents, which is an equally tempered major third.

5 Creative Portfolio

We explored this concept design within a variety of artistic contexts throughout this project, and in doing so curated four exemplary recorded performances and compositions. Each of these

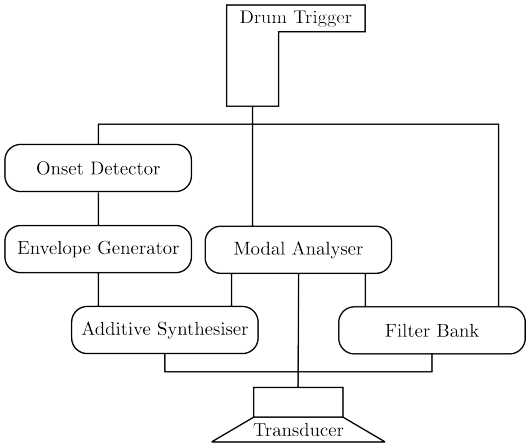


Figure 2: Diagram of the *drum-modal-feedback* software.

recordings situates our concept within distinct creative environments, and utilises a range of artists from a variety of musical backgrounds to assess the sonic nuances and technological limits of our concept's design. These recordings have been made available online, as part of a web portfolio attached to this publication.[6] In recording these performances, we also documented our immediate reflections resulting from these processes, so as to outline our concept's prevalent artistic constraints.

5.1 Julia Set X Barrell Jones

Julia Set is an audiovisual performance duo, co-curated by Lewis Wolstanholme and Francis Devine [49]. Julia Set have a diverse background performing experimental music, and often employ a variety of contemporary approaches to both their improvisatory and compositional endeavours. For this piece, entitled *myopic*, they collaborated with the percussionist Sam 'Barrell' Jones[7], who has had extensive experience performing alongside a variety of jazz and pop artists.

myopic was recorded live in a studio as part of a two-day recording session. The aim of this session was primarily to write and record various pieces of improvised music that explored live electronics and interactive percussion performance. *myopic* was the only piece during this two-day session which employed an augmented percussion instrument. Whilst recording this work, the piece was performed four times, with the fourth take being the one contained in our aforementioned composition portfolio. In the lead up to this recording session, Sam's only other contact with augmented percussion was during a single afternoon rehearsal.

For this performance, the group used a Roland RT-30H drum trigger and attached a Dayton Audio DAEX25CT-4 transducer to the underside of their snare, as portrayed in figure 1c. For their software, the group used a simple VST delay in between the drum trigger and transducer, as at this point in time our modal feedback and resonance software had not yet been developed. The delay's feedback and delay time were controlled by Lewis using a DAW controller, which encouraged a collaborative exploration of this technology between Lewis and Sam. Although this was a new soundworld for the group, many of the performative technologies previously used by Julia Set X Barrell Jones employed this

[1] The source code for this work: https://github.com/lewiswolf/drum-modal-feedback
[2] *SP-Tools*: https://github.com/rconstanzo/sp-tools
[3] *HISSTools*: https://github.com/HISSTools/HISSTools_Impulse_Response_Toolbox
[4] Node for Max: https://docs.cycling74.com/nodeformax/api
[5] TypeScript: https://www.typescriptlang.org
[6] Composition portfolio: https://lewiswolf.github.io/drum-modal-feedback-compositions
[7] Sam 'Barrell' Jones: https://barrelljonesmusic.com

approach towards sonic collaboration - where each member's improvisation cyclically guides and influences the improvisation of another.

In isolation, a delayed signal works well to create a simple yet dynamic feedback loop using our hardware, however there are distinct limits to the sonic colours which can arise through this method. Often the feedback's pitch content is determined by the delay time, and has limited flexibility on what can be achieved through percussive technique and parametric exploration alone. When set to specific delay times however, it is possible to catch and resonate a drum according to its modal frequencies, however it is not possible to manipulate the details of this sound any further.

5.2 Lewis Wolstanholme X Ciarán Corr

Lewis and Ciarán have been long time musical collaborators, releasing their first piece of music together in 2018. Ciarán is a successful performer, producer and musical director in his own right, whose work ranges across numerous different styles and genres. In recent years, the two have collaborated on a multitude of studio compositions, and similarly the work that they have presented here was created within this familiar setting.

All of the percussive material for this work was performed by Ciarán, and recorded during a one-day session. The overall form for this work was planned in advance, however this work was not conceived as part of a larger project, but instead as standalone exploration of percussive feedback and resonance. During this one-day session, the pair recorded 1-2 hours of material, which was later cut up, arranged and fully produced. Prior to this one-day session, Ciarán had not previously performed with an augmented percussion instrument, but had been made aware of its sonic potential.

For this work, both a snare drum and floor tom were augmented using OP-Sensors and Dayton Audio DAEX25CT-4 transducers, arranged as shown in figure 1a. For their software, they primarily used the *drum-modal-feedback* Max patch coupled with a VST delay. During this session, the pair explored various facets of these pieces of software, both in isolation and in combination. Stylistically, the two aimed towards creating a piece of music that explored some of the more liminal qualities of percussive feedback through contrasting playing styles and extended techniques. As with the previous Julia Set X Barrell Jones project, Lewis controlled the various sonic parameters during this session using a DAW controller. For each drum, Lewis controlled the delay time, the amplitudes of both the additive synthesiser and resonant filter bank, as well as the maximum modal frequency these synthesisers could produce. In this context, the relationship between each musician was more that of a producer and a performer rather than a collaborative improvisation. The performative interaction between the two was very much structured and preplanned, allowing for specific sonorities to be captured and explored at particular moments during the recording process.

Working in this studio context allowed for the directed exploration of the augmented percussion soundworld, and enabled the group to hone in on particular techniques and sonic outcomes. These techniques included damping and stretching the skin whilst the drum was feeding back, which created a sort of tremolo effect, and experimenting with the effects of different beaters and mallets, which allowed for a variety of more subtle and metallic sounds to emerge. In many instances, however, the pair found it challenging to repeatedly perform the particular sounds they were aiming for, as a number of the parameters in the *drum-modal-feedback* Max patch were either randomised or remained unclear with regards to their more detailed sonic function. Often the pair were attempting to create melodic passages of feedback, which they were marginally successful in achieving, however they were not able to repeat the same musical gestures with a desired degree of accuracy or predictability.

5.3 Napoleon Skywalker

Napoleon Skywalker is a Canadian electronic music duo comprised of Jordie Shier and percussionist Carson Gant. As individuals, Jordie has a background in experimental arts practices, whilst Carson has experience performing alongside multiple jazz, pop and hip-hop artists. The two have been collaborating for over 15 years, specialising in the performance of live, experimental dance music, and have explored both highly structured and improvisatory approaches to their compositional practice.

For this project, the duo recorded an improvisatory piece during an afternoon session in a rehearsal studio. Although an overall form for this work was not planned in advance, this improvisation served as a dedicated exploration of the augmented percussion soundworld. Prior to this session, Jordie prepared a series of parametric controls to structure their exploration. Carson however, did not have any previous experience working with augmented percussion, and so his performance was guided solely by aesthetic intuition.

The pair used a Dayton Audio DAEX25CT-4 transducer attached to the bottom of a snare, as in figure 1c. Due to unforeseen circumstances in the lead up to this session, the pair did not have access to a drum trigger, and so used a Shure Beta 57A as a topmic for the snare. The pair used a digital delay pedal preceded by the *drum-modal-feedback* Max patch, with a variety of this patch's parameters being controlled by Jordie using a MIDI controller. These parameters included the amplitudes of eight modal resonators, as well as coarse control of their modal frequencies. Prior to this experience, the pair had already explored musical collaboration through a number of distinct means, however this was the first time that Jordie's artistic improvisations had such a direct result on both Carson's playing and overall sound. This unfamiliar dynamic in many ways added to their creative explorations, as they had no particular expectations of what this collaborative dynamic would achieve.

Throughout this session, the pair created an extended groove based improvisation which explored various melodic uses of feedback. Due to Jordie's use of independent amplitude controls, the pair were able to shape the duration and loudness of each modal resonance with great melodic flexibility. At times however, they found the frequency results of their modal analysis limiting, and as a result were not able to command as broad a range of sounds as they would have liked. This issue was particularly apparent in the lower range frequencies, which the pair found had a natural tendency to emphasise only the very lowest dominant mode, and not those which were close to it. Lastly, the pair felt that the digital delay pedal that they were using was a necessity to maintain musical and aesthetic interest throughout their performance, both in terms of adding additional rhythmic and textural material.

5.4 Rodrigo Constanzo

Rodrigo is a performer, improviser and researcher who often works at the intersection between instrument design, improvisation, and chaotic soundworlds. He has been active as a performer for nearly 30 years, having worked across a variety of musical contexts and styles. Rodrigo specialises in improvisatory performance, both as a solo artist and as a collaborator, and often searches for new ways with which to extend upon his improvisatory practice with respect to both technique and technology.

For this project, Rodrigo created two recordings which emerged from his initial explorations with the *drum-modal-feedback* software. The aim of this process was to discern a liminal soundworld of his own, utilising a set of interactions that he felt paired well with our concept. In doing so, his approach maintained that the underlying modal feedback and resonance were the focal point of his improvisations. These recordings were made during a single session, after first experimenting with and preparing a performative relationship with the software. Unlike the previous recording artists, Rodrigo both played the drum and controlled the software himself, and so this preparation period was an integral part to his process. As well, this was not the first time that Rodrigo had performed with an augmented percussion instrument, having previously used a number of transducer and feedback based effects throughout his practice.

For these recordings, Rodrigo used an OP-Sensor and a Dayton Audio DAEX58FP transducer that was attached to the inner body of a 20" gong drum, as shown in figure 1b. Alongside these devices, Rodrigo also made use of a number of other drum augmentations, as well as variety of extended techniques whilst playing. For his software, he used the *drum-modal-feedback* Max patch using mainly the additive synthesiser, which he extended to satisfy his own performative style and instrumentation. Rodrigo used SP-Tools to perform additional onset detection and sonic analysis, which he used to parametrise his performance. Throughout his recording, Rodrigo also made us of a set of custom designed Max for Live plugins[8] for adding distortion, delay and stuttering effects.

Whilst recording this work, Rodrigo noted that he had difficulty getting the particular sound that he wanted with regards to lower range modal frequencies. In many senses, this issue was twofold, as he felt that his particular hardware setup was not able to accurately produce some of these lower range frequencies, but also that the acoustic instrument he was using naturally produced an overpowering amount of lower range frequencies that masked the subtleties of his performance. In both instances, it seems as if our design did not quite lend itself to the acoustic sound of the gong drum, however Rodrigo did still experiment with and perform using the gong drum's higher frequency modal content. In doing so, Rodrigo used the higher range modal frequencies to create a variety of nuanced textures that complemented his other percussive augmentations. Throughout his performance, however, Rodrigo also remarked that he wanted to explore more variability amongst the envelope generator used as part of the additive synthesiser, so as to engender a more transformative and unfolding soundworld.

6 Reflections

After completing our four artistic explorations, we have noticed a variety trends that have emerged in relation to our concept's sonic qualities and the potential of our technologies. These trends have emerged naturally through our practice, despite each of us contributing to this project through our own distinct means and aesthetic intentions. Each of these creative endeavours has demonstrated to us the artistic possibilities imbued within this soundworld, and confirm many of our initial artistic aspirations that were present when we began exploring this concept. We here reflect upon these findings, and whilst some of these reflections have already informed our concept design, there remains a number of aesthetic possibilities to be developed through further exploration.

6.1 Upon the Sonic Concept

In each of the recordings presented here, it is apparent that our treatment of drum feedback is applicable to a wide range of sonic styles and compositional environments. From studio composition to live improvised performances, our approach to drum feedback can act as both a subtle addition to the overall musical texture, and as a focal point of compositional creativity. Of particular interest, is that although our technological concept engenders a wide ranging soundworld, many of these compositions exhibit a number of sonic commonalities. Long and drawn out complex tones are a recurring feature throughout each of the four compositional endeavours, with each musician choosing their own approach to explore the various colours of these tones through their individual use of our technology. These explorations of timbral colour often encouraged their respective performers to play into these moments, or rather leave space for these moments to occupy their own weight within the overall compositional form. This feature was particularly noteworthy during the Julia Set X Barrell Jones performance, which saw the structure of this work revolve around the unique moments of sonic variability that arose during improvisation.

In collectively reflecting upon our activities, we discovered that some of the more colourful and melodic moments of feedback were readily sought after during our individual compositional processes. It should be noted that the use of feedback that Jordie was able to capture most accurately resembled our underlying influence of David Torn [43] and Jeff Gregorio [13]. Due to the way that Jordie parametrised his use of the resonant filter bank, he was able to create an unfolding cascade of resonant pitches in response to various drum strikes throughout his piece. This sonic device is something that Rodrigo also sought after in his work, which can be inferred from his critique of the envelope generator used as part of our additive synthesiser. Similarly, this sonic quality is also something that Lewis aimed towards whilst recording with Ciarán Corr - a sound which he was able to achieve through his approach to parameter control, but was not able to exhibit with the same degree of flexibility as Jordie. Although it is clear that all parties aesthetically sought after this sound, its particular quality was not discussed in detail until after all four compositions had been completed. Similarly, when reflecting upon many of our other background influences, any moment of perceived melodic intricacy became a strong aesthetic reference point for us. As such, it is one of this augmented percussion instrument's defining qualities - that it is capable of going beyond the expected percussivity of a drum, and transform it into an instrument which occupies a plethora of musical functions within a given aesthetic context. In highlighting our prevalent desires towards this sound, there remains a number of aesthetic possibilities to further explore this quality through composition and performance.

[8] Confetti Plugins: https://github.com/rconstanzo/confetti

6.2 Upon the Technological Concept

During the early stages of this project, the Julia Set X Barrell Jones recording session acted as our initial inspiration to develop our approach towards modal analysis and explore more of the timbral nuances embedded within this concept. In reflecting upon the later three compositions, it is clear that our approach to analysis and synthesis enabled us to curate a more diverse soundworld than what was possible during our initial performance. As this functionality can be employed alongside a wide variety of percussion instruments, its application allows for a resultant sonic consistency which can be further relied upon in aesthetic contexts outside of the ones we have already explored. It is clear from both Napoleon Skywalker and Rodrigo's experiences however, that to properly feedback lower range sonorities, further tests are needed to ascertain the appropriate hardware and software configuration to use alongside a particular drum.

One of the exciting versatilities of our technological approach is its applicability to both solo and collaborative performance environments, which demonstrates the ability for artists to employ this concept alongside a variety of distinct performative relationships. A consistent complaint amongst the later compositions however, touched upon the remaining difficulties in interfacing with our modal analysis approach. Although each creative endeavour interfaced with this software in a unique manner, the response from each of these activities suggests that it is not yet immediately intuitive to actualise particular aesthetic effects. In a similar sense, under the pressures of a performative environment, this technology is not yet reliable enough to call upon in moments of directed aesthetic pursuit. For example, Lewis and Jordie took similar approaches to controlling resonances with MIDI and DAW controllers, but the effects that they were capable of producing can be contrasted in a number of qualitative ways, with Lewis in particular not capable of easily achieving the particular sound qualities he imagined. Additionally, all examples of creative exploration use a delay effect as part of their setup, with each creative endeavour arguably relying upon this effect for its complimentary ability to produce feedback, as well as its functional familiarity, navigability and reliability. As a result, it seems that to fully develop our concept, further inquiries need to be undertaken to discover a more refined interface design for incorporating our use of modal feedback and resonance during practice.

7 Conclusion

The concept of an augmented percussion instrument designed around modal resonance and feedback is one that pertains to an intricate and varied soundworld. Through our own technological design, as well as the designs of others, it is clear that there is a rich sonic vocabulary attributable to this concept that is applicable to wide variety of aesthetic contexts. And the many sonic facets of this concept engender a multitude of compositional and functional possibilities within a range of performative environments. In our own design implementations, we have curated a dedicated approach towards these sonorities, via our development of a hardware and software architecture specifically focused towards a responsive and flexible incorporation of modal feedback. By examining this concept through the lens of creative practice, we have also outlined some of the key features of this sonic vocabulary, as well as pointed towards ways in which they can be further explored within future projects, in terms of both creative realisation and design implementation. The work presented here serves to incentivise the continued application and interpretation of this concept, as the true form of this conceptual knowledge only becomes more apparent through new and unfolding contexts.

Ethical Standards

All research carried out as part of this work was conducted by the authors, except for select musical works which were written in collaboration with other artists. All collaborating artists gave express permission for their work and acknowledgement to be included in this research, and they retain all rights to their musical and artistic products. The technological assets explicitly developed as part of this work were designed by the authors and have been open-sourced accordingly.

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