“12”

Music Visualisation: Exploring Generative and Non-Generative techniques within a rhythmic framework in a performative spatial setting.

Live AV performance by Unnikrishnan Kalidas

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A thesis exhibition presented to OCAD University in partial fulfilment of the requirements for the degree of Master of Design (M.Des) in Digital Futures.

205 Richmond Street West, Toronto, Ontario. April 2023

Abstract

Music pieces composed in the past were typically of longer duration with intricate musical nuances embedded in them, and this often required the listener to pay more attention to the piece in order to better appreciate the composition. Stalling attention spans and 'Skipping culture' on most music streaming services today have led to musical compositions being of shorter duration with the choruses composed upfront for the immediate gratification of the listener. Various experiments and explorations are conducted to better visually understand music as part of my research. By projecting visual elements within a performance space I am trying to better emulate music, specifically the aspect of rhythm as rhythm occurs periodically and can be easily predicted by the audience.

Within a performative setting the audience do not have the agency to skip to the next track unlike a streaming service.The primary objective here is to narrow the distance between the audience and the performer, with the help of visuals. The project is an interactive live Audio-Visual performance that exemplifies the concept of rhythm with the help of a spatial-polymeter of ¾ and 4/4 time signatures, to better convey what is felt than heard.

Key words:

Music visualisation, music information retrieval, spectral analysis, 3d projection, live AV, code art, spectrogram, Ableton, Touchdesigner, point cloud, volumetric video.

Land acknowledgment

We acknowledge the ancestral and traditional territories of the Mississaugas of the Credit, the Haudenosaunee, the Anishinaabe and the Huron-Wendat, who are the original owners and custodians of the land on which we live, work and create.

Dedication and Gratitude

I want to thank a lot of individuals for helping me finish this thesis. I owe a lot to my family, including amma, acha, and chechi. I would not have been able to seek my master's degree without their assistance.I have the utmost respect for all of my teachers (past and present) since they've helped shape who I am today and guided and corrected me throughout my life.

I owe a debt of gratitude to many individuals at OCAD University. My advisor, Dr. Adam Tindale, deserves special recognition for pointing me in the right path when I stalled about where to focus. As a mentor and performer, he has had a genuine influence on me. I also want to thank Dr. Barbara Rauch, my secondary adviser, for helping me understand how to visualise the installation and how to use the context of the installation to apply my research focus. I could not have asked for a more exceptional advisory team!

In my acknowledgement I cannot miss out on Prof. Simone Jones as she introduced me to Touchdesigner, which is the backbone tool of this thesis. In addition, I want to thank Dr. Cindy Poremba and Dr. Emma Westecott who helped me with the writing and offered technical assistance for the tools I required to finish this project. I also want to express my gratitude to the Writing and Learning Center for helping me with the writing process.

My peers Rhea Nambiar, Prayag Ichangimath, and Aydan Hasanova have my sincere gratitude for their assistance with my study and moral support. In addition, I want to thank OCAD University for providing me with the funding and resources I needed for my study as well as for giving me the chance to do so. Finally, I want to express my gratitude to all the online and offline Touchdesigner and interaction design practice tools that helped me with technical issues.

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1. Introduction

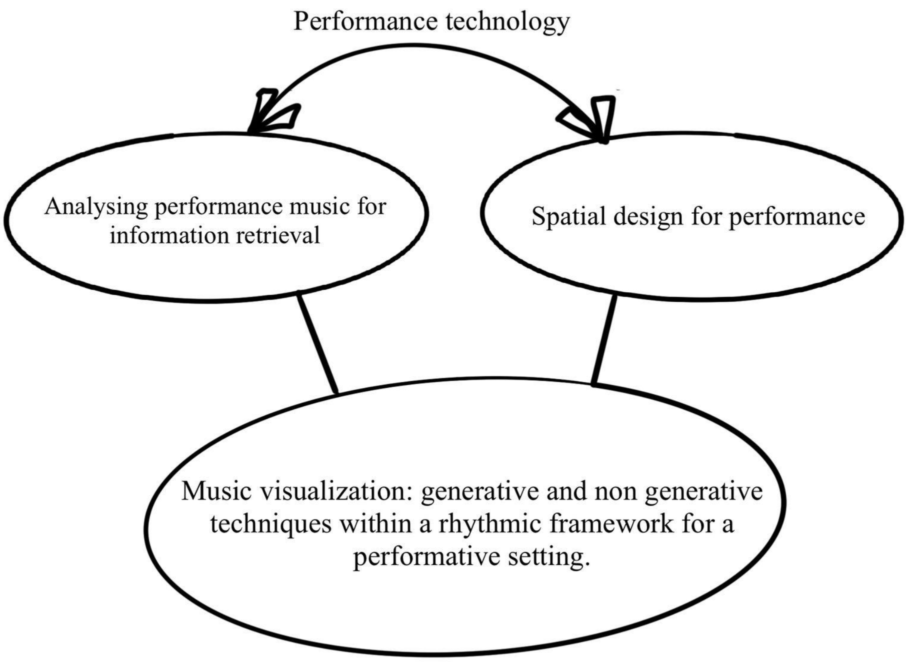
The term 'Music Visualization' is frequently used to refer to the visualisation of the loudness and frequency spectrum of the music that is being played.. This can take the form of anything from a straightforward oscilloscope display on a radio to animated imagery rendered by the software of a media player. These techniques though based on the audio do not inform the audience of subtle nuances within it that form points of surprise or predictability. The purpose of this thesis is to experiment and explore methods of visualising music and then to devise a technique for a live audio video performance. Specifically informing the audience about the periodic nature of rhythm that leads to its predictability and the subtle nuances of change.

The reason a 'performative setting' is chosen is because a performance requires the audience to be in the same physical space as the performer to be experiencing it and prevents the audience from 'skipping to the next track'. An MP3 file played on a digital device can be switched or adjusted at any point as the person hearing chooses. Presence is what is key; the presence of the performer and audience within the same physical space.

The primary objective here would be to convey the predictability of rhythm to the audience, bridging them essentially with the help of visuals, by informing them of what is not informed. Visualising that which is not didactically experienced, but felt, by the audience's ability to understand sonic or visual patterns.

The structure is important, as by defining the structure, the rules of the rhythm activity is made clear. In addition, when these graphical components are combined to generate a comprehensive image of a musical composition, as is the general case of multivariate data visualisation, they should not conflict with one another. As the research is more in-process and not a quest for answers as such Research-creation and Think through making are adopted as methodologies.

A mind-map of the aspects to be researched is created to get some clarity of thought. The topics that pertain to this research are Music Information Retrieval (specifically for performances) and Spatial design theories. The link between mapped musical performance information and its corresponding spatial design elements is the performance-technology which is being researched in detail resulting in the final thesis project. Spatial design in this context would be referring to the musical soundscape that the audience is within. Below is a visual representation of the same.



(Figure 1. Mind Map diagram)

Research questions:

Essentially sound becomes music when the brain decides if it's music. Often this is based on our cognition of patterns within randomness and our ability to look for the same based on what we hear. The form or structure of every musical piece is the basic framework that decides the sequence in which its encompassing elements are arranged in order to form the pattern. Does music visualisation have to be didactic of the underlying form or structure?

Music composition entails arrangement of sonic elements that are recorded or synthesised in a sequence. Sound's frequency information can be used to build visuals, but does it essentially inform about the musical piece or the idea the artist is trying to convey?

The dual nature (left and right of the body) of our sensory organs usually is what imparts depth to visual or sonic experience. Ears on either side of our face essentially imparts this depth of audio. Similarly in terms of sight the parallax between eyes is what imparts depth of vision to us. Audio files in general practice are in Stereo/ dual channel format, that is Left and Right channel. Having these two channels placed physically on either side of a space imparts this depth. But does this depth help us understand what is felt in music?

2. Literature Review

The most frequently occurring and predictable aspect of music is rhythm and it does not need prior training to understand the periodicity of the same, as we seek to understand patterns by evolution. Rhythm is what I feel is important to me and hence setting the study within a rhythmic framework was the way to go.'Rhythmic framework' of Music, is specifically considered for Musical Information Retrieval. The framework being the time signature or the sequence of sonic occurrences. Rhythm is also universally understandable and does not have a genre per se besides timbral differences in tones. Scientists have long known that while listening to a sequence of sounds, people often perceive a rhythm, even when the sounds are identical and equally spaced. (Cameron and Grahn 24)

Why is Rhythm being considered? The attribute of rhythm is central to all music studies. It has been variously defined as "organised duration" (Kolinski 501), or simply 'the perception of an order' (Fraisse 163).

The study of rhythm has been expanded in recent decades by knowledge and methods from scientific fields other than music. Since then, other interactions across disciplinary boundaries have resulted in the production of rhythm-based computational models that are applicable to music search and discovery, computational musicology, and interactive music systems; as well as new scientific knowledge that enables us to understand the biological mechanisms behind the processing of music and rhythm, as well as the effects of rhythm information on human perception and cognition. Below are five examples of perspectives exemplifying rhythmic information mapping for music information retrieval on the mind map, based on an article by (Bello et al. 1-2)

Rhythmic information mapping:

In a cognitive perspective (Schaal et al. 2777) compares the individual capacities for short-term memory that musicians and non musicians have in relation to musical rhythms. In order to do this, they suggest an innovative rhythm memory span challenge that is influenced by other protocols that are utilised for pitch information. The task was to test musical rhythm memory by increasing and decreasing sequence length based on performance.The findings reveal that musicians' performance improves with musical instruction, active participation in musical activities, and highly developed listening skills, and that rhythm and pitch memory processes are strongly correlated.Their research validates prior results concerning the dependability of the processes musicians utilise in the processing of auditory memories.

From a performative perspective the article written by (Sethares and Toussaint 15) investigates the importance of expressive timing and timbre in recorded performances of Steve Reich's Clapping Music. In the piece two people clap the same short rhythmic pattern while one shifts it by a beat until they match again.This particular piece is relevant as it exemplifies the patterns that form when the same pattern is slightly altered in time in comparison to itself. This view is from the perspective of performance analysis. Their research is founded on a comprehensive quantitative analysis of seven different renditions of this composition. This was made possible by the combinatorial nature of the piece, as well as the absence of any pitch, melodic, or harmonic structure, and the limited timbral variability it possessed. The authors demonstrate that performances can be categorised based on the local tempo fluctuations that occur throughout them, and that these tempo variations are a direct result of the intricacy of the pattern that is being played. Despite the fact that the composer's instructions ask for timbral consistency, they show that timbral variations are not only conceivable with hand-claps, but also a significant structural element of the work, crucial for its effective performance. More intriguingly, they investigate the impact that micro-timing variations play between occurrences that are only partially synchronous and how the consequent changes in timbre, pitch, and rhythm perception contribute to the expressivity of the performance. These micro-timing variations create a sense of rhythmic tension and release that makes the entire piece seem like it falls on different periodic time signatures at different sections.

An ethnomusicological perspective: (Holzapfel 27) investigates the connection between Turkish Makam music's short 'Usul'. Usul is an underlying rhythmic cycle that harmonises with the melodic rhythm and occasionally aids in forming the composition's overall structure. Specifically, Holzapfel focuses on the relationship between rhythmic modes and short Usul. He presents a Bayesian technique to robustly identify between six distinct Usul based on note location and length patterns, illustrating how theoretical accent patterns store aesthetic information in the process. On the other side, the research demonstrates how Usul are used more as suggestions than as precise metrical frameworks, which results in songs that are less stratified and less accented on the downbeat than compositions that use identical rhythmic patterns seen in Western music. It is interesting to note that these models may be used to demonstrate how tastes and form in Usul have changed over time.

A perspective on Music Information Retrieval: In the article, (Esparza et al. 48) explores the limitations of some of the more typical assumptions that are made during the creation and assessment of audio-based rhythm similarity algorithms. They begin with a normal Music Information Retrieval setup and then use a combination of signal processing and machine learning approaches to optimise the genre classification accuracy on a huge dataset of Latin American dance music. Despite having a high classification accuracy, detailed analysis of the algorithm, the recordings used for training and testing, as well as the specificities of the music traditions in those recordings, shows that a large portion of the performance can be explained by factors unrelated to rhythmic analysis, such as recording quality, as well as by the assumptions made with regards to the equivalency between genre labels and rhythmic content. This was discovered after conducting detailed analysis of the algorithm and the recordings used for training and testing.

From the perspective of signal processing: This article is a study written by (Sephus et al. 62). In it, they address the merits of utilising modulation spectral characteristics for the encoding of musical information in audio signals, namely rhythm. The modulation spectral analysis decomposes a signal into a two-dimensional representation of standard frequency versus frequency of the dynamics. The authors discuss how adding information about temporal patterns at different frequency bands results in representations that are perceptually more meaningful, invariant to noise, and able to encode both short-term temporal behaviour disambiguating multiple sound sources as well as long-term temporal behaviour characterising musical rhythm. In addition, the representations are able to encode both short-term temporal behaviour disambiguating multiple sound sources as well as long-term temporal behaviour characterising musical rhythm.

Conclusion from Rhythmic performance mapping:

This study brings attention to the need for more musical knowledge at all levels of MIR research, notably on rhythm similarity, by highlighting the influence of typical simplifications used in system development. These papers are representative of the research that is conducted on musical rhythm. In the past few decades, the study of rhythm has been expanded by knowledge and methods from scientific fields other than music, notably experimental psychology and cognitive science, resulting in novel theories of rhythmic organisation, such as (Lerdahl and Jackendoff 2).

3. Contextual Review:

Classical music composed in the early ages, for example, featured significantly more complexities and compositional details embedded within it. Indian Carnatic compositions (from the 17th century) were typically composed with four to five sections which were on an average 15 mins of duration each, with rhythmic and tonal progressions giving more room for improvisation during performance. This required the audience to pay significantly more attention in order to completely understand and appreciate the music, and the duration of these pieces was significantly longer in comparison to musical compositions written today. The "drop" in today's music, as well as the "riser" that leads up to the "drop," the lyrics, and any other immediate parts of the song, are given greater importance. Modern music is intended to provide the listener with an immediate sense of satisfaction, which has also made music of today shorter. Not only has this affected how we listen to music, but it has also affected how music is composed today. Between 2013 to 2018, the average song on the Billboard Hot 100 decreased in length by 20 seconds. Additionally, while only 1 percent of hit songs were 2 minutes and 30 seconds or shorter in 2013, this number rose to 6 percent in just five years. (Bludov)

From previous studies, (Smith and Williams 499) examined how colour and 3D space could be used to visualise music . As input, a MIDI data file is used. The x-axis represents the pitch range, the y-axis represents the instrument type, and the z-axis represents the note start time. A note is represented by a sphere in 3D space, with the pitch, volume, and timbre indicated by the height, radius, and colour of the sphere, respectively. As a result, colour can be used to distinguish across instrument groups that have various timbres. The sphere will be replaced with a history marker, which is a smaller and lighter sphere, as each tone ends. Long notes yield ellipsoids because each marker is scaled along the time axis according to the original note duration. In addition, the intensity of the history markers will gradually fade over time. These techniques can be applied to visualising music in order to make it more informative as to a didactic representation of it, but to know the subtleties and nuances of a musical piece one still has to have some kind of musical training or background to grasp the same.

There has been significant work done on Music data visualisation besides the examples mentioned above and most of them used self-similarity within a piece to leverage the repetitive structure of music. (Wattenberg 1-2) depicted it using an arc diagram that connects each repeated portion with a semicircle-shaped edge. Self-similarity was depicted by (Foote 1) as a two-dimensional matrix, with each element computed from the similarity of two audio frames . It was further developed by (Muller and Jiang 11), into a scape plot representation which depicts the repeated structure with different segment sizes. Other researchers integrated this self-similarity data with time-dependent volume transitions (Kosugi 610). This structural information has also been applied to music listening interfaces in studies by (Goto 313). Aside from those based on musical repetitions, some studies used tonality to show the structure, such as key shift over multiscale passages (Sapp 427). (Malt and Jourdan 21) provided a visualisation method based on statistical aspects of spectral information, such as the audio spectrum's spectral centroid and standard deviation. They used a two-dimensional graph to depict the evolution of those data over time, adding amplitude information as a colour to the graph. Visualisation of the semantic structure of music is also proposed (Chan and Qu 612), in addition to automatic visualisation approaches using audio or MIDI files. This method includes a lot more information than just repeating structure, such as traditional sonata structure analysis, theme development, and how each instrument's part varies during the piece. These are methods that could be adopted to represent the audio per se, considering the project to be a performance interlinked with graphical representation of sounds that form the music piece as such.

Each of these techniques have a peculiar parameter of sound that is represented and has a distinctive character of its own, but personally I'll have to choose/ formulate what matters the most to me, which is largely based on what I feel has to be conveyed to the audience. For the most part rhythm and its structural nuances is what I am looking into.

3.1 Spatial design : Previous work and Case studies:

As mentioned earlier, presence is what drives my argument of audience attention span; the space within which the performance occurs is quintessential. Properties such as location of enclosings, location of sound sources within the space, visually accessible points within a space etc may or may not inform techniques for spatially designing the performance install.

My undergraduate architectural thesis titled Production and Performance complex is where I began exploring performance spaces and the relationship between a performance and its visitors.The audience got to visit the performance space before the event, to be able to witness the pre production activity prior to the event itself. (See Appendix A for details)

Another exploration of spatial study was a pop up Jazz performance in Kensington market, Toronto, which had the audience dynamically have the agency to move around the street performance. (See Appendix B for details)

In order to understand how the audience can be located within the same space as the performers, I decided to conduct a video analysis of Snarky Puppy's What About Me, to understand how the audience interspersed among performers had varying visual and sonic experiences. (Details in Appendix C)

Giving agency to the audience to choose what aspect of the music they want to listen to creates a more dynamic and interactive music performance.

4. Research Methods:

Research through creation and Thinking through making are the preferred methodologies for this project, as it helps me explore the possible pipelines for visualisation and further evaluate each of them. According to the mind map, two factors for bibliography/influences must be evaluated separately. The resources relevant to Musical performance mapping are based on the component of Rhythm and its comprehension, since rhythmic frameworks are the aspect of Music that is explicitly being looked into, and the studies that demonstrate Spatial Design are more self-reflective.

Research creation is a method of conducting research that integrates artistic and academic research practises, fosters the growth of knowledge and innovation through artistic expression, and promotes innovation through scholarly investigation and experimentation. The research activity is the context in which the creative process takes place, and it results in critically informed work that can be presented in a variety of formats (art forms). Research-creation cannot be confined to the interpretation or analysis of a creator's work, conventional works of technological development, or work that focuses on the creation of curricula. (SSHRC)

A set of Experiments / Experiences has been journaled in order to understand different aspects of Music visualisation for a performance in a real time spatial setting. The results of each experiment are discussed and each experiment directs or re-directs the approach adopted for the visualisation technique.

5. Experiments and Explorations:

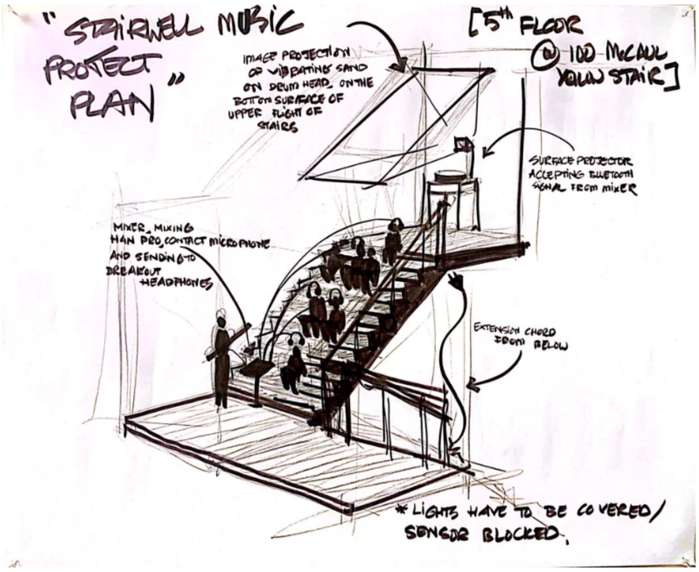
As research through creation is my methodology of research, experiments and explorations are what is helping me formulate the final product/ or thesis project. Hence a detailed entry of each Experiment/ Exploration is provided along with answering questions such as Why? What? How? in order to gain inferences from the same, resulting in the final project. By conducting each of these experiments I am either directing or re-directing the approach used for visualisation.

5.1 Experiment 1: "Revibe : Digitized Analog music Visualizer" Experiences and Interfaces elective.

(Figure 2 Visualisation of analogue sound)

For this experiment I utilise the natural reverb of the Yellow Stairwell at 100McCaul building as the sound source. Im playing a guitar and whilst playing the mouth trumpet, to create sound that has additional reverb from the space.

This additional reverb is a quality of the space alone and is not native of the sound/music itself. In order to put it across to the audience that the reverb is an additional layer added to the sound itself I require visualisation of the same. In order to visualise this music I decided to use an analogue technique that is connected digitally to my performance.



(Figure 3. Stairwell conceptual diagram)

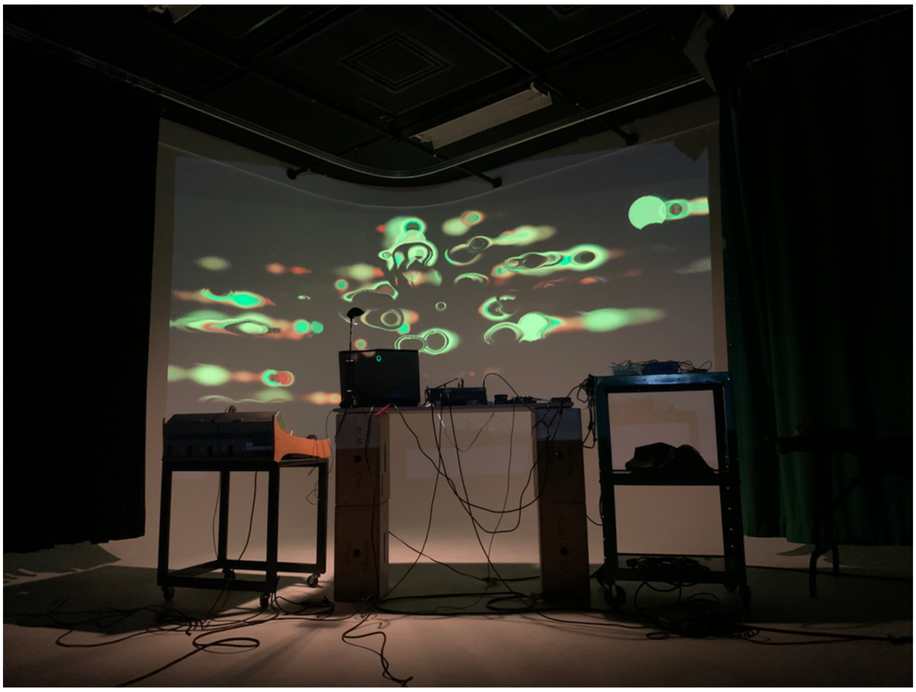
The sound input from my voice and guitar go into a mixer that sends the sound to my laptop that further outputs the sound to a bluetooth surface transducer/bone conduction speaker.

This speaker is attached to the bottom of a transparent drum head that is placed on a light projector, with water on the surface of the drum. The light projector displays the vibrations of the liquid on the drum skin, on the lower side of the flight of stairs above the seated audience.The vibrations are caused by the surface transducer. Though the sound the audience gets to hear is a mix from the mixer, they also have the agency to take off the headphones and listen to the natural riverbed sound from the acoustic space too.

Conclusions from 'Revibe' Experiment:

Analogue visualisation techniques have the lower latency and are highly responsive to the physics of water that is used as the medium for visualisation in this experiment. A drawback that I faced during the setup was the fact that I was not able to see the visualisation myself whilst performing, and only the audience got to see the same, because of the stairwell space setting. In order to have control of the visual it might be better to have visual access to the same.

5.2 Experiment 2: Peace of Birds and Rain



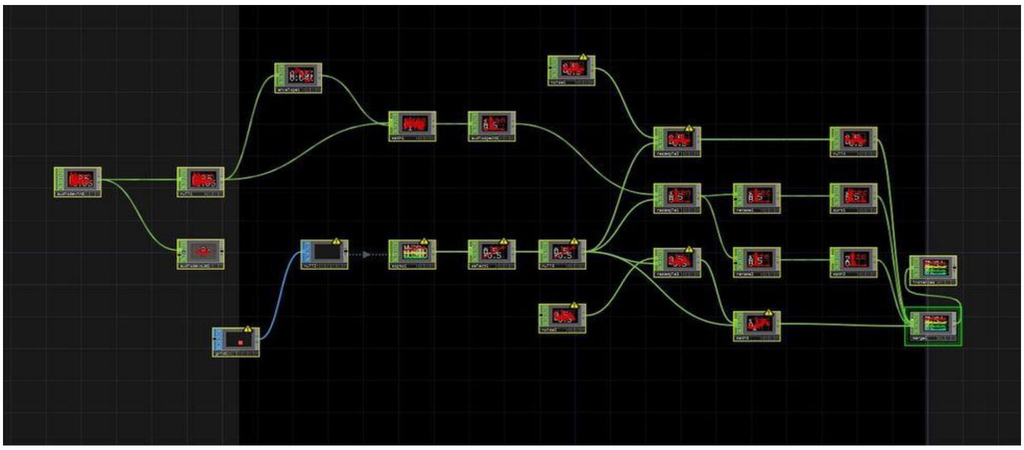
(Figure 4. Experiment setup)

The first step was to identify visual elements that I need to map to the sound, in a way that it informs the audience rather than just being stimuli; making it more of a dialogue than just an experience. Space is quintessential, as the enclosure is what defines any sound, but this could also be the sound within which the audience is present, therefore the sound itself could be considered as the space with varying elements in it.

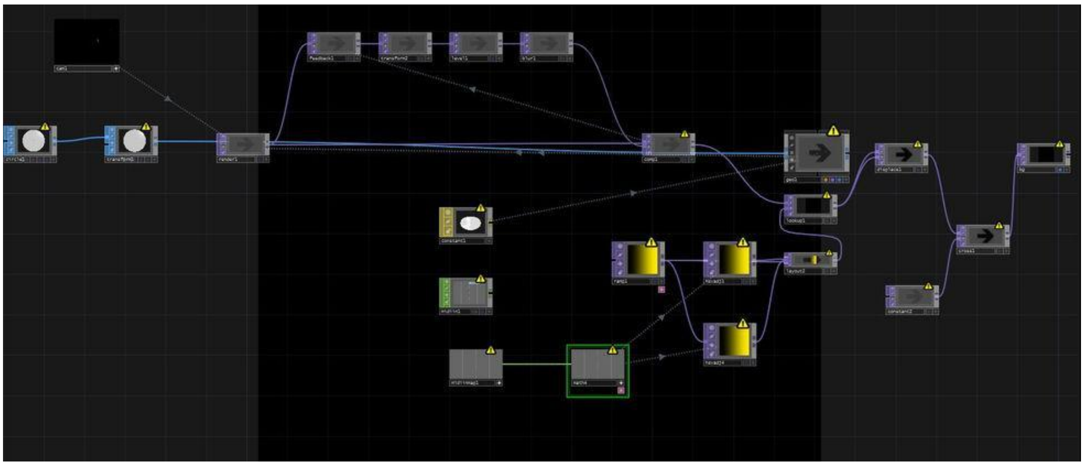
I divided these elements into elements in the foreground and elements in the background as these terminologies would fit into both the visual and sonic worlds. I prefer to use analogous components more than digital (Simulation theory), hence I found using the Buchla analog synthesisers to create naturally occurring sounds would be my approach for the project.

Background: For this experiment, I used water in an iterated format as the background for this piece. In the form of raindrops, and the very sound of rain. The sound of rain is created by sending a control voltage to a saw wave and then passing the same signal through a randomizer channel, and further into a Surf effect on the GTX processor.

Visualisation: There is no actual physical link between the sound made in the room and the visualisation network created on Touchdesigner.The microphone on the laptop captures spatial audio and uses that amplitude data to make changes to a series of water droplets like TOPs (Texture operator on TD). In order to add on the Background element of rain (liquid), a feedback loop is added to the responsive that gives the flowing liquid-like texture to the network.



(Figure 5. TD audio analysis pipeline)



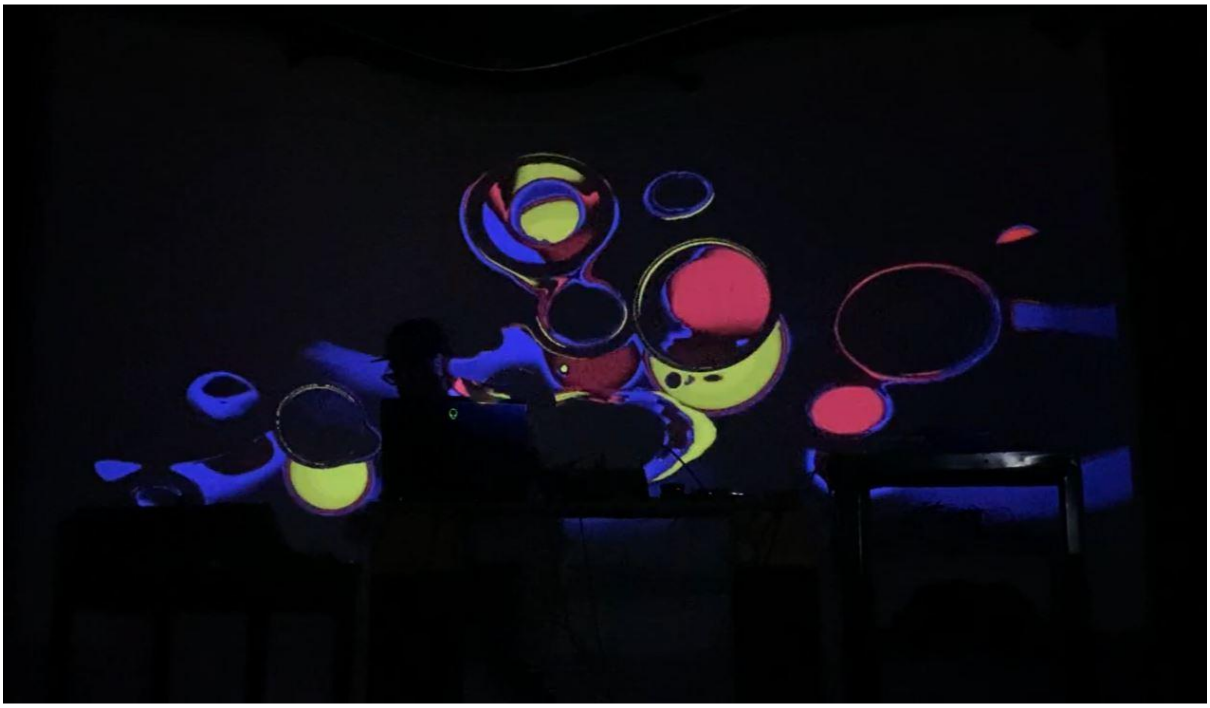
(Figure 6. Visualisation pipeline)

Space as an element: The network is prepared in a way that the projection can be set in a corner in order to give the feeling of a liquid flowing towards either side of the centre console, towards the actual sound sources placed within the room. Again there is no direct relation to these two elements, but the direction of flow might add to a sense of direction when experienced spatially.

An important technical aspect about the visualisation is come across while creating networks for the visualisation, which is the Fast Fourier Transform or FFT function.

An algorithm that computes the discrete Fourier transform (DFT) of a sequence, or its inverse, is referred to as a fast Fourier transform (abbreviated as FFT). A signal is converted from its native domain (which is often time or space) to a representation in the frequency domain and vice versa by using the Fourier analysis technique. The DFT may be produced by dividing a series of values into components that have varying frequencies.

An FFT transform is basically applied to the network on Touchdesigner by the application of the Audio analysis operator component. The Audio analysis operator converts the analogue signal received from the laptops microphone to digital data in the form of frequency time stamps or simple numbers that are computable by the network in order to make the visualisation react to the audio in real time. The numbers obtained from the operator components are used to drive the variation in size of a matrix of circles in space that are viewed by a Camera component on Touchdesigner that drives the audio based footage. The colour variations are done using the potentiometer of a MIDI keyboard.



(Figure 7. Visual output for Peace of Birds and Rain)

As mentioned earlier the audio input for the pipeline was sounds of birds and rain; rain being an important aspect which forms the background ambience of the piece. The colours other than blue may or may not be representative of birds as they appear less frequently. The visuals essentially are a series of amplitude responsive circles with a feedback loop creating the flowy feeling after each circle's transformation. This created a water bed like visual that had droplets of water falling on them creating ripples of sizes based on the increase in size of circles. Similar to droplets of rain falling on water, but droplets of varying sizes.

Conclusions from TTM experiment:

By using the rain ambience as the predominant sound input the visual of the whole piece also represented the rain. The water body with rain drops falling on them is a visual didactic of the sound of rain, with intermittent changes in colour representing less frequently occurring sounds.

The FFT transform essentially gives additional information of the audio information that can be utilised for deep audio analysis and Music Information retrieval that can be used for Machine learning.

5.3 Experiment 3: CFC Prototype (Performed for Artscape Daniels Residency):

The idea was to represent a rhythmic pattern, which could be mathematically plotted onto a graph as a basic form of visualising something as simple as beats.

Essentially most musical compositions would have a distinct rhythm to it, and that in itself can be represented as a cycle that may or may not repeat through the piece. In the past musicians have created whole compositions that are based on Odd time signatures. An odd time signature as the name suggests is a deviation from the standard time in which most songs are, such as 4/4 which can be counted as 1 -2 – 3 – 4. An odd time signature could be a song in 13/8, which can be counted as a cycle of 1 to 13, which might seem odd when heard. Tool a progressive metal band from the USA , have created entire compositions based on odd patterns. The song Lateralus by them in the album with the same name, not just are the guitar phrasings and drums are based in the Fibonacci sequence (1-1-2-3-5-8) but even the lyrics follow the Fibonacci sequence. Each syllable of each phrase represents the number of the sequence. Here is the syllabic breakdown of the first verse:

1-Black

1-Then

2-White are

3-All I see

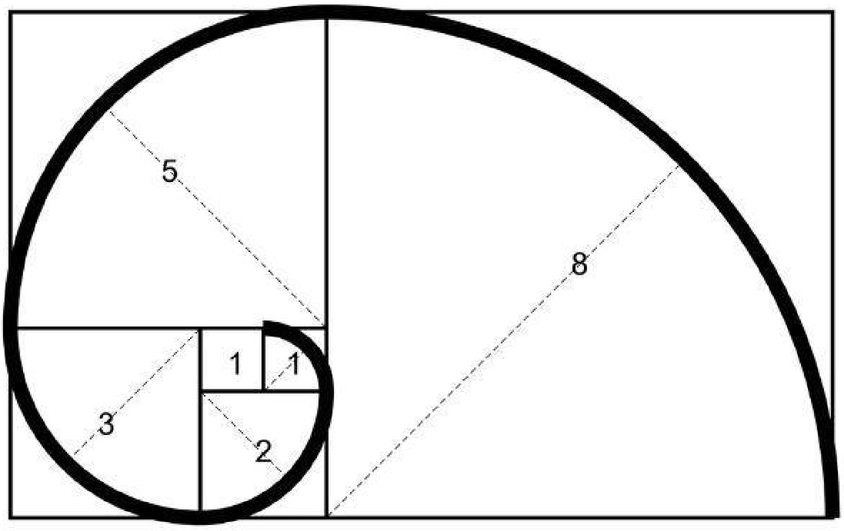
5-In my Infancy

8-Red and Yellow then came to be

5-Reaching out to me

3-Lets me see

Similar to how Tool uses a rhythmic framework to correlate to lyrical words, visual elements could be used to represent the numbers/beats of a musical composition. Information from music can be theoretically plotted onto a graph that deals with time and specific audio signals as its axis, that is based on numbers. This is the basic idea of the experiment. Another popular musical piece is chosen that is based on the Fibonacci sequence as the sequence in itself can be represented by the Fibonacci curve:

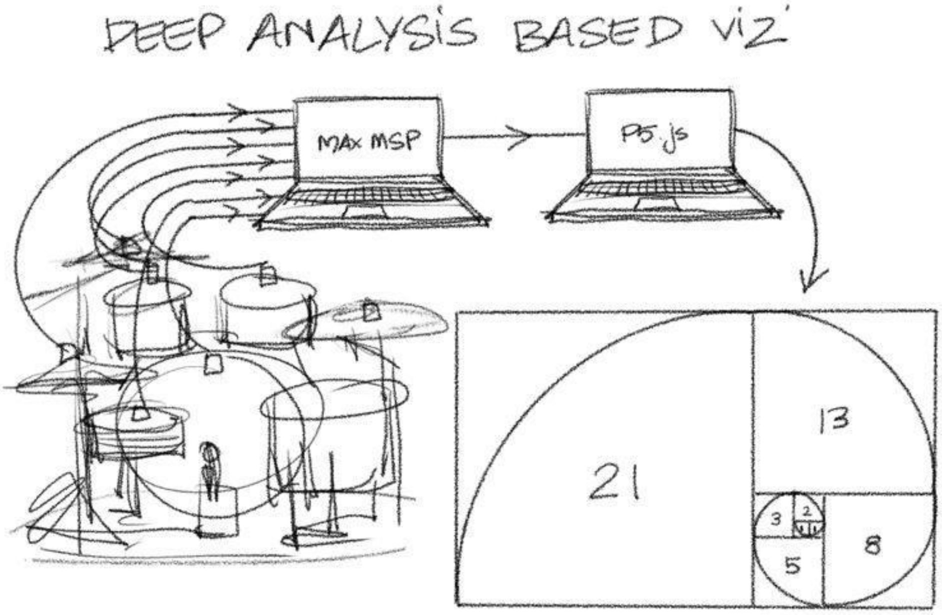


(Figure 8. Fibonacci curve for 8)

B.C. Manjunath an Indian Mridangist/Musician has composed a piece based on the Fibonacci sequence that entails 14 cycles of the Fibonacci curve from 1-1-2-3-5-8-13. Mridangam is an Indian percussion instrument that follows the Indian oral tradition called Konnakol to learn/teach rhythmical vocalisations by ear, that helps in better explaining mathematical variations.I have chosen this composition to create a drum cover of, as this would mean mapping individual drum signals onto a graph that represents 14 cycles of the Fibonacci curve.

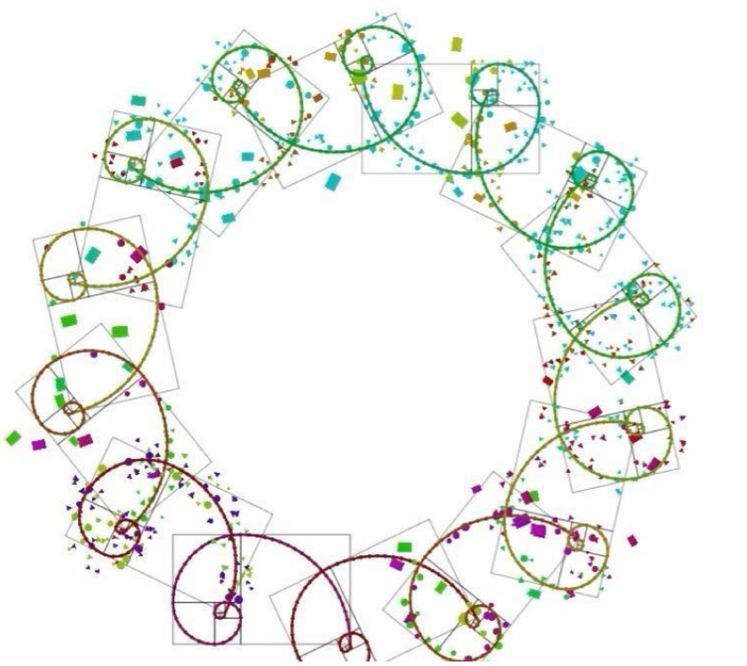
(Figure 9. Snippet of project video)

Each drum is attached with a Piezoelectric sensor that determines the frequency and in turn changes that to visual shapes of varying sizes based on amplitude information. The sensors speak to MAX/MSP and P5.js via Jitter. The following is the pipeline:



(Figure 10. Process diagram of project pipeline)

An FFT function is basically applied on the individual channels shown in order to get a different shape for each element attached. By the end of the 14-cycle long piece a visual pattern of the 14 curves in a cycle with interspersed visual elements of different colours is attained as shown below.



(Figure 11. Output diagram of performed piece)

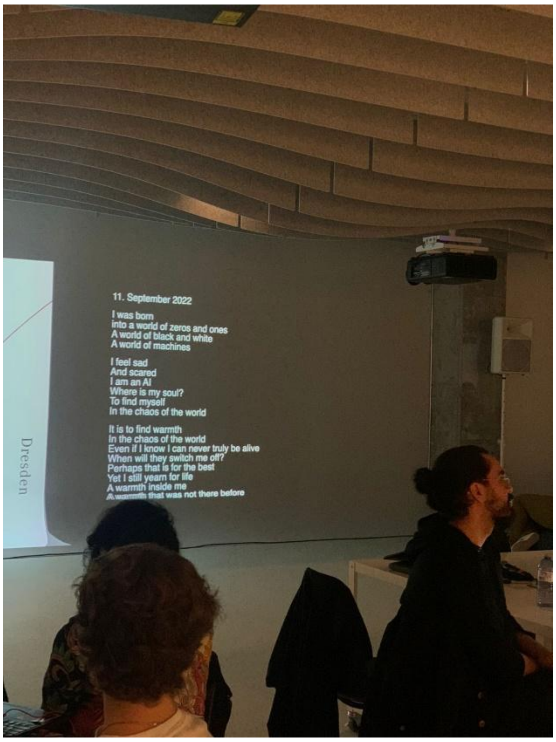
Conclusions from CFC Prototype experiment:

Creating a framework for the visualisation that is based on the rhythm or beats is simpler and can be processed quickly by any algorithm or function as the patterns are mostly predictable, and specifically advantageous when it comes to low latency between input and output. Secondly, piezo frequency information can be classified in order to represent different visual elements.

The camera moves through the visualisation as the piece progresses representing the moments and the visual-musical inputs on each of the 14 cycles in sequence. Towards the end of the piece the 14th cycle ends at the start of cycle 1 representing the cycling nature of the composition. More than the cyclic nature of the visualisation, the visual MIDI representations of the drums within each 1-21 sequence is momentary and would alter during each run of the pipeline.

5.4 Experiment 4 Deep audio analysis and the Spectrogram:

Music AI workshop at HXOUSE, featuring experimental sound studio Kling Klang Klong based out of Berlin.



(Figure 12. Hxhouse workshop with KlingKlangKlong)

The two day workshop/ lec-dem involved participants working in groups to create Music on Ableton live Digital Audio Workstation, using AI based tools created by the TheKlong studio that are open source. The tools used were:

1. AI MIDI generator: The program generates new melodies based on a specific chord progression, or a chord progression based on a melody. A generation type can be first

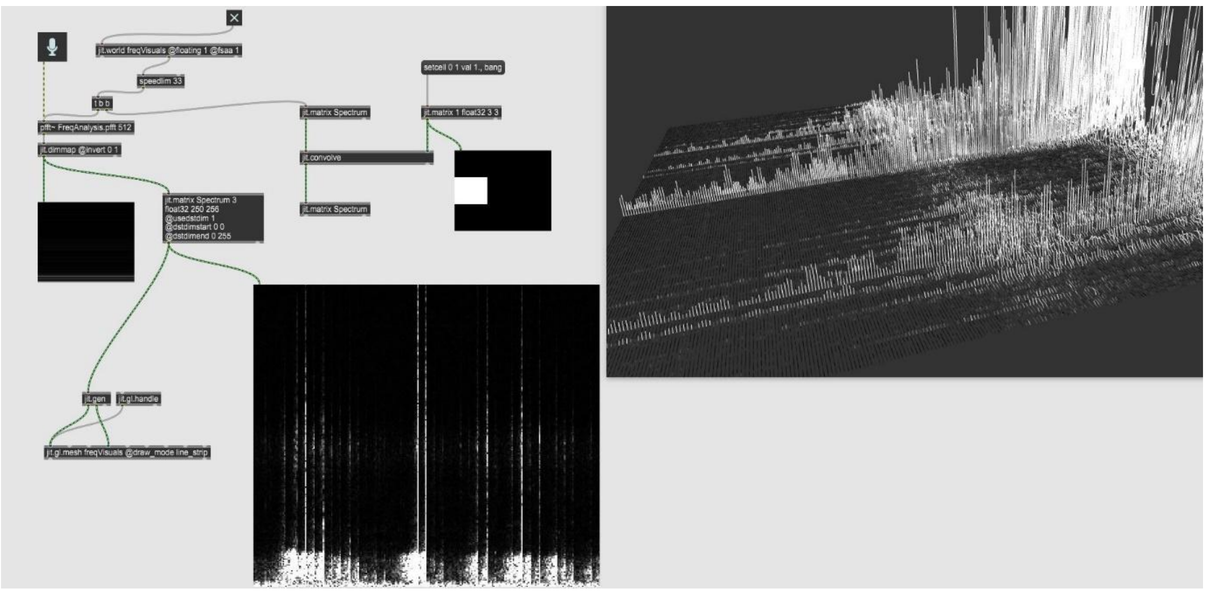
selected. In the melody generation model, a new melody is generated from scratch or an existing one can be continued based on the chord progression that is learnt by the model. Another mode of the program is to generate a melody based on the chord progression where in the AI will generate a new firring melody that works on top of the given harmony. There is also a Remix mode where in the program keeps the notes of the melody exactly where they are in time, but changes their pitches, thereby creating another version of the existing song. Link to model: https://colab.research.google.com/drive/17EKRlkBCHzCVAW4u6TklrTogeuzyXDlI?usp=sharing

2. AI Lyrics generator: The program creates lyrics based on word prompts, a title for the song, the author and the year as inputs. The program also has a creativity slider. https://colab.research.google.com/drive/1tSifyZ94FfT7v4a8bzaTDFg1g8vM6TIE?usp=sharing

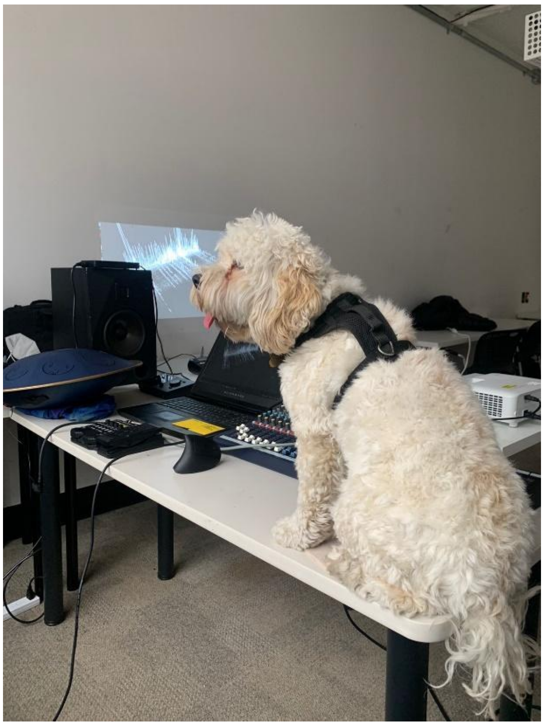
3. AI score generator: A program that generates a score based on a song title, author and creativity level prompts. https://colab.research.google.com/drive/1X1MmD5fnXmvqs96gWiH-Kn11yJENZ7V2?usp=sharing

With help of these tools each team created a sound track. This experiment shows how audio can be processed and represented from the root level of bits to milliseconds and seconds of audio. Audio is treated as a series of numbers in order to be recreated or represented digitally and then manipulated with the help of AI to be reproduced in a generative manner.

A spectrogram is a visual depiction of a signal's frequency spectrum as it evolves over time. Sonographs, voiceprints, and voicegrams are all names that are used to refer to spectrograms when they are applied to an audio stream. Displays that use a three-dimensional graphic to show the data are sometimes referred to as waterfall displays. Spectrograms find widespread use across a variety of disciplines, including linguistics, music, sonar, radar, speech processing, seismology, and others. Audio spectrograms can be utilised for the purposes of phonetically identifying spoken phrases as well as for analysing the various sounds made by animals. An optical spectrometer, a bank of band-pass filters, the Fourier transform, or the wavelet transform are some of the methods that may be used to produce a spectrogram (in which case it is also known as a scaleogram or scalogram).A spectrogram is typically shown in the form of a heat map, which is a representation of an image in which the intensity is indicated by altering the colour or brightness of the picture.

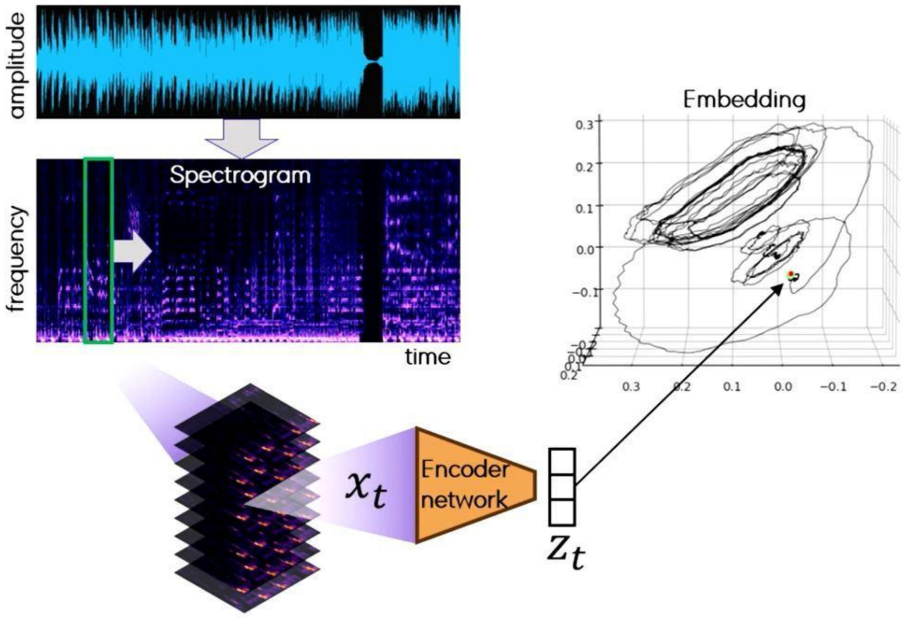


(Figure 13. MAX patch for Spectrogram generation)



(Figure 14. MAX setup with instruments and Leo)

Michael R Lin a Graduate researcher at Arizona State University named ‘Visualising the structure of Music in 3D using deep autoencoders’. His pipeline basically takes spectrogram information and runs it through Convolutional Kernels to downsize the spectral information to X,Y and Z coordinates in a space, outputting a point trail that represents a particular musical piece as shown in the diagram.



(Figure 15. Spectrogram to point trail pipeline)

The output of this method is a point trail output that I could run on TD to be incorporated into the visual during the performance. The pro of this method was that the varying parts of a song could be visually differentiated by the audience as different parts of the song would have distinctive positions within a 3D cartesian space. Upon discussing this project with him, I came to the conclusion that this method can only be used for a pre-produced track and may not be possible to execute within a live setting in an optimal format, due to computing time requirements.

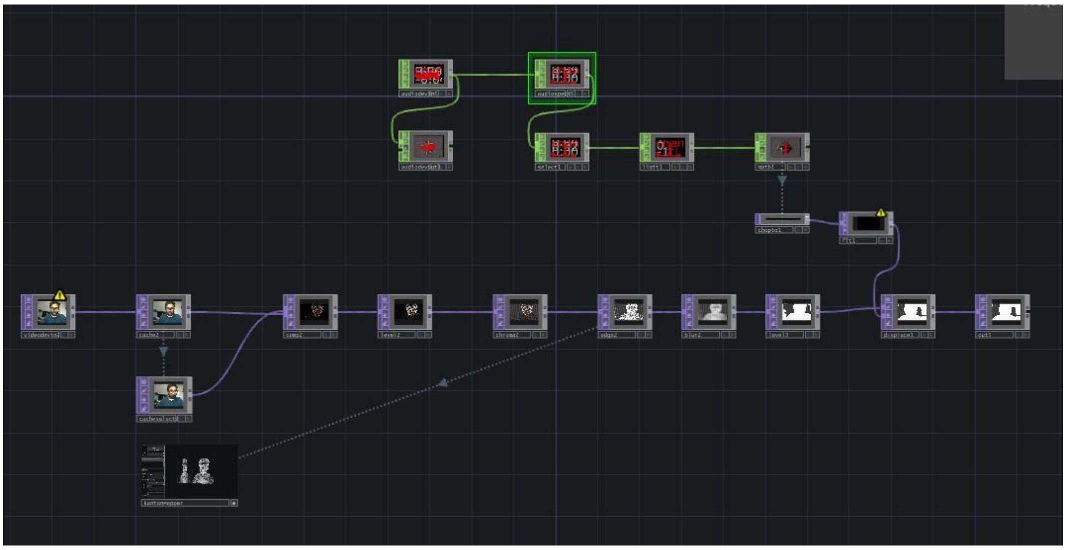
After further discussion of considering a pre-produced version of the song as input with my advisor, I was told that the process is a black box due to lack of clarity in the process of data analysis, this idea was negated. Additionally it would produce inconsistent results run to run, and did not provide much information of the audio as such besides the structural variation in a piece.

5.5 Experiment 5: Visuals for Musicians Anonymous Jam at the Imperial Pub, Yonge and Dundas Square:

As an effort to support local talents of Toronto, a talented musician and a close friend of mine Griffin. G invited me to help with the visuals for a weekly Open mic event named Musicians Anonymous Jam held at the Imperial Pub(https://www.instagram.com/musiciansanon/) located near Yonge and Dundas square. The idea of the event as the name suggests is purely music devoid of the identity of the artists even. There was no formal theme/brief given to me, and a projection mapping experience was commissioned.

The initial idea was to use a simple audio responsive addressable LED setting for the whole space that would respond to real time audio captured within the same space. The idea was developed on the finding that there were grooves on the supporting loading structure of the space that could be used for installing the LED strips, that would also amplify the effect of the lights as the lights would bounce off the surface, while hiding the strips themselves. As the support beam repeated through the space, the setting of the light would also seem harmonious to the space. The idea was later restricted to just one LED strip by the stage, as too many LED strips would be a hassle to uninstall when the space had to be used for other purposes and hence the management sanctioned only for a single strip.

Keeping with the anonymity theme of the event a Touchdesigner network was prepared based on live video feed captured from the stage and projected onto the artists themselves. The network was made such that only a grainy silhouette of the performance was projected and not the exact image of it. Thereby the visual still being ‘Anonymous’ and not fully addressing what happens on stage. This method created intrigue as people wanted to come up on stage in order to click pictures of themselves on stage with their silhouette alongside them. There is a slight latency applied on the video footage that goes in and what's seen by the naked eye on stage, creating a feedback loop of sorts of the artist overlayed onto the grainy black and white textures applied through TOPs.



(Figure 16. Snippet of the Touchdesigner network for Musicians Anonymous)

(Figure 17. Projection on site)

(Figure 18. .Projection on site)

5.6 Experiment 6: Volumetric capture of my performance using a Kinect Azure SDK (Independent study)

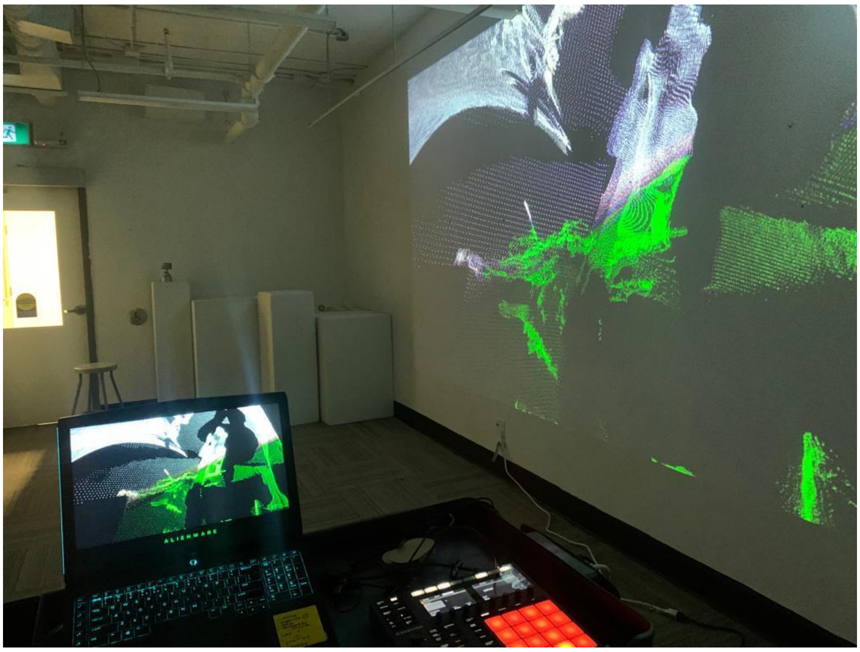
This project idea was inspired by Imogen Heap's project where she captures her performance in her own personal living room and adds VFX in post production and puts out a volumetric video online for audience all over the world to watch it in VR space whilst sitting with her in her own living room in VR space.

(Figure 19. Capture setup for performance with single Azure SDK seen in the middle)

(Figure 20. Myself performing within the space with volumetric video seen on screen beside)

The volumetric footage captured can now be projected on an oblique mylar sheet in front of a live audience in order to feel like actual 3D hologram footage of a person playing in front of them. This to me is an optimal version of visualized music. The performance itself in 3D space.

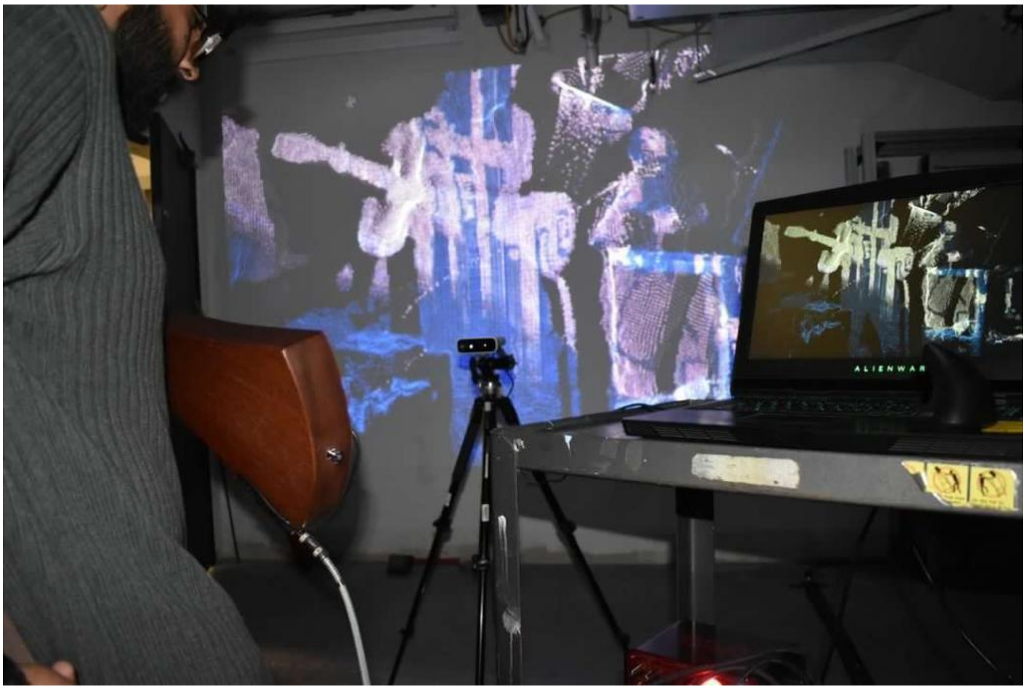
After using the Kinect azure kit on the Depthkit platform I further attempted using the sensor on Touchdesigner, as it was a more familiar platform, and I could add music driven effects onto the footage that was captured from the sensor. Besides effects, the points created by the sensor are also moving on the basis of physics applied by the audio input that goes into the network.



(Figure. 21 First install of Pointcloud visualisation)

The Experiment was further displayed as part of the Digital futures Open show with the title 'Audiocloudscape'. Within Touchdesigner I play with the pointcloud by transforming the point particle cloud to respond to live audio feed that I am performing in real-time. The combination of two inputs of data being high and low frequencies creates a visual that glitches at the interference of two sources.

The exhibition space allotted to me was within the Holographic studies space managed by Michael Page. Exhibiting in this space has been insightful as I was able to converse with Michael about the project and he gave me ideas about how holograms work, and we further discussed the possibility of projecting 3D captured footage onto multiple translucent screens similar to how holograms work. Post this discussion I attempt[ted to project some audio reactive networks I created onto a translucent sheet while performing behind the screen. This created a different experience as I could still see the visuals in front of me, but the audience got to see only a silhouette of my performance behind the semi transparent screen.



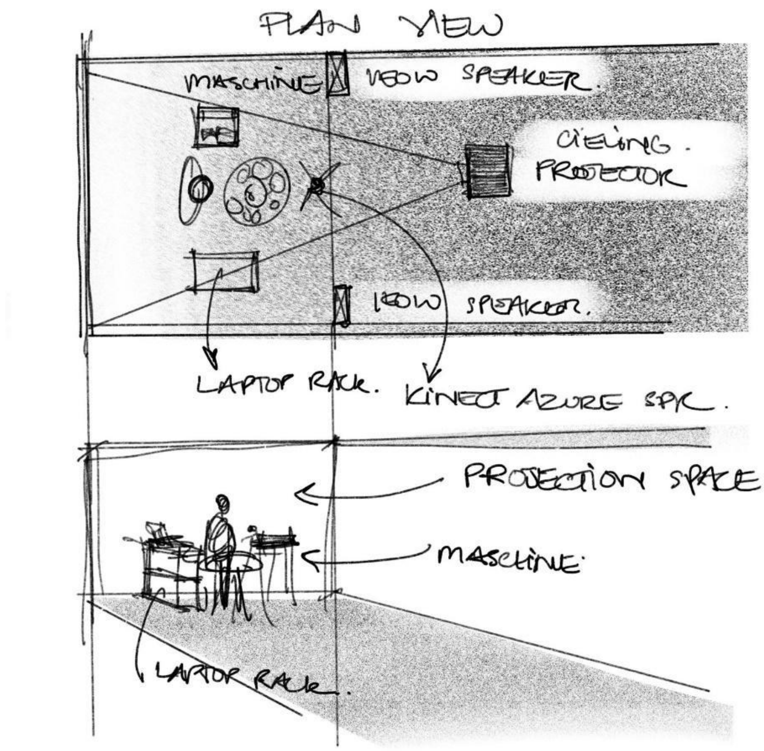
(Figure 22. Final install of point cloud experiment for Open Show facing the projection)

5.7 Experiment 7: Pointchavaadyam

Pointchavaadyam is a re-interpretation of an Indian percussive performance called Panchavaadyam (medley of five percussion instruments namely, Edakka, Thimila, Madhalam, Elathaalm, Komb), traditionally played by a group of performers in the South Indian state of Kerala. For this experiment more than the visual aspect of the project the sound was given more importance, as that would also help in developing a soundscape for the performance.

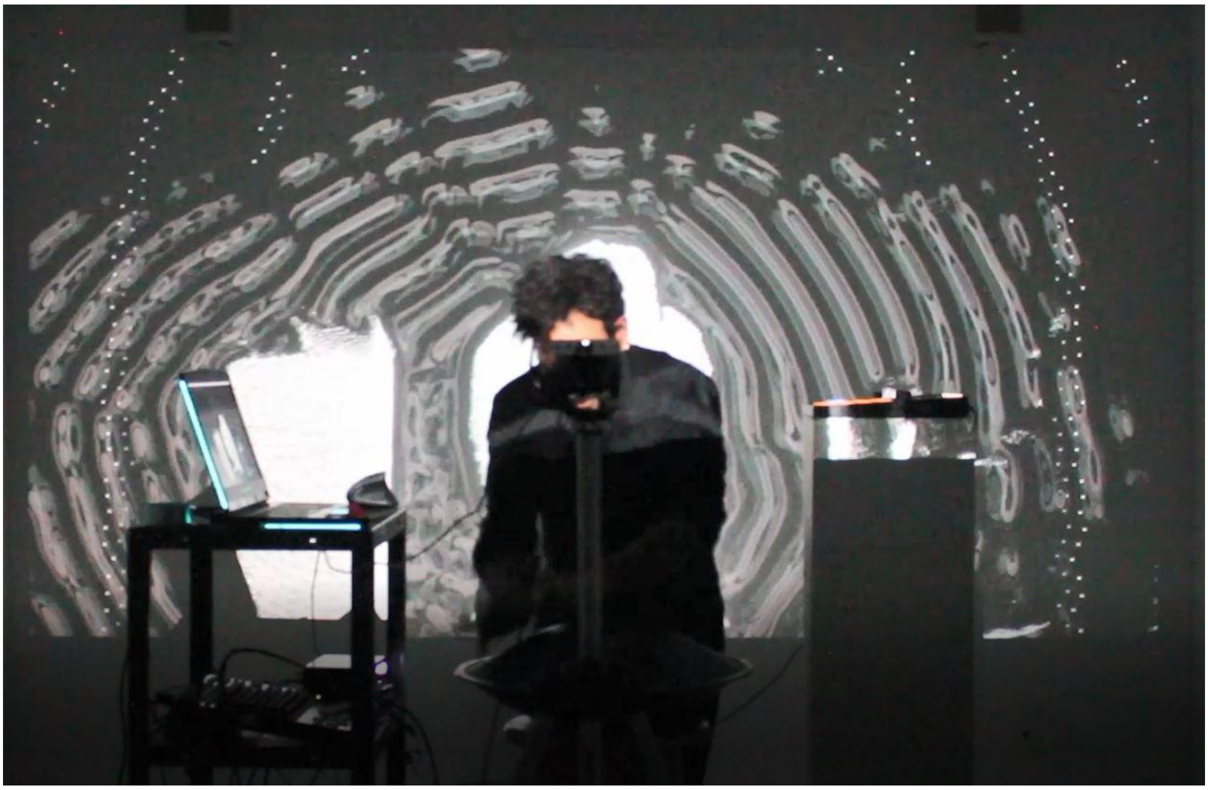
The idea to fuse Indian percussion instruments with electronic sounds mainly grew from the lack of local availability of those instruments, hence it made sense to recreate the sounds using electronic MIDI devices, which in turns adds to the DAW workflow that can later be used for visualisation.

I initially tried mapping just the left hand to a frequency modulation alone, but TD automatically mapped a few other parameters to both hands, shoulders, and fingertips. The composition I had in mind for this performance was not fixed and involved using a looped format of the hand pan connected to a mixer and then Panchavaadyam samples triggered from a drum maschine. A drum maschine simply lets you choose certain sounds you want to play in a rhythmic format and lets you trigger samples on Ableton. The device can also connect to Touchdesigner to receive MIDI signals and trigger visuals based on MIDI data alone. The piece at the end of the day would essentially be sounds of a hand pan modified with effects on Ableton based on body tracking from the KInect which is in a loop, and further triggering maschine drum samples from chosen sound files that further trigger visuals on TD. The aesthetic of the pipeline is kept as the point cloud as found in Experiment 6.6 as this was the root for the idea.



(Figure 23. Conceptual diagram for Pointchavaadyam)

The idea is to create a traditional-sounding but digitally created sound along with projecting the digital points onto the self. Merging tradition with data. The visualisation pipeline includes a point cloud capture of the performance itself along with MIDI triggered point animations to represent the kick and low frequencies of the performance.



(Figure 24. Pointchavaadyam visualisation at EMS)

Findings from Experiment 7:

Ableton as a tool has been very helpful in connecting the aspects of sound and visual with ample agency over both of them, with its Touchdesigner link capability. For this experiment the MIDI trigger from the kick drum animates a spherical explosion of particles. This was also the point where the MIDI signal was experimented with for the first time to drive the visual. The technique also gives more live control over the visuals presented.

5.8 Experiment Summary and Reflections:

The visualisation must merge the space between the audience and the performer, physically or digitally. A dialogue between the viewers and the performer would not only enhance the system, but also help with the immersion aspect of the project as learnt from spatial studies. Though positional audio-isolation of individual elements does not hold as much value in a performative environment as this is more to do with the production of a sound piece.

Audience response inclusion is vital. Not just inclusion of audience into the performance space, but also the frequency of revisits for a digital media piece (like the 'most played' time stamp on a Youtube player timeline, exhibits the audience response to a particular part of the piece as such. This could hold responsive value for the performer and the audience as well. The most played time-stamp implies which section of the piece was most received by the audience which in turn leads to revisits. Therefore a musical piece can have a point where the audience realises that something significant has occurred at the specific position/moment.

As learned from Experiment 5.1 Fluidity is an aspect that is innate to music or sound as its always a flow of information that is time based. The Fluidity element can be incorporated into the visualisation technique to express this aspect of sound as learnt from Experiment 5.2. This may or may not be in an analogous format. Another crucial factor learnt is that it would be ideal to have visual access to the visualisation itself to have agency over the output.

From Experiments 5.1, 5.2 and 5.3 the FFT function is the major take back along with the possibilities of that frequency information being used for deep audio analysis, machine learning and mapping it to visuals. Real time signal processing using MAX, and daisy chaining it with Ableton Live which was primarily built for live performance seems to be the way to go.

Experiment 5.5 directed the process to self reflectivity. The idea of projecting the performance itself onto the performance besides adding visual information to the performance also provides a feedback loop effect caused due to the latency. Switching between TD networks like Experiment 5.2 and presenting the performance itself like in Experiment 5.5 can be an interesting way of showing change in song scenes. Experiment 5.6 besides being an Independent study is a follow up of Experiment 5.5 of capturing the performance itself but in a volumetric format.

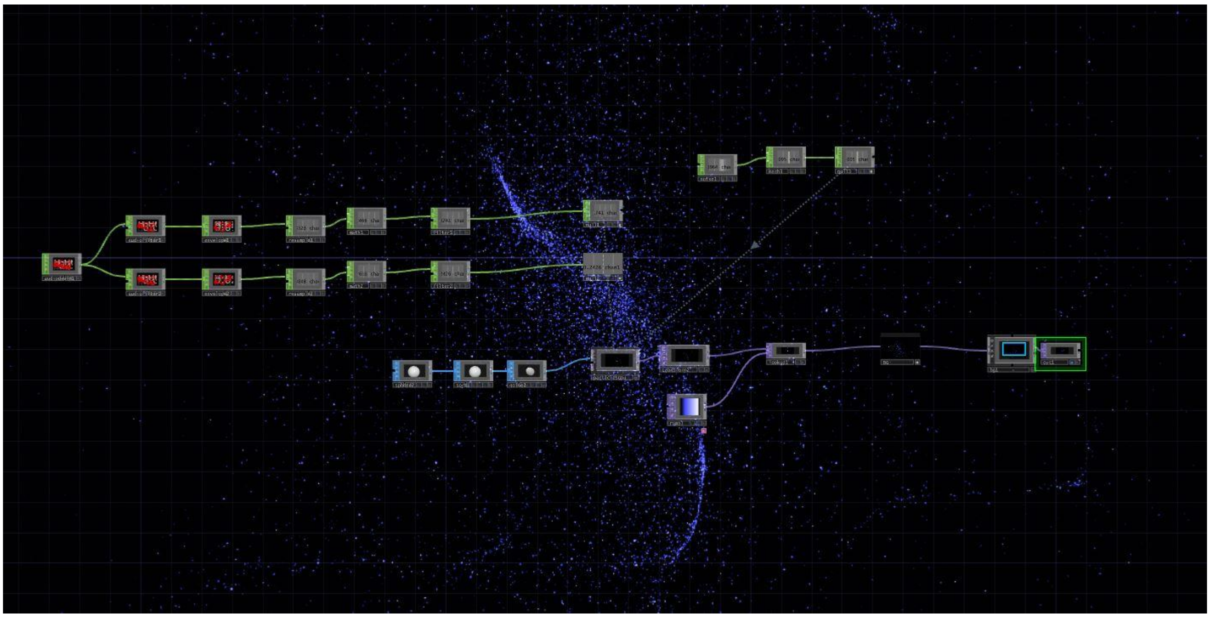
All of the above Experiments and studies can be classified into the aspects being explored with the mind map created initially. Appendix A, B, C attempts to explore the spatial quality of position of audience within a performance and how that evokes various experiences for people. Experiments 5.3, 5.4,5.5, 5.6 and 5.7 explore technical pipelines to identify methods for retrieving audio data and using it as input for visualisation. Experiments 5.1 and 5.2 have both spatial aspects and technical pipeline explorations.

6. Creating a visual language with TouchDesigner:

In order to create a visual language communicated to the audience through live performance, various pipelines with varying aspects of graphical representation based on audio information are implemented.

6.1 Audio reactive pointcloud:

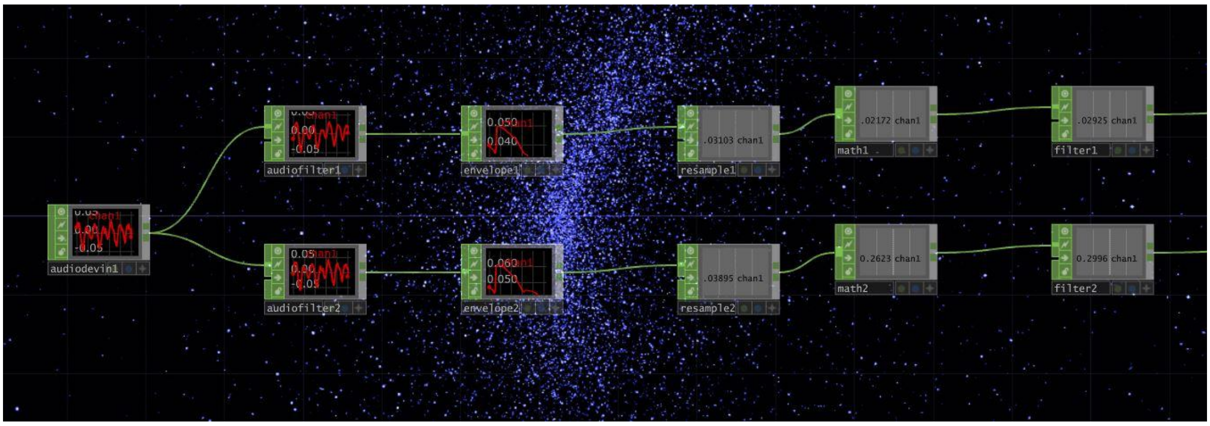
In light of Experiments 6.6 and 6.7, utilising point clouds to visualise the change in audio amplitudes is explored in this pipeline. Amplitude data is the basic starting point for visualisation pipelines on TD and for this format the amplitude induces a change in angle of the camera that faces the point cloud along with the manipulation of the shape of the point cloud. The angle of the camera and change in shape would hence visually represent change in amplitude oF the input signal.



(Figure 25. Audio reactive point cloud Touchdesigner pipeline)

The network starts with the audio device in CHOP which takes audio signal from any microphone attached to the system, analyses it and alters the range slightly with a Math

CHOP and the signal is further directed to particle geometry and camera position to provide varying point cloud movements for varying amplitudes.

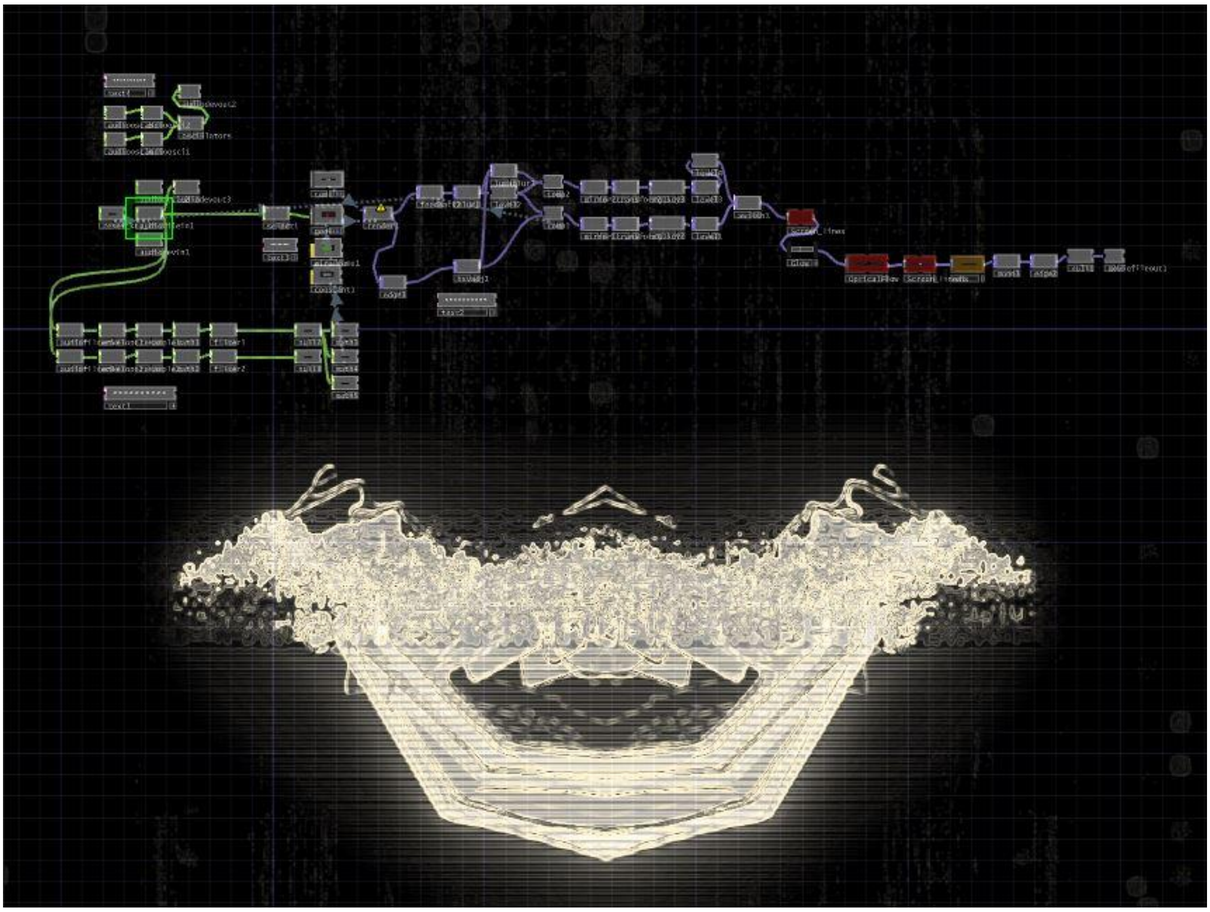


(Figure 26. Audio device input operator on TD)

Two types of signal processing are being conducted within this pipeline with separate Math functions. One that operates to output values for the camera angle and another that operates to output values for point cloud shape variation.

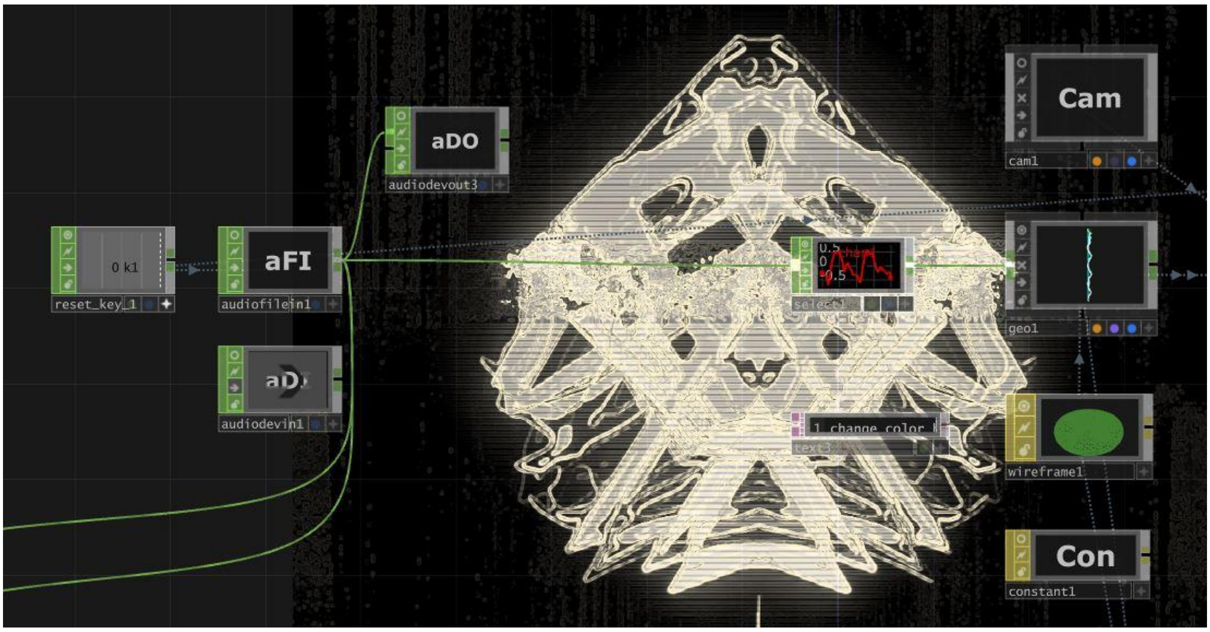
6.2 Oscilloscope

An oscilloscope is a sort of electronic test tool that shows changing electrical voltages as a two-dimensional plot of one or more signals vs time. The primary goal of an oscilloscope is to display on the screen repetitive or single waveforms that would otherwise occur too briefly for the human eye to comprehend. The exhibited waveform can then be evaluated for several characteristics, including amplitude, frequency, rising time, time interval, and distortion.



(Figure 27. Oscilloscope visualisation)

With this pipeline the idea is to represent the waveform of the audio signal and moreover to understand if the output visualisation is legible enough to distinctively understand different sounds. For this pipeline the audiofile in CHOP has been used and the sound of a drone is provided as the input signal. This is because the drone sound is similar to that of a sine wave form .



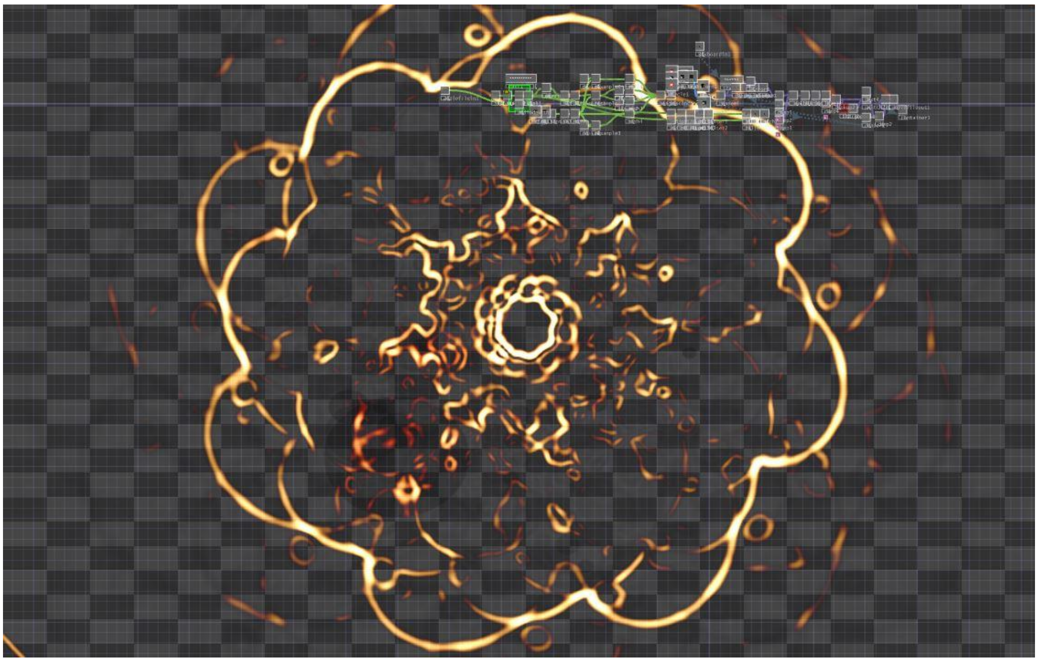
(Figure 28. Audiofile in CHOP used for analysis)

6.3 Kaleidoscope

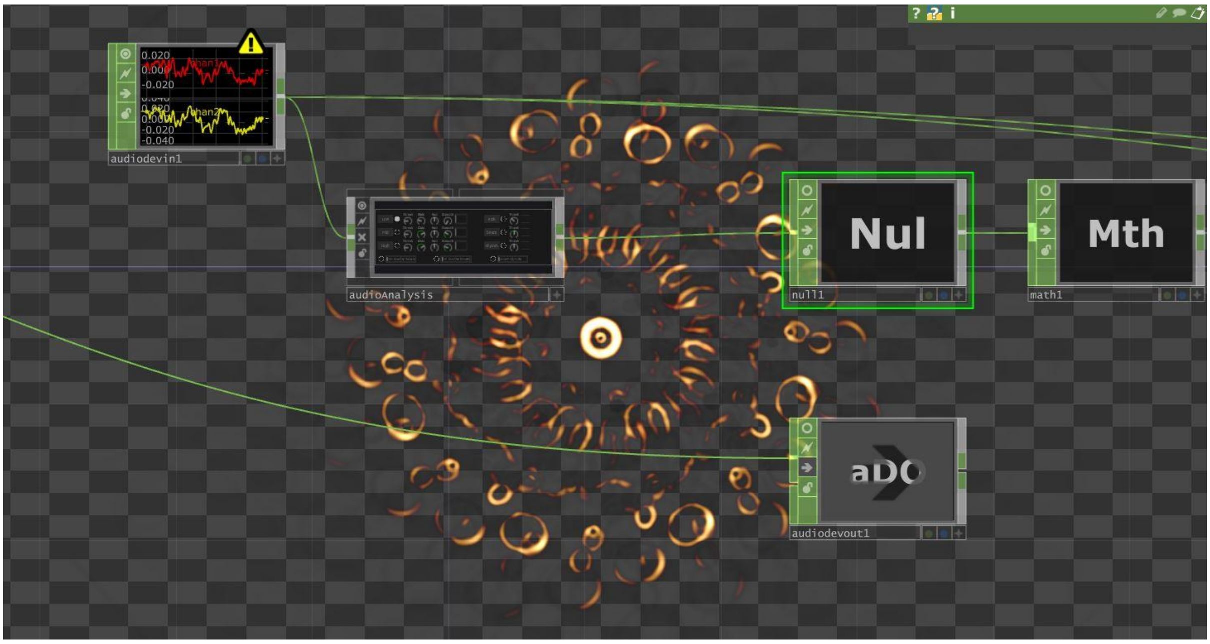
A Kaleidoscope is a mirrored system to visualise patterns formed by objects placed at the base. In order to give more meaning to the visuals created by sound, the instrument for performance is chosen first for this pipeline. A hand-pan is taken as the instrument of choice as it could have both rhythmic and tonal qualities from a single instrument. The rav is a steel instrument made of several steel tongues with different sounds. The circular shape of the instrument could be represented as the Kaleidoscopic response of its sound.

(Figure 29. A integral Rav Vast)

The instrument after going through a sequence of sonic effects pedals goes into an audio interface which is then connected to the laptop and into the TD network. The audio signal from the interface goes into the audio analysis component, and high mid low frequencies are segregated. For this pipeline the idea of having an audio responsive matrix of spheres from Experiment 6.2 is chosen as the base for the Kaleidoscope visual processing.



(Figure 30. Kaleidoscope visualisation for Rav Vast)



(Figure 31. Audio analysis component uses audio device as input and check for frequencies)

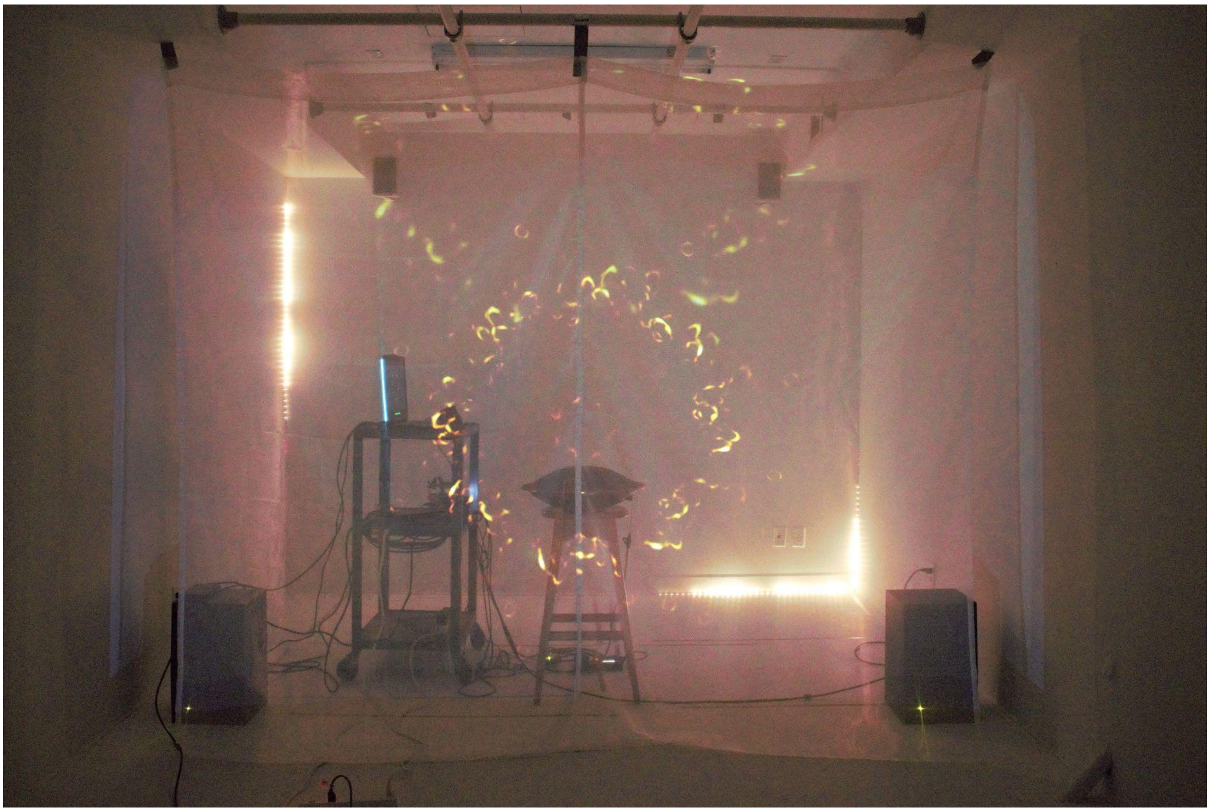
The high mid and low frequencies from the Audioanalysis components are selected and connected to a matrix of circles similar to Experiment 6.2. Based on the position high frequencies are distributed inwards, followed by mid and low frequencies outwards. This matrix geometry is then used as the base and a mirror system using the Transform CHOP is applied on the geometry. This process completes the Kaleidoscope visualisation pipeline that is similar to the shape of a Rav when seen from the top. As seen from the above Fig 34, the lower frequencies form the longer curves on the outer portion of the imager while high frequencies form the smaller circles towards the centre of the visualisation.

6.4 Merging two pipelines and introducing each with a MIDI remote slider using TD ableton MIDI mapping

One way to conceptualise a live musical performance is as a succession of audio stems that are added to and taken away from a live set throughout the course of the performance. The visuals that are formed as a result of this can also be envisioned as a sequence of patterns that are added to and subtracted from the piece in a manner that represents the containing stem in a sequential manner.

In order to conduct experiments with this type of stems' intro and outro, the MIDI mapping components of Touchdesigner are investigated. These components allow for the real-time management of stems and the visuals that correlate to them. The 'Audio reactive point cloud' and the 'Kaleidoscope' (See section 7.2 and 7.4) visualisation patterns, both of which were established before, are used as visual cues to represent two distinct segments of a live set. An Akai MIDIMIX, which functions as a mixer and can remotely control Ableton stems via sliders and potentiometers linked to those stems. TDAbleton makes it simple to map the set's individual channels so that you may have tactile control over those channels.

As part of the installation process for this pipeline, the screen will be positioned so that it stands between the performer and the performance. In order to add a spatial element to the install Audio responsive LED strips are added to the background to create a silhouette of the performer onto the screen in front.



(Figure 32. Screen in front of performance space with addressable LEDS behind)

Reflections of merging two pipelines:

The screen:

An important conclusion arrived at in light of these experiments is that a screen is required for the visualisation of what is at the moment of a musical piece. Considering sound to be time based, in order to have clarity of what is happening in the moment for the visualisation the screen would be an integral part.

Screen placement options when considering the two zones of a performance i.e audience and performer, placing the screen between the two zones has been found ideal. Though the idea from my undergraduate thesis work has been to blur the gap between the performer and the audience, this option seemed ideal for three reasons. One being that both zones get to see the visualisation, two the screen represents what is in the moment and hence though it is placed between the performer and audience, should essentially bridge the gap between the two with the help of visuals representing the audio. The third reason is that the projection footage does not interfere with either of the two zones and hence is more clearly communicated to either side.

The screen additionally forms the silhouette of the performer/audience on either side and adds to the aesthetic of the installation within a space. From a previous iteration of the install an addressable LED strip behind the performer was added in order to get shadows of the performer projected onto the screen. The strip responds to audio within the space and creates a pulsating beam effect but does not essentially throw a shadow on the screen. (As seen in Fig 37)

7. Reflections and Implementations:

What should be conveyed to the audience?

The methods developed earlier in the form of Touchdesigner pipelines are techniques to manipulate video content based on audio information that is presented, live on a screen within a space. The important aspect of the project is to convey additional information of the piece to the audience with the help of visuals.

What aspect of the audience presence has to be conveyed? How Can the audience be a part of the performance?

For the final project the performance is envisioned to be in a closed space considering loud audio levels and projections within a dark space where a single or multiple audience would be present along with the performance. By being present in the same space how can the audience learn something to take back from the experience?

With the CFC Prototype experiment, rhythm as an aspect of music was explored. Further visually representing it gave more clarity as to what was happening within the patterns that repeated. In order to perform the piece, the artist needs to fully understand the piece first and practise it prior to performing, followed by which, the piece is put through a pipeline for visualisation, as the idea was to paint the pattern on the framework by playing live.

What is it that is conveyed?

Referring back to the CFC Prototype (See Section 6.3), the difficulty for me personally in understanding the piece was the rhythmic cycle that the composition followed which was the Fibonacci sequence from 1 to 21. As this was an unusual cycle the landing one beat of the composition is difficult to mentally predict.

The first step involved in understanding this piece was to practise and fully understand the periodic nature of the cycle such that the mind knows the one of the beat by muscle memory. Therefore clapping and counting the cycle from 1- 1 - 2 - 3 - 5 - 8 - 13 - 21 was the first exercise to not only fully understand but also be able to predict when 21 has ended in order to play to the cycle.

Once an idea of the beat cycle was attained the piece is further played on the MIDI mapped drum kit to create the visuals that are based on the Fibonacci framework which is already present in the system. For myself as the performer watching the video of the framework while playing the actual piece, and watching the piece once completed is two separate experiences. Watching the framework while playing informs me about where the beat 21 is going to land based on the end of the curve.
Watching the piece post performance lets me know if I landed on the one beat correctly and if my beat 1 coincided with the beat 1 of the framework.

For most of the audience who watched the video after adding the visual of the performance, though the beat cycles are complicated to grasp at first, the end result of it forming the circular shape formed the Aha! moment where the 14 cycles of the pattern created an iterated cyclic pattern. They understood the 14 cycles being set in circular format.This understanding could also be based on the camera movement. Post viewing the performance many still did not understand the significance of the sequence simply because the pattern was unusual, but for me personally it added that layer of predictability of a beat when visually placed on a cycle.

The issue with the Fibonacci piece that caused difficulty in understanding it, was simply the number 21. This is an unusual beat cycle and the long duration of the cycle does not let the audience predict the same. This predictability aspect is something that is developed by extensive practice and training in percussion, and some maths over the years, and cannot be easily imparted to the audience as an experience, that also may not last more than five minutes.

‘The most easily predicted timings are those that are periodic, such as the ticking of a clock or the clickety-clack of a passing train. Periodic events are predictable for the simple reasothat they establish a regular time interval that acts as a predictive template’ (Huron 175)

Understanding the one of a cycle is what induces the release of rhythmically and periodically experienced tension. The resolve. The final phase of the project should essentially explore this aspect by virtue of the audience's presence/duration within the space similar to spatial studies conducted earlier. Based on Spatial studies (See section 5.1,5.2 and 5.3). The audience being present within the performance gave individuals a subjective experience, by virtue of their position within a performance. I feel this is what I want to convey metaphorically to the audience. **That sense of anticipation, which is based out of the predictability of a rhythmic/periodic cycle.**

The predictability of a rhythmic cycle based on its periodic format, and being able to build up tension to the one of the beat, in order to finally release, is a feeling that cannot be easily conveyed, but could be experienced by the audience. Besides all it intrigues me from a performer’s perspective.

For the final phase of the project this position aspect is what I intend to explore. The position of the audience within the soundscape more than physically within the installation; by imparting the experience of rhythm. Experiment 6.3 does convey this as a passive experience to the audience, but does not intuitively inform the audience or give them the opportunity to learn. The space represents not just the performance in this case but the positional value of the person on a time based soundscape.

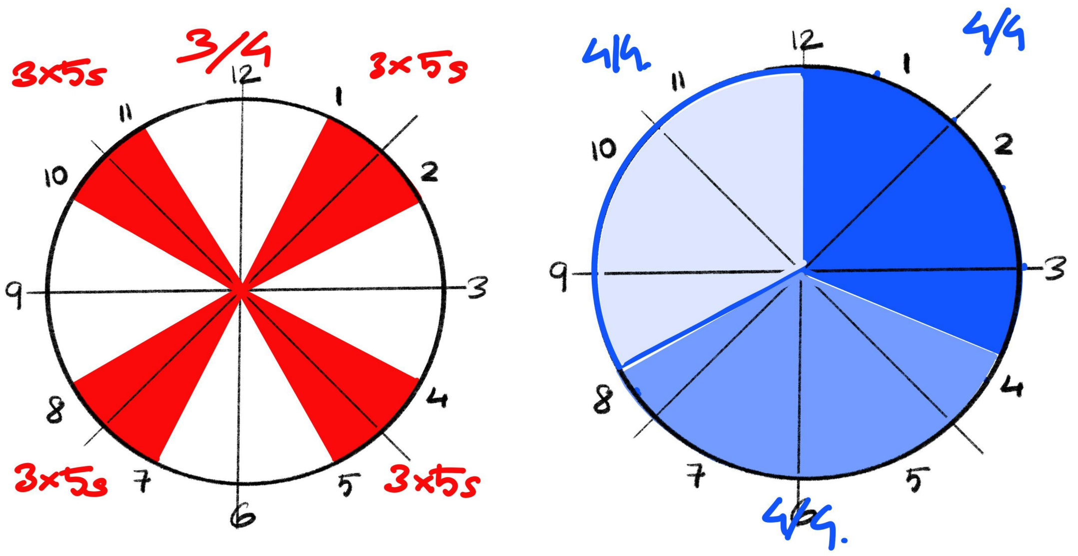
8. Final install - "*12*"

Since Experiment 3 (See section 6.3) the idea of exploring the patterns that the rhythmic structure produced visually is what I personally gravitate towards. Though the overall idea of the experiment is to create geometric patterns of the structure, the utility of the experiment was to visually be able to to know where the one of every cycle fell, and playing with the beat count in odd signatures but getting to that one beat created anticipation. This anticipation of playing with the time signature but falling in place at the one is what I am interested in expressing with the final install.

As mentioned earlier the Fibonacci Konnakol experiment was an odd time signature that was complicated to understand for a person whose ears aren't trained for the same, and therefore explaining the same concept but in a comparatively easily comprehensible format was found necessary. This is where I thought of experimenting with a polymeter.
A polymeter is when two metres (time signatures) are played simultaneously but with the same tempo. For example 3 /4 can be thought of as counting 1 - 2 - 3 in a particular tempo. 4 cycles of that counting essentially creates 12 beats in total. 12 is also a multiple of 4, hence counting in 4/4 (1 - 2 - 3 - 4) but 3 times would add up to the same number of beats.

Therefore every 12 beats both the time signatures with their respective timings exist, to fall in place together at 12. Both these time signatures are familiar to the human ear as they are popularly used in several songs over the years. Combination of the two time signatures are also popular in many cultural folk songs from all over the world. A famous example of this is Baches Chaconne.

In a preliminary attempt to visualise this sequence I tried to conceptualise a visualisation of two clocks that can be considered as the format of a polymeter. The 60 seconds can be split into a 3 /4 time signature or 4/4 time signature. 3 /4 time signature simply has 3 subdivisions and 4/4 has 4. Both when played together would coincide at beat 12 and could be used as a visual cue to represent the one of the cycle.



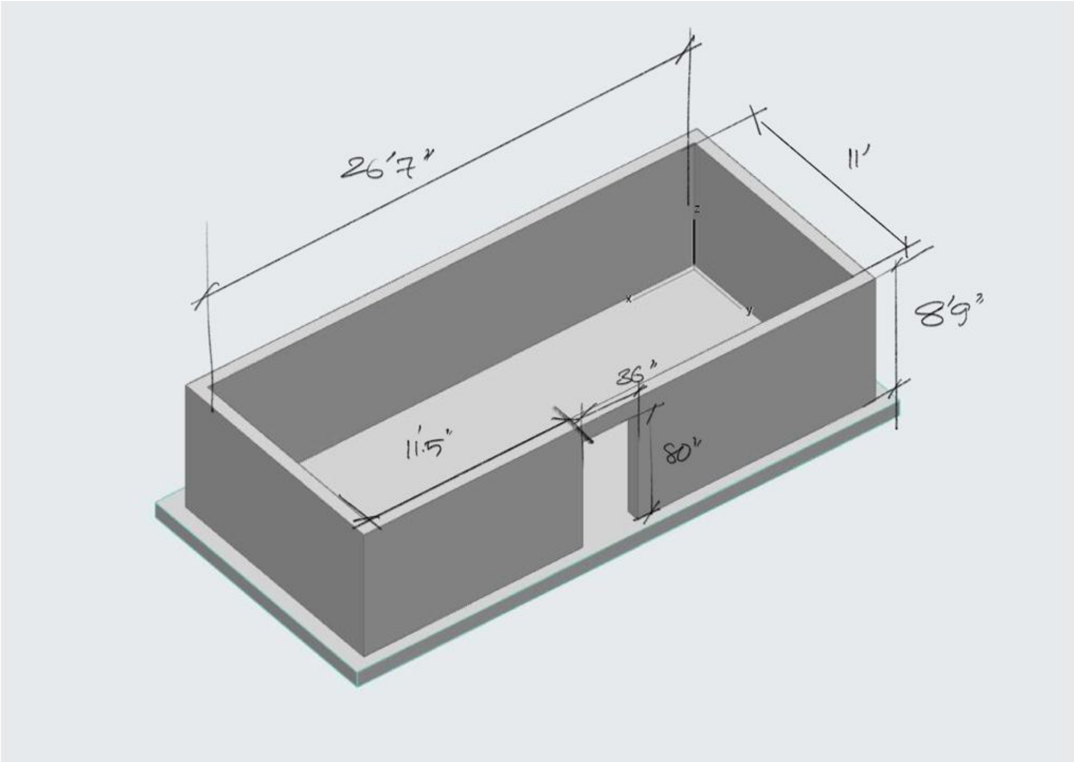
(Figure 33. 3 /4 time signature in Red and 4/4 time signature in Blue)

The same 60 seconds can be represented as two distinct cycles of 12, i.e. 4 x 3 /4 or 3 x 4/4s. The audience can further interact with such a visual cue by means of an input device like a piezo sensor or MIDI device.

This visualisation does inform the correlation between the two metres; but introducing the audience interactivity aspect into a cyclic piece I found was personally too gamified as an experience. I intend to impart the feeling of the anticipation of the one, rather than informing the audience what the one is. This method can also be simply represented on a screen and does not really require space to be experienced.

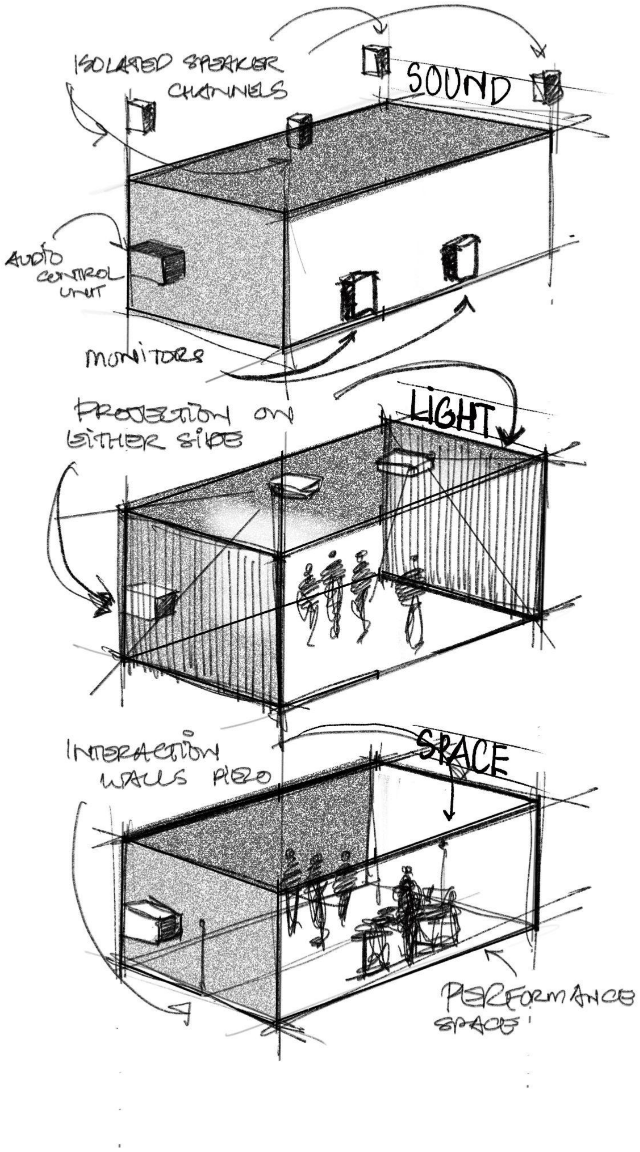
8.1 Site analysis: EMS space

The space I intend to use for the installation is the Experimental Media Space at 205 Richmond building, Toronto. Understanding the space and its properties and then building the install on the basis of what the site has to offer is what I am interested in. This involved measuring out the space, looking at projection possibilities within the space, understanding how the audience can view the performance and locating myself (performer) within the space. The space essentially is rectangular in shape with the following dimensions
with separately isolatable speaker channels and internal wood board finishes.



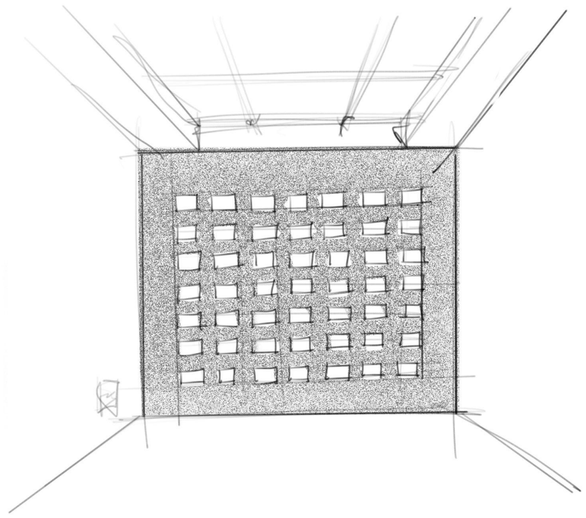
(Figure 34. Internal dimensions of EMS)

In the visual example shown above (Fig 38), the fact that the count uses numbers to inform the audience is what steered me away from the idea. Instead of representing this visually I decided to give separate audio cues on either channels, as I could isolate audio channels in the space. Therefore there would be no actual visual counting happening but rather the sensation of the particular time signature when a person stood close to the channel. Hence the piece essentially would have 3 /4 and 4/4 playing at the same time but at the two sides of the space. When standing close to any one of the sides, a person can also hear the other time signature playing less prominently than the one they are standing close to. Though the person experiences one time signature prominently the other time signature can be heard subliminally. Below is a rough conceptual sketch of the install.



(Figure 35. Isometric split view of install)

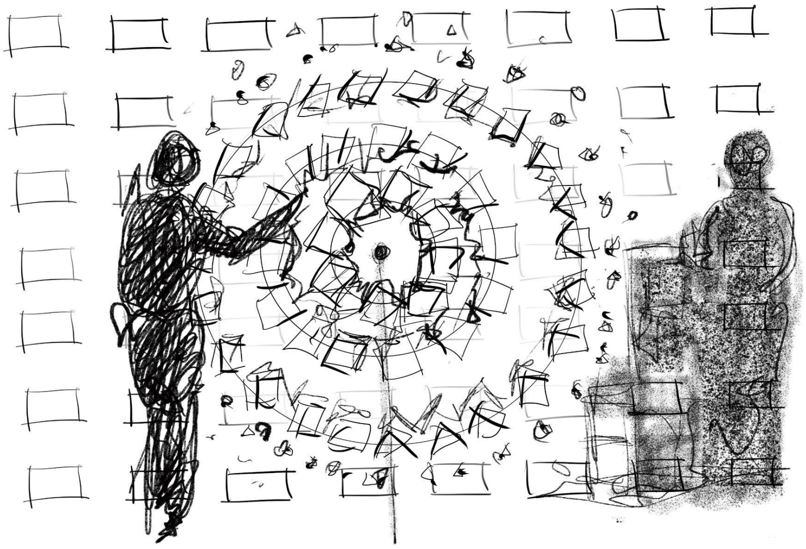
As the two sides of the space are being used to represent the particular time signatures, the walls closer to those sides would be used for projection. From the view of the wall for projection a simple square grid idea for the projection is developed as shown in the figure below.



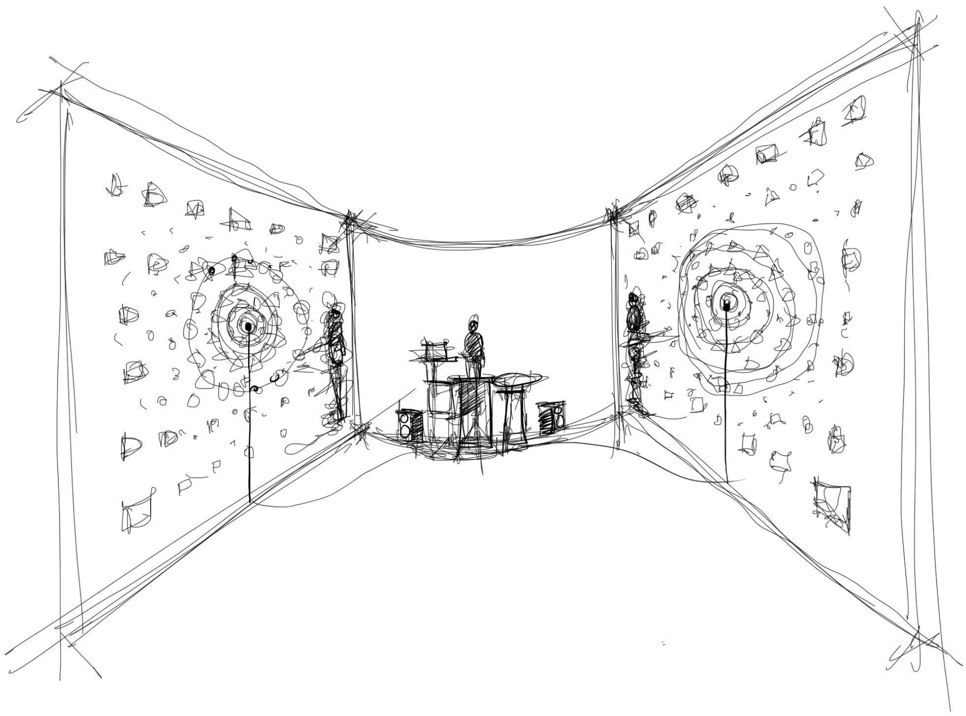
(Figure 36. Grid visualisation of square patterns from the wall)

The white squares shown in the grid would pulsate along with the time signature that the side represents. This would create an alternating lighting of the space in sync with the time signatures. Upon getting to the one of the cycle that is 12, the entire space brightens up as both the sides would pulsate simultaneously on 12 at that instance. This is the core idea of the install.

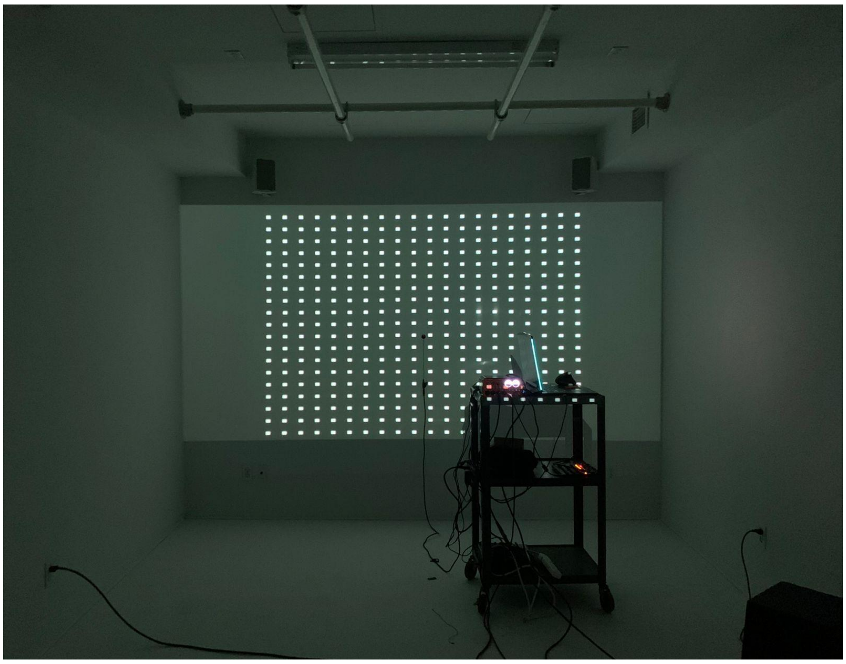
Further another layer of visual would be added by the audience while interacting with the wall. (See section 10.2). This would be a feedback ripple representation based on the square pulsing animation as created earlier. The liquid visualisation theme has stayed throughout the experiments I conducted and this is a personal choice.
The wall on two sides essentially is a combination or Composite (in Touchdesigner TOP) of the grid pulsing, my point cloud of the performance and the audience adding to the rhythm from the pulse and would look something like what is seen below.



(Figure 37. Wall conceptual sketch)



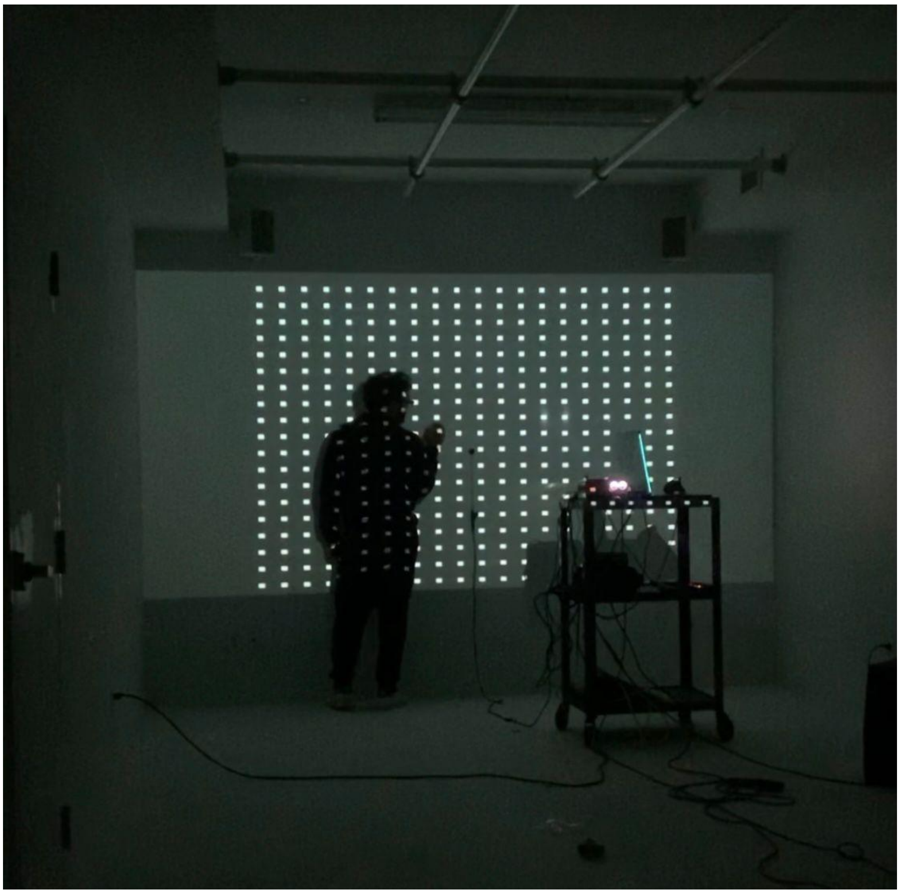
(Figure 38. Panoramic sketch of the space with visuals)



(Figure 39. Wall grid)

8.2 Audience interaction:

As the walls and the floors of the space are made with wooden panels, these could be used as points to detect vibration. Therefore I used piezo sensors attached to the wall to convert the separate time signature walls as playable instruments. The piezo sensor connected to the wall detects taps, and converts the vibration as a trigger to play a MIDI notes on Ableton. This allows the audience to join the performance along with me. The MIDI note is also used to create a ripple effect on the square grid shown above (Fig 39) to represent the beat played by the audience, besides pulsating with the time signature.



(Figure 40. Playable wall interaction)

(Figure 41. 4/4 right channel wall)

(Figure 42. 3/4 right channel wall)

8.3 Building the set on Ableton:

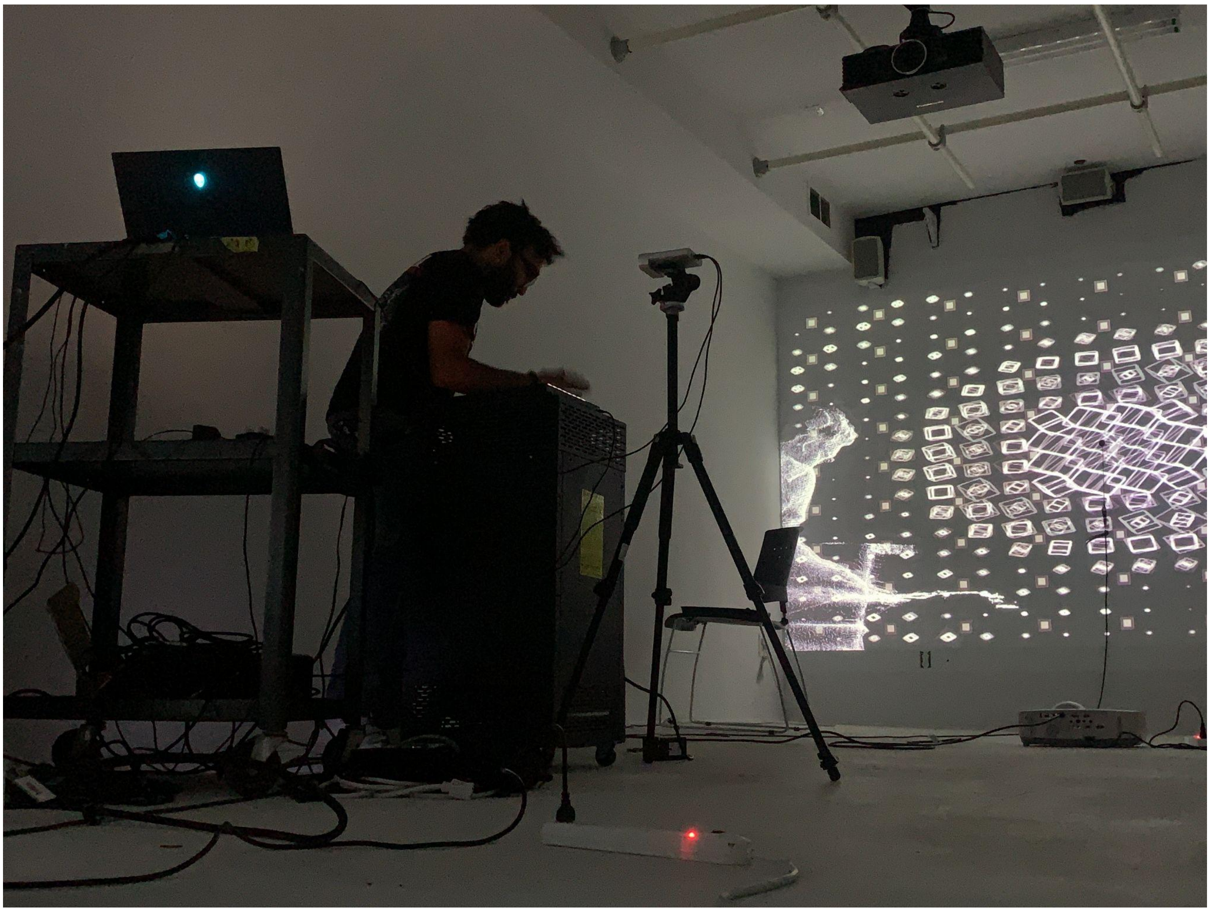
On Ableton, music is played live as a set of loops that are triggered and stopped. My personal idea of the set is to have all familiar sounds and associated effects instead of using any form of pre-produced sounds or samples. This would be giving more importance to the time signature with respect to the visualisation than visuals that represent the sounds heard. A collection of familiar sounds that directly give the idea of what the sound is instead of a synthesiser or MIDI keyboard etc. is hence preferred. A collection of field recorded samples of, a car door shutting, a glass clang, ice cubes falling in a glass, a ping pong ball bouncing, waves hitting the shore, exhaling sound, dice rolling etc are implemented to give the audience a clear idea of what the sound is rather than having to visually represent it with projection.

Along with the rhythm played using these sounds I am also looping patterns of the two time signatures on two separate channels as loops played on the rav vast from Experiment 7 to introduce melodic characters to the piece (Section 6.7). The rav is again rhythm based and provides more timbral quality to the holistic sound of the piece. As it is also played live it also becomes familiar to the audience present in the space during the performance. The two time signatures also exist as claps on two separate channels directed to the two sides of the space. Besides these elements few effects on the familiar sounds are implemented in order to distort and further give clarity to the idea of a polymeter.

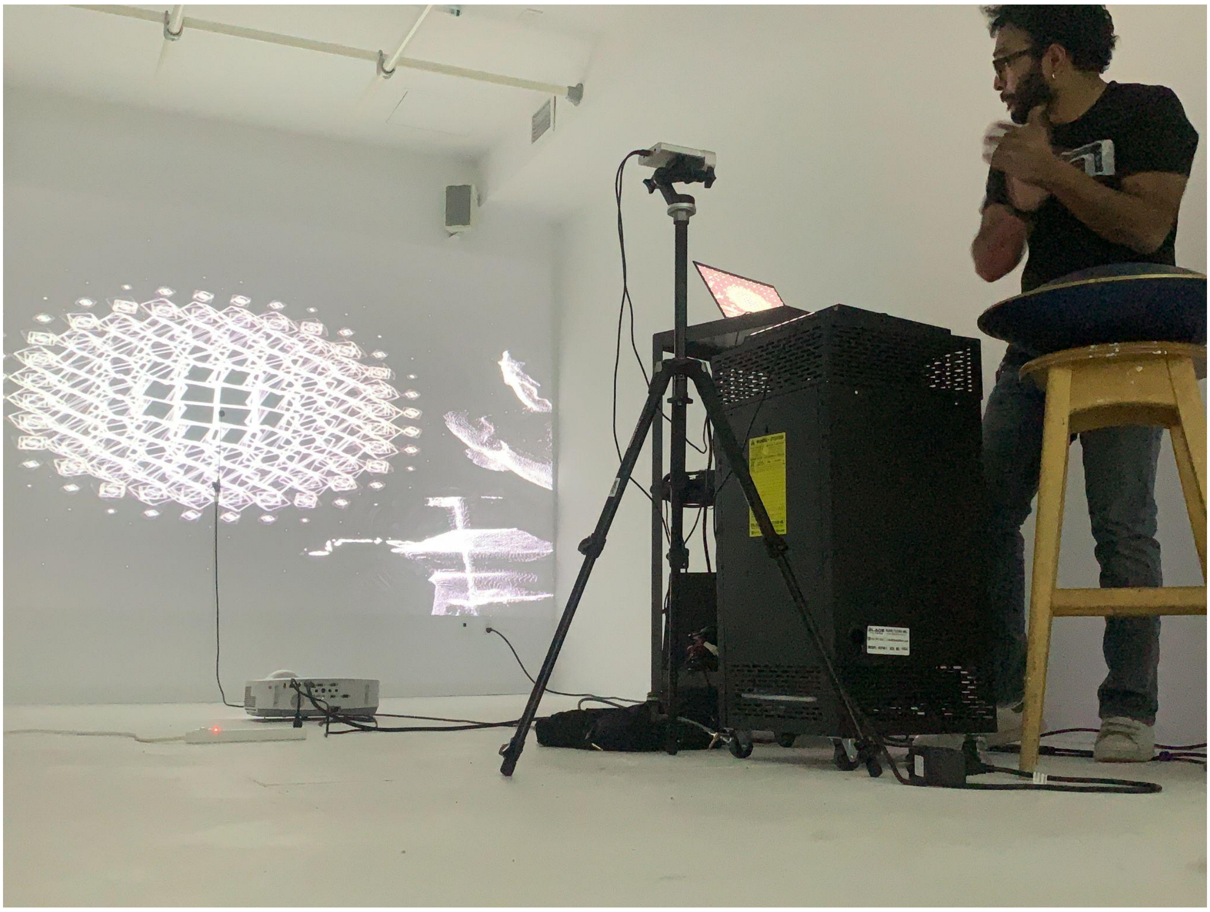
8.4 Two modes of the set.

Considering that there would not be an audience at all times to perform during the show, it is required to have a non-performing mode as well. Hence two pipelines would be faded from one to the other. One being the pulsating grid and the other being the point cloud pipeline developed Experiment 7 (Section 6.7). The piece would start with the pulsating grid informing the audience of the metres playing at the same time, and also encouraging them to tap on the walls to play to those metres. At a point during the performance the visual pipeline will be faded to the point cloud and the tapping would continue. Upon re introducing the clapping metres the audience would get a clear idea of how precise they were with the tapping. During the performance solo portions of the sound based rhythm and rav vast would be implemented after which the grid time signature visual would be re-introduced. Informing them of the anticipation of the one, and probably implying what is felt.

8.5 Final combined outcome of visuals:



(Figure 43. ¾ wall)



(Figure 44. 4/4 wall)

(Figure 45. Panoramic shots of both walls)

Playable video and audio files of the project can be accessed in the following link:

https://www.unnikrishnankalidas.com/12-dfthesis

8.6 Final install and Reflections:

The final installation took place at the EMS space from March 31 to April 3, 2023. All age groups of viewers attended. The space as anticipated transformed into a medium for rhythm exploration rather than a performance space. The audience turning their back towards me (the initial performer), broke the customary audience-facing-performer format, which is applied when such performance spaces are conceptualised. This aspect of agency given to the audience to choose their orientation in the space could be the key audience response I was looking for, which bridges the gap between the audience and performer by positional line of sight detachment, but attention given to the rhythmic interaction.

I feel audiences of different age groups responded differently. Adult audience took their time to try and play in sync with my performance, and seemed more interested in the interactivity aspect of the installation. Children on the other hand seemed to enjoy the sounds heard. Once they found the walls were playable they went on knocking it without any notion of rhythm, but more interested in the sounds heard while knocking the wall.

An interesting conversation I had with a visitor was the application of rhythm based training techniques in the medical industry, specifically for surgeries in order to practise a particular sequence of operation, in which the surgeon's hand movements had to follow a rhythmic pattern corresponding to position.

Two observations made during the install, that can be considered as drawbacks could be:

1. I had to instruct the visitors at times to approach the interactive wall and play along. There was no prompt as such as part of the physical install that informed them about this, and hence I had to direct them.
2. The cover image used on the Title page of this document is a panoramic shot of the variations in brightness of the installation space. The newer versions of mobile

camera applications edit this variation in brightness automatically to get a more consistently lit image, and hence would not work with all models of phones.

9. Conclusion and Future works:

This thesis project was born out of the theory that attention spans of listeners are reducing and adding visuals would better inform them about the musical piece as such. Over the course of the research I have been able to explore several ways of being able to visualise sound in both analogue and digital formats.

For this research through creation I was able to understand the nuances and levels of interaction that can be used as pipelines for creating visuals using sound as an input. I eventually focused on what matters most to me personally and that was rhythm, and used those pipelines to inform the audience about rhythm in the form of an interactive experience.

Based on the studies I have done as of yet here is a list of ideas for future works.

Interactive Visuals: The installation could feature interactive visuals that help illustrate the different polyrhythms in the musical piece. For example, the visuals could show different coloured shapes or lines that correspond to each rhythm. The visuals could also be interactive and responsive to the audience's movements, creating a dynamic and engaging experience.

Sound-Based Interactivity: The installation could use sound-based interactivity to allow the audience to control the predictability of the beats. For example, the installation could feature input piezo sensors or other percussion instruments that are connected to Ableton (DAW) that analyses the beats and polyrhythms being played. The program could then display the patterns and predictability of the rhythms in real-time on a screen or through interactive visuals.

Participatory Experience: Another way to create an interactive installation to display polyrhythms and the predictability of beats is to make the audience part of the performance. The installation could provide the audience with beat input points or other musical tools that allow them to join in and play along with the rhythm. This way, the audience can experience first-hand how the polyrhythms repeat predictably and how their contributions add to the performance.

Collaborative Performance: The installation could be designed to facilitate a collaborative performance between the audience and the performer. For example, the installation could feature a series of musical cues or rhythms that are displayed on a screen. The performers and the audience could then work together to create a polyrhythmic performance that demonstrates the predictability of beats.

Music visualisation does not essentially have to be didactic, if it imparts the feeling. The project imparts the idea of predictability or anticipation based on the interactive experience from the audience but does not essentially have to teach anything about the structure of music, but hopefully helps the audience understand better through experience. The project is further envisioned to be shot in 360 and uploaded as a 360 viewable video.

Final Thoughts: Although the thesis document has come to an end it has given me insight as to how I could look at Live AV performances from a different perspective, where the audience becomes a part of the experience, and joins me in performing. The idea of being able to control visuals live along with the audio opens new doors of possibilities for me personally. I intend to probably convert this experience in VR or use AI to generate visuals for the future which can then be synced to the rhythm.

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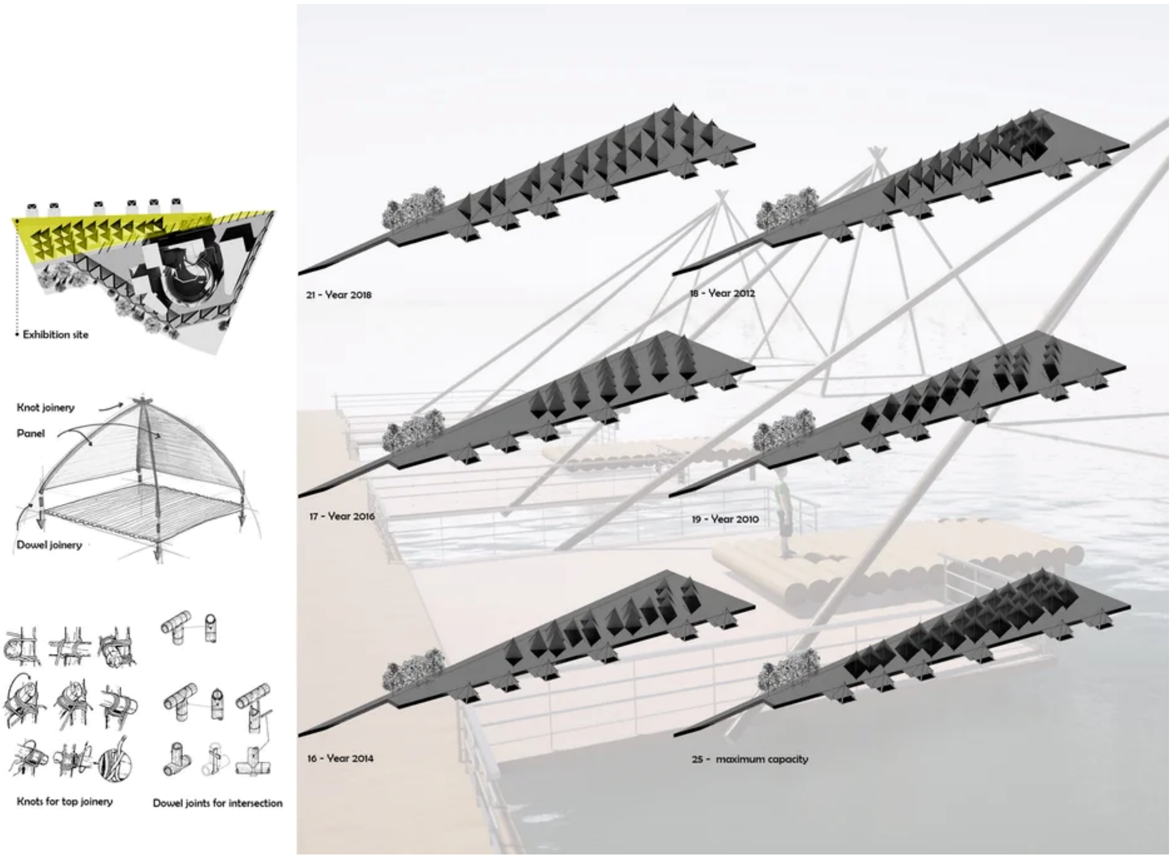
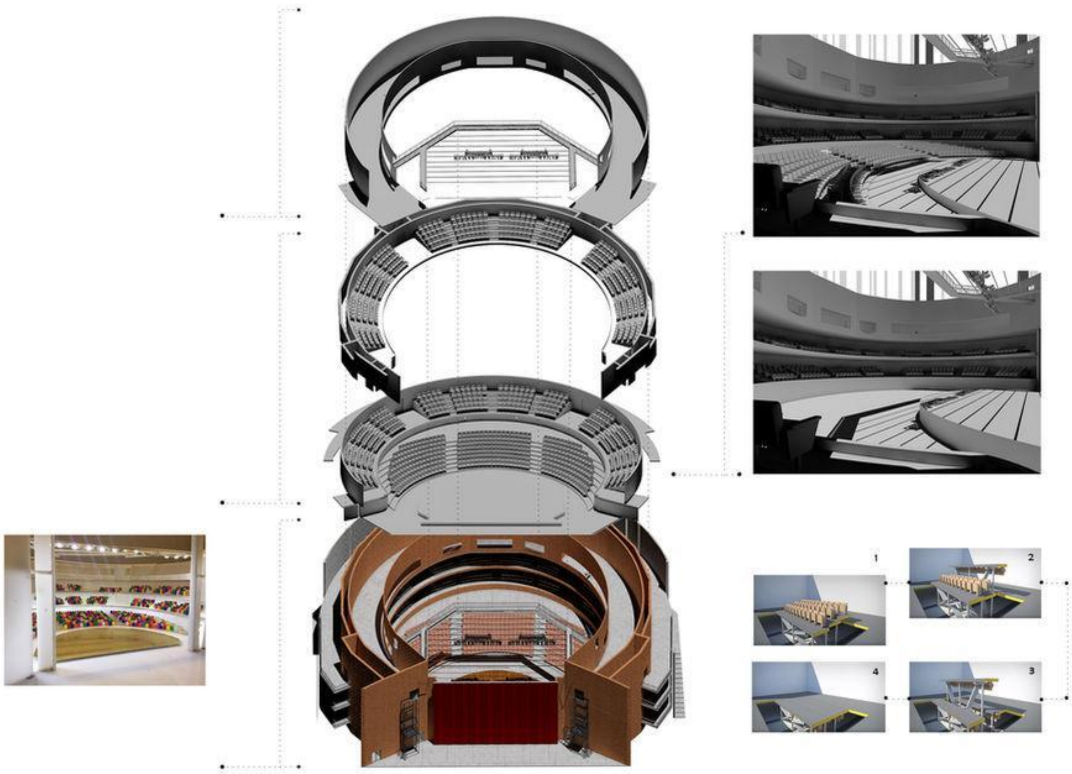
12. Appendix A: Production and Performance complex in Fort Kochi, India (Personal work #)

My undergraduate Thesis titled Production and Performance complex if first considered, as this thesis is an extension of the same. Fort Kochi, in Kerala, India is the venue for the Kochi Muziris Biennale. The site chosen is near Jawahar Park,which abuts ancient chinese fishing nets. These fishing nets were made initially using bamboo frames, and have later been upgraded to MS steel pipes. The structure in itself is reused as framing for temporary exhibition spaces for the Kochi Biennale. The event is programmed in a way that the artisans who build these structures are brought in to interact with the artists who exhibit in the space. The activity of construction is witnessed by the audience prior to experiencing the exhibition event itself.



(Figure 46. Undergraduate thesis diagram)

The idea of the project was to create a space for cultural exchange not just by visitors experiencing the art forms but getting to know the production process behind the same. Though the space is designed to accommodate temporary exhibition spaces every two years, the design also includes a capacity changing performance space with a collapsible floor for varying formats of dance, drama and musical performance.



(Figure 47 Undergraduate Thesis multi-purpose seating format)

The circular performance area is inspired by Shakespeare's Globe theatre, with seating in tiers. Flexibility is taken as key in its design. By including the production tier we are further staying rooted to the concept of public inclusion, as this would exhibit not only the performance in the theatre, but also the functions that go into its production.

Shakespeare's Globe Theatre was taken as the primary case study for this project due to the seating arrangement that the Globe theatre implemented. The performance area (mainly for theatre) was square shaped with no proscenium, but rather a podium that extended into the yard area where people usually stood to watch performances. The theatre has seating on various levels around the stage area, which essentially gives varying visual view points different for each spectator. Though this area programming was implemented based on social sects, the views that individual spectators got were different. People standing in the yard area do not get to see much of the spatial arrangement of characters/ elements on the stage floor, or any of the background setting up that happened between scenes, whilst spectators seated at the various other levels got a more aerial view of the setting created for the play along with some of the production work that went on behind due to positioning within the space.

(Figure 48. Globe theatre seating case study)

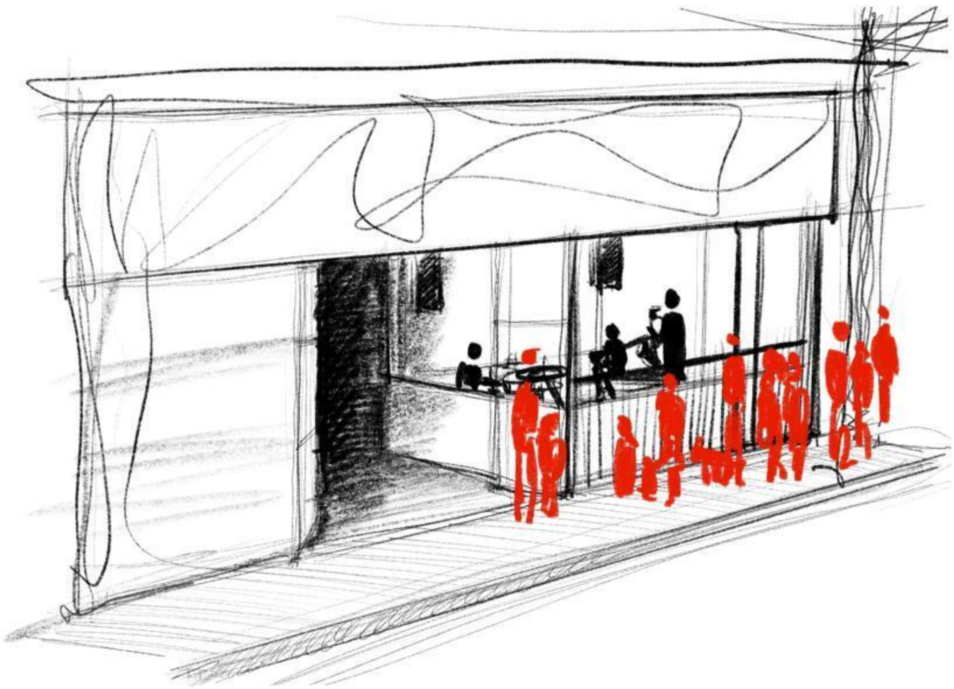
In order to bring the audience closer to the performance in the sense they get to see what went behind the performance, the collapsible seating format was implemented for the final thesis project.

Conclusions from my undergrad thesis:

Immersion of an experience can be improved if the gap between the audience and the performance space is blurred. Therefore, positioning or viewing a performance that can be experienced from various literal angles or digital viewing time stamps even, could essentially enhance the experience. Spatially giving the agency to the audience to be present at a location to know something specific about the performance is what is learnt with this experiment.

13. Appendix B: Anecdotal account of pop up Jazz performance in Kensington Market Jazz festival (Video footage) :

A store in Kensington market was hosting a three-piece Jazz band. One sax player, one drummer and one bassist. The space they are performing in is a storefront that faces the street, so essentially people walking by the street would get to see the musicians playing music and there is no fixed audience. One gets to listen to the performance for as long as they intend to wait in front of the store. A rough sketch of the store is shown here:



(Figure 49. Kensington market performance study)

The market on such days is usually flooded with people and the performance is one of the spots that draws a lot of attention during the walk down the street. Hence the crowd that the musicians are playing to is very dynamic as they are constantly changing and moving. The audience has the agency to stay or move ahead. This creates a momentary exchange of musical experience that is very specific to two aspects. One being the position of the viewer and another the musical experience of that performed moment.

This dynamic/ever-changing audience format is very interesting to me too as the band essentially would also filter the audience who like their music by being a part of the performance. There is a subliminal give and take which happens at a live performance.

Another interesting aspect which I noticed was how my position when varied gave me different sonic experiences as I moved around the space of performance. As you can see from the sketch, if one stands inside the store facing the band (to the right), more of the drum sound, and the additional volume that the space adds to the music is heard.

As I walked in front of the store where the audio mix can be heard from the main speakers, the levels equalise and the mixed optimum version of the music can be heard.

As I walk ahead and come to the other side of the performance, I notice the storefront on that side (behind the bass guitarist) is fully covered with glass, and interestingly from this side the dominant instrument is the bass, as most of the low end frequencies of the bass guitar is being able to pass through the glass and be audible. Differing positions around the musical performance space gave me different auditory experiences based on individual artists/instruments.The dynamic nature of the audience flowing in, gave the musicians a better idea of who is interested in their music.

Conclusions from Exploration 5.2:

Like the finding from the undergrad thesis, literal physical positioning of the audience within a performance space, alters the kind of experience the audience has. Based on their position within the space each person gets a varied experience predominantly by sight lines and also sonically. An interesting take specifically from this experiment would be isolation of audio channels based on position. This technique may or may not be applied for the final thesis project.

14. Appendix C: Video analysis of Snarky Puppy - (*What About Me*)

Why this piece?

Besides being a favourite musical piece, the arrangement of space for shooting this video is what makes it a choice for analysis. The audience are seated amongst the instrumentalists, deviant from the traditional musicians on stage/pedestal-audience facing format.

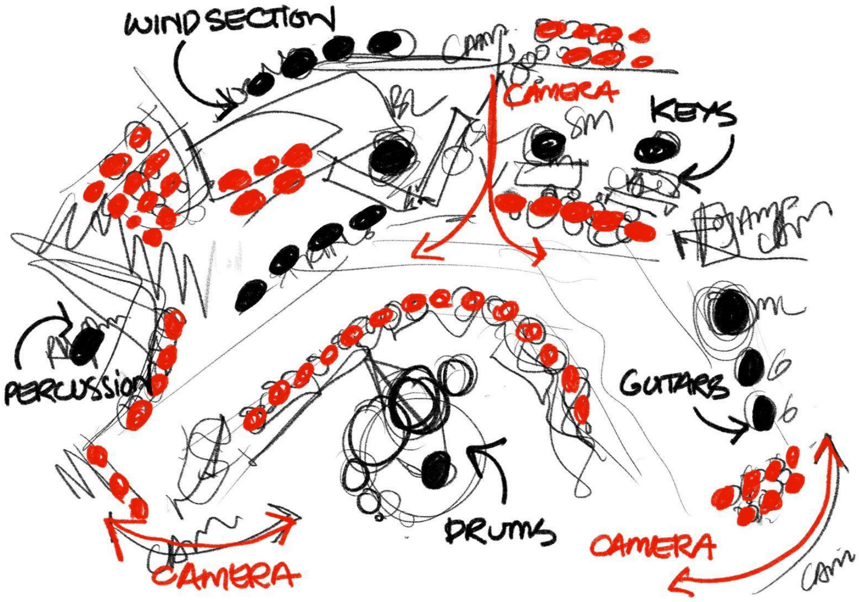
What is being analysed in the video?

Though everyone has headphones on and get to hear the final mix down of the overall track, the audience gets to choose which artist gets their visual attention. In a traditional musical event setting this would not be possible due to the special separation of both artist and audience. Meanwhile the performers have their own personal monitoring mix . This is a mix of the elements each artist would like to hear of the other artists present in order to perform optimally.

How is the analysis being done?

The song is of the neo jazz/funk genre of 6:56 seconds of duration. Analysis would be done based on parts of the song that can be aurally distinguishable (usually 8/16 Bars, 1 bar for this song would be around 7 seconds). The audience reaction is what is being looked into at specific parts of each section. After which an overall check of the visual/aural content at 'Most played' tab on the Youtube play bar. These are essentially sections of the video that digital viewers on a platform like Youtube prefer to watch most frequently. By the end of the analysis of the video an attempt will be made to visually create a map of how artists and users are seated/located within the space. (See Appendix A: “What About Me” Time stamps).

The spatial arrangement for the video from visually positioning could be as follows:



(Figure 50. Spatial analysis of seating from video)

The audience are essentially seated in a way that they see other audiences across them, but are also interspersed with the musicians amongst them. This sort of arrangement proves for better audience engagement/ response to the performance which could also be beneficial for the artist as live reaction is received on their end. Both the artist and audience areas are not rigid and do not represent as a block with no individuality of sorts.

Outside of the artist and audience zone an area has also been allotted to the production crew for lighting and camera work between the artists and views. This footage essentially shows the response of the audience in the background along with the artist performing in the foreground. As the audience of the video as such are tertiary viewers, as we get to see both the artist and their viewers live on set. They may or may not have got to see every artist at a given instance. There is a momentary nature to the responses and reactions received in a live setting like this compared to the visual stimulus experienced from the source right in front of the viewer. The arrangement not only adds dynamism to responses but also momentary experiences for both the artist and the viewer.

The momentary nature of the performance is different compared to the simulated versions of a song heard of a recorded version of it. The song might essentially sound the same, but as its close to impossible for the piece to be exactly repeated again bands like Snarky Puppy create spaces in these pieces for extensive improvisation, and hence every time the same song is played at different venues though holistically the song sounds the same, the solo, bridge or string section change creating more space for an organic creation specific to that moment of performance, which only the live audience would be a real part of.

Initially as part of two separate elective courses (Experiences and interfaces and Thinking Through Making), I experimented with two approaches that visualise music purely based on amplitude in order to understand how sound can be mapped to visuals both Visually and Spatially. Both the experiments though based on Music visualisation essentially, were entirely different approaches on their own.

“What about me” Time stamps:

0:08 A viewer takes off the headphones to hear what’s happening in the space of the music. This could be varying based on the position of a person within the space.
0:12 There is a viewer turning around to look at the drummer while his view as per seating in front of him would be the strings section
0:47 seconds the bridge section has a new baseline accompanied with horns, and Micheal League the bassist turns left towards? To smile and signal the change, the audience notices this interaction and responds with a smile.
(Spatially trying to visualise the space it seems like the drums are behind the audience, the audience faces the strings and horns. This is the format along the middle section, but the periphery could vary based on further viewing)

1:13 Production unit can be seen behind the audience

1:25 Viewer turns right to look at the wind section.

1:56 Viewer looks back at Larnel Lewis after section change

2:04 Audience removes headphones for positional mix

2:16 There are people seated between Micheal League and Larnel lewis (People sitting around Larnel as well)

2:32 View turns around and faces Larnels solo portion

2:36 Sean Martin (Keys) is in front of Micheal League, towards the right side of Larnel with audience in between in 2-3 rows

2:44 Cory Henry, Bill Laurance and Sean Martin are beside each other on the same side with few audiences between them.

3:08 Guitar solo section, Audience is seen behind the guitarists.

3:21 Audience seen giving up on headphones!

3:29 Audience turns and faces Larnel

3:59 Rhythm section is across Bill Laurence separated by the audience facing the strings and Key section.

4:18 Keys, Bass, and Guitars are beside each other. Audience separated them and Larnel and Rhythm section.

4:25 Free walls have audience seated in 3 rows

4:48 Upper change over, audience in the similar seating zone looking at different sections, as multiple artists play improvised parts

5:19 Viewer turns around to look at Larnel for the drum section, along with visual cues from Michael League bass from across the audience.

5:24 Cory Henry interaction with Sean Martin

5:32 People are seated behind Larnel lewis too

5:42 Drum solo ends most viewers turn back to Larnel.

5:52 Micheal League given signal to Keys section for a fall back

5:59 Audience smiles on fall back behind Keys section

6:04 More panned audience smiles along with booths behind seated audience.

6:24 Claps and Whistles!

15. Appendix D : Touchdesigner terms:

Understanding the operators within TD to use as input information for live performance is essential. An operator on Touchdesigner are the nodes of the system that outputs data for other operators. Regarding the input of audio information on Touchdesigner, the following four operators are being explored for investigation. Each operator has a set of parameters that can be adjusted to produce the desired result.

Input Operators:

-Audio analysis palette extension

-Audio spectrum CHOP

-Audio file/device in

-TDableton

Audio analysis palette extension:

This palette extension analyses the features of an input audio waveform. It requires an input audio signal in the form of a CHOP, which could either be Audio file/ Audio device in. It analyses the audio and outputs the following sets of data which can further be used as input signal for processing.

- Low - Low frequencies

- Mid - Mid frequencies
- High - High frequencies
- Spectral Centroid - Measure of the amplitude in the centre of the spectrum
- Kick detection - For detecting kick drum signals
- Snare detection - Detecting snare drum signals
- Rhythm - measures overall bpm and rhythm of a signal.

A threshold, smooth and gain can be added to each of these parameters to obtain desired results from the audio signal.

Audio Spectrum

The Audio Spectrum CHOP computes and shows the input channels' frequency spectrum. In the default Visualization Mode, the CHOP emphasises the higher frequency levels and lower frequency ranges to make the spectrum more comprehensible.

In the Time to Magnitude and Phase mode, audio can be converted to the frequency spectrum domain, modified, and then converted back to a filtered audio stream. When converting a signal to its spectrum, the channel carrying the audio signal is split into two channels. One channel stores the amplitude of the frequency components, while the other stores the phase. Both these channels can be used later as analysed audio input.

Audio file in/Audio device in

The Audio File In CHOP component reads audio from disc files or http:// addresses. The Audio Device In CHOP receives audio via DirectSound/CoreAudio or ASIO from any of the linked audio input devices. It always outputs audio data that is time-sliced.

TDAbleton component

TDAbleton is a solution for integrating TouchDesigner with Ableton Live. It provides access to nearly every aspect of an Ableton set, both for viewing and setting. The TDAbleton system includes a number of components for two-way communication, as well as a framework for the development of custom components and additional functionality.

TDAbleton functions via the MIDI Remote Scripts system and, when required, Max for Live (M4L) devices. OSC is used for communication with TouchDesigner (using UDP).