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Master's Programme in Sound in New Media

Lost Dimensions

The Rise and Fall of Quadraphonic Surround

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Abstract

The topic of this thesis is the quadraphonic audio surround standard, its history, influence and future.

The first part of the thesis is an overview of the history of quadraphonic audio, the events that led to the conception and later demise of quadraphonic audio as a surround sound standard, and the promises and challenges of the technology as perceived by various experts and contemporaries. More recent developments are also reviewed.

The second part showcases the author's research and experimental projects using quadraphonic audio systems. The emphasis of the author's work has been on the creative and musical application of quadraphonic surround systems and inventing novel techniques for their practical application by utilizing modern digital audio processing and programming.

A focal point of this thesis and the author's interest in quadraphonic audio is the symmetry of the standard quadraphonic system, fundamentally differentiating it from modern cinema-derived surround sound standards. As quadraphonic audio was deemed a commercial failure by the late 70s, it was quickly abandoned and largely forgotten, but perhaps some unique possibilities were lost in the process.

Keywords Quadraphonic, Surround Sound, Spatial Sound, Pure Data.

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Tiivistelmä

Tämän opinnäytetyön aiheena on kvadrofoninen surround-standardi, sen historia, vaikutus ja tulevaisuus.

Opinnäytetyön ensimmäinen osa on katsaus kvadrofonisen äänen historiaan ja tapahtumiin, jotka johtivat kvadrafonisen äänen syntymiseen ja myöhempään hylkäämiseen surround-äänistandardina, sekä kyseisen tekniikan mahdollisuuksiin ja haasteisiin eri asiantuntijoiden ja aikalaisten näkökulmista. Myös viimeaikaisempaa kehitystä tarkastellaan.

Toisessa opinnäytetyön osassa esitellään kirjoittajan kvadrofonisiin äänijärjestelmiin liittyvää tutkimusta ja siihen liittyviä kokeellisia projekteja. Kirjoittajan työn painopiste on ollut kvadrafonisten surround-järjestelmien luovassa ja musikaalisessa soveltamisessa, sekä uusien kvadrofoniseen järjestelmään yhteensopivien modernia digitaalista äänenkäsittelyä ja ohjelmointia hyödyntävien tekniikoiden keksimisessä.

Tässä opinnäytetyössä ja kirjoittajan kiinnostuksessa kvadrofoniseen ääneen tärkeä kiintopiste on perinteisen kvadrofonisen järjestelmän symmetria, joka erottaa sen perustavanlaatuisella tavalla nykyaikaisista elokuvaäänijärjestelmiin perustuvista surround standardeista. Kun kvadrofoninen surround-standardi todettiin kaupalliseksi epäonnistumiseksi 70-luvun lopulla, se hylättiin nopeasti ja unohdettiin suurelta osin, mutta ehkä joitain ainutlaatuisia mahdollisuuksia menetettiin samalla.

Avainsanat Kvadrofonia, Surround-Ääni, Tilaääni, Pure Data.

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LOST DIMENSIONS

The Rise and Fall of Quadraphonic Surround

1 Introduction

The topic of this master's thesis is the quadraphonic surround standard, its turbulent history and possible future uses. The way this topic is examined is through a historical literary review and a subsequent journaling of a body of research and development work by the author that concludes in a master thesis project and a master thesis exhibit.

The first section of the second chapter examines the turbulent history of the quadraphonic surround sound standard, how it was invented, how it was perceived during its early rise in popularity and what ultimately caused it to fail as a commercial product, leading it to be all but forgotten. In the second section of the first chapter, further developments and current trends are looked at. The perspectives brought forward by this background research were instrumental in informing design decisions during the author's own research and development work.

The third chapter journals the author's journey with quadraphonic sound, from first coming into contact with the idea, to the research and development of software and hardware tools for working with quadraphonic sound, finally leading to the creation of the *LOST DIMENSIONS* sound installation and master thesis exhibit.

The main motivation in researching this topic was finding and creating ways to use quadraphonic surround systems in interesting musical ways, as the system was originally intended for reproduction of music. This contrasts strongly with modern surround sound standards that have been popularized through cinema. One could argue that modern surround standards, like 5.1 and 7.1, while containing within them an idea of a directionality, also contain the idea of a visual medium to be focused on and subsequently an idea of a hierarchy between sound and image.

On the other hand, the topic of this thesis continues a clear thread in the author's artistic work; researching and inventing new ways of musical expression, for the contexts of both sound art installation and live music performance equally. Additionally, in the author's previous body of work in music production, both as a musician and an engineer, an interest in using technology in inventive new ways to create productions and performances that exceed the expectations of the audience was a continuous driving force.

Even as surround sound technology continues advancing towards more complex systems, musicians are still producing music mainly for stereophonic two-speaker systems. From very early on in the planning of this thesis, it was decided that a distinctly less engineering and science focused approach would be assumed. This approach would be more intent on mapping interesting and usable artistic and musical terrain within the possibilities of the quadraphonic surround system, disregarding such parameters as accuracy or realism of the system as somewhat irrelevant for these purposes.

Conceptually the author's artistic work revolves around three specific themes. Firstly the theme of the allure of evolving technology, and how it represents something simultaneously intoxicatingly beautiful and ominously manipulative. The second theme is the theme of lost technologies and the constantly shifting perception of the future of technology and humanity in relation to it. The third important theme is the continuous and progressive distortion of human memory and experience under the influence of evolving digital technology. The expressive minimalism and dissonant appreciation of technology present in the work of artists such as Ryoji Ikeda and Mika Vainio has been a continuous source of inspiration for the author, both from a thematic and a musical perspective.

As the topics of this thesis are a continuing and constant focal point in the author's work and research, this thesis should be read more as a progress report, rather than a culmination of any thread of research.

2 Quadraphonic Surround Then and Now

2.1 Quadraphonic Sound - A Short History

The lifespan of quadraphonic surround as a commercial product was remarkably short. While initially considered a groundbreaking technology by many, ultimately, very few had the opportunity to create or even experience material produced for this format. This chapter will investigate different accounts on quadraphonic audio from before, during and after its heyday, bringing together a comprehensive view on the perceived promises and issues of this technology, and what led to it being forsaken.

It might be impossible to definitively say who first invented the idea of quadraphonic surround, but some researchers may have envisioned multichannel audio recording and reproduction from as early as the 1930s. For example, in 1931 Alan Blumlein filed a patent for a four channel sound reproduction technique in "remarkable anticipation of modern 'matrix' four-speaker systems" (Gerzon, 1974), some 20 years before the introduction of commercial two-channel stereo sound. According to one account, quadraphonic surround was first conceived in New York in 1968, during some dinner small-talk between the record producer Thomas Mowrey and Robert Berkovitz, an executive for a stereo equipment manufacturer Acoustic Research. (Günther, 2015, p. 170).

While perhaps not the first time the idea was considered, this talk between Mowrey and Berkovitz started a series of events that led to a rise of interest in quadraphonic surround audio. A year after their talk, in 1969, Acoustic Research Inc. demonstrated this technology in the form of listening rooms in New York's Grand Central Terminal and Harvard Square, in Cambridge, Massachusetts (Berkovitz, 1969). The demonstrations also included FM radio broadcasts in the Boston area, two sets of simultaneous stereo broadcasts for the possibility for four channel listening (Berkovitz, 1969). Interestingly, in his report, Berkovitz seems to allude to the possibilities of quadraphonic audio as a more realistic and possibly interesting way to replicate and create sonic spaces and experiences, possibly contrasting it to the more idealized sonic space created by stereo mixing techniques.

> There will be no attempt to duplicate the sound field at some hypothetical best seat; the aim will be rather to exploit the sonic potentialities of the new medium creatively. (Berkovitz, 1969)

At the time, according to Whyte (1970), there was excitement about the new technology, and many saw a direct parallel between the invention of stereo and the invention of quadraphonic. However, Whyte also notes that it had only been a little over a decade since the general public had been introduced to two-channel stereo sound, following the previous one-channel mono standard. Moreover, from the very start, some seemed to question both the benefits of the technology and the motivations of the industry.

> After spending twelve years convincing the record-buying public that two ears are better than one, high-fidelity manufacturers have now embarked on a drive to prove that four ears are twice as good--atleast. (Time, 1969)

Nevertheless, quadraphonic sound started gaining popularity and was generally considered an important future format. So evident seemed the ultimate triumph of quadraphonic audio that most large recording sessions of classical music were reportedly operated "with half an eye directed toward a quadriphonic future" (Darrell, 1970).

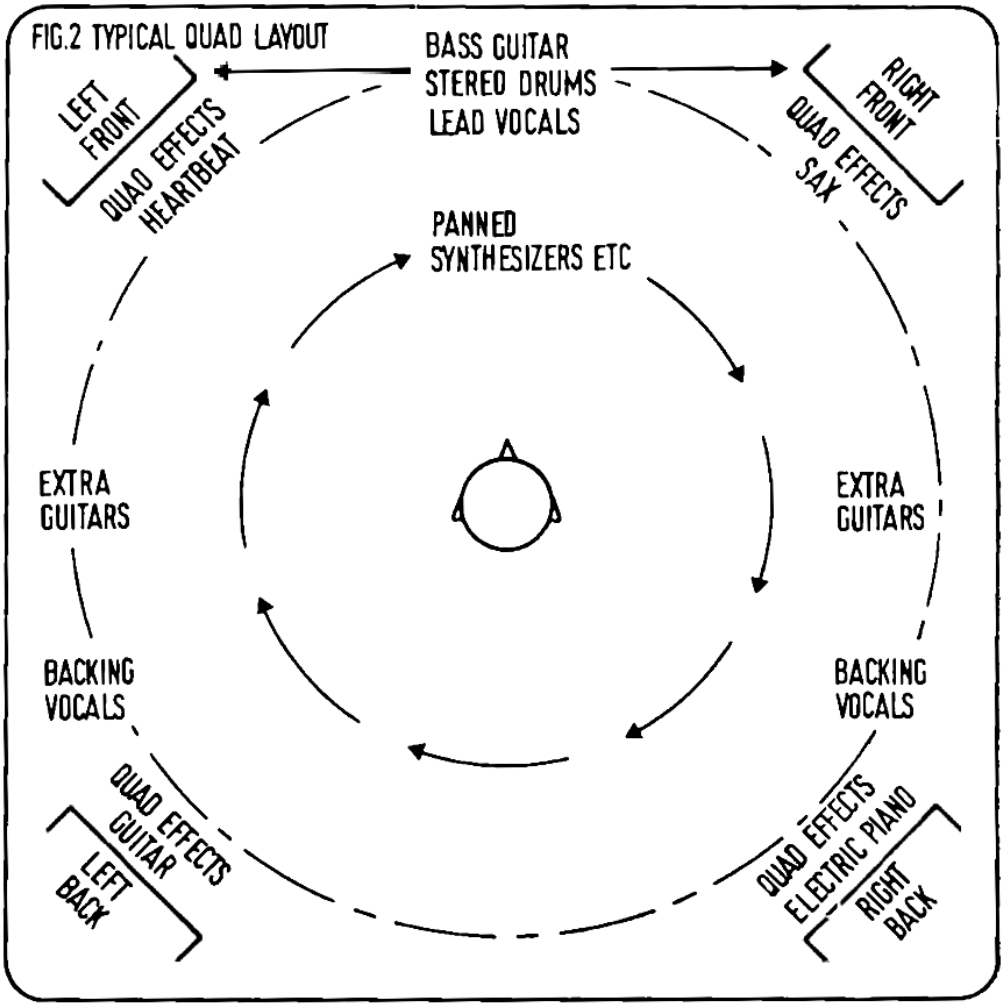
As early on there was a lack of material that had been produced for quadraphonic surround, there were many attempts at creating quadraphonic surround sound from stereo recordings. While at the time some claimed that it was indeed possible to get a "genuine surround stereo effect" from stereo recordings (Gerzon, 1970), others found these techniques lacking at best, and at worst, a part of a culture of dishonest marketing.

> One of the problems was that most of the recordings released in albums marked "Quadraphonic" were actually only stereo. They relied on one of a handful of "Matrix Quad" bootstraps to turn the actual stereo two track recordings into four separate signals for your quad amps and speakers. In truth, they were out to get something for nothing. Pure corporate greed and larceny, nothing new here. (Carlos, 2001)

During the early 1970's quadraphonic audio was also experimented with in popular music production. One of the best known albums produced into a true quadraphonic format during that time was Dark Side of the Moon by Pink Floyd, engineered by Alan Parsons. Some have even suggested that the quadraphonic version was considered the main release during production.
Although Dark Side of the Moon was monitored in studios equipped for stereo reproduction, many sections were recorded with regard to the eventual quadraphonic reduction, even though this took more track space than would have been necessary for stereo. (Parsons, 1975, p. 50)

The quadraphonic mix of Dark Side of the Moon was released in several different quadraphonic formats, some better than others (quadraphonicquad, 2015). While today this original quadraphonic mix can be difficult to find, some praise it as an exceptional achievement of audio engineering by Parsons.

> Those that have heard it will attest to the fact that it is quite remarkable, and surely a masterpiece when we consider the equipment available to him during 1973. (quadraphonicquad, 2015)



[Figure 2.1A Quadraphonic panning in *Dark Side of the Moon* (Parsons, 1975, p. 50)]

It has been argued that the rapid decline of interest in quadraphonic sound was caused by a combination of several factors. The content production for quadraphonic systems was slow at first, leading to sluggish demand, there was general confusion about the possibilities and requirements of quadraphonics and ultimately the various competing proprietary formats brought in by different record labels caused the standard to be difficult and expensive to work with (Postrel, 1990, p. 183).

> In the face of customer ambivalence, and hence difficulty in developing a simple and convincing rationale for quad, audio retailers by and large made only weak efforts to sell the new medium, and were quick to abandon it when it was not instantly successful. (Postrel, 1990, p. 183)

From a more technical perspective, one challenge the quadraphonic format faced was the lack of previous research. While stereo sound had already been studied and experimented with for 25 years when it was first introduced commercially in

the 1950s, almost no research had been conducted on quadraphonic surround when it was released commercially (Gerzon, 1974). This seems to have led to general disillusion when the technology did not meet the expectations of professionals, and ultimately even those who were previously optimistic about the future of quadraphonic surround had to admit its shortcomings.

> Not surprisingly, hastily introduced commercial systems have proved to be sub-optimal. (Gerzon, 1974)

While praised as a revolutionary technology by some, quadraphonic surround was ultimately deemed commercially unviable, and by the end of the 1970s, almost no more quadraphonic records were produced. The combination of lacking fundamental research, overzealous marketing and a format war between major recording labels had caused the quadraphonic surround standard to quickly lose general appeal. This could have been the end of quadraphonic sound, but for one reason or another, the quadraphonic surround format continues to fascinate people even to this day.

2.2 Resurgence of Quadraphonics

The quadraphonic surround standard reached its short-lived peak in the early 1970s. During that time, the technology, which had initially been seen as revolutionary, proved to be a commercial flop. This caused this new technology to be promptly abandoned and almost entirely forgotten. Although some might consider quadraphonics dead and buried, it seems that the interest in this particular format of spatial audio has survived. In this section of the thesis, some newer examples of the use of quadraphonic surround sound and thoughts of contemporary artists working in this field are examined.

> The technology for quadraphonic has been around since the 60's but sometimes, like in this case, it takes looking back to be able to look forward. Sometimes, we forget to look back at these things. I think on an emotional or even cultural standpoint, this is where quadraphonic seems to resonate, it just feels more natural. (KamranV 2018)

With the widespread adoption of newer multichannel audio systems in home theater setups since the 1990s, some record labels have started re-releasing old quadraphonic recordings. However, these releases are often remixed to be compatible with newer and more widely available 5.1 and 7.1 systems. For instance, Pink Floyd's famous quadraphonic mix of "Dark Side Of The Moon" has been re-released in the 5.1 standard (Discogs 2023).

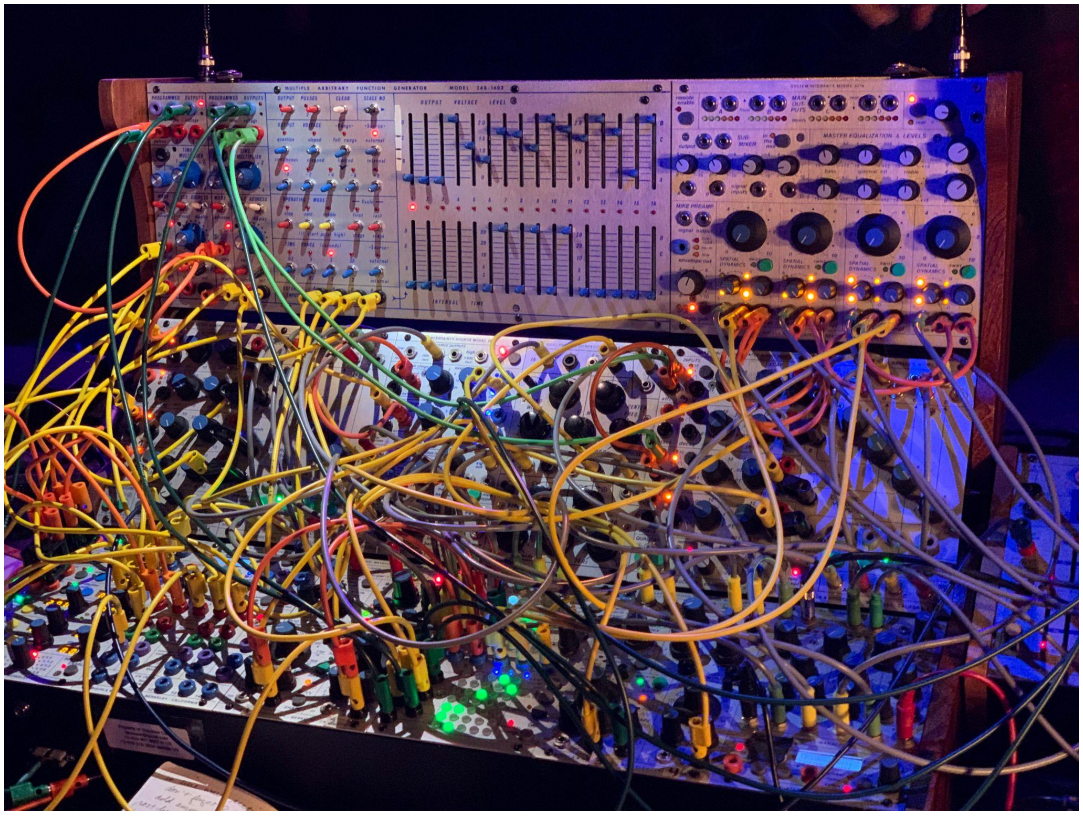
Another interesting trend indicating the renewed interest in quadraphonics is the reissue of many quadraphonic recordings from the 1970s for the first time. This trend highlights the rapid decline in the popularity of quadraphonics, as a significant amount of material was recorded but never progressed to production or release. In 2015, the classical music-focused record label Pentatone planned to release SACDs of old quadraphonic concert recordings after discovering over 250 tapes from the 1970s containing quadraphonic recordings (Günther 2015). Such discoveries are particularly valued by those working in the field of surround sound technology, such as Jean-Marie Geijsen, who worked on the Deutsche Grammophon Gesellschaft recordings.

> It's exciting when you listen today and hear that colleagues back then were doing practically the same as what we do now, but without a center channel. Many of these recordings sound almost brand-new — very direct and very detailed. For me personally, this is fascinating and motivating. Boring it certainly isn't. (Geijsen 2015)

While some old quadraphonic recordings have found a new life through reissues, there is also interest in creating entirely new quadraphonic music. In 2022, the Texas-based band ...And You Will Know Us by the Trail of Dead released a quadraphonic mix of their album "XI: Bleed Here Now." Band members Conrad Keely and Jason Reece have expressed a sense of missing out on the surround sound experience until Keely delved into the history of quadraphonic recordings

(Bear 2022). As an advantage of the quadraphonic format, Keely pointed out the low barrier of entry for producing quadraphonic music; owning two pairs of speakers constitutes a quadraphonic system, while also lamenting the fact that many great originally quadraphonic releases have been forgotten and are no longer listened to (Beajour 2022).

Another example of a more recent release in the quadraphonic format is Suzanne Ciani's "Live Quadraphonic" (2018), an LP recording of one of Ciani's quadraphonic performances played on a modular Buchla synthesizer (Figure 2.2A). Quadraphonics are not a new concept for Ciani tho, as she has been working with this technology since the late 1960s. (Calore 2018).



[Figure 2.2A Suzanne Ciani's Buchla synthesizer used in her quadraphonic performances (Jgilla2012 2021)]

Ciani's collaborator, producer KamranV, has been involved in producing several albums released in the 5.1 surround format but notes that it often did not work well (Calore 2018). According to him, the center channel and subwoofers in 5.1 systems were a disruption to artists and producers when trying to create a sense of space, while in contrast, quadraphonic surround has often felt like a more approachable and musical environment (Calore 2018). KamranV also observed that those working with surround sound often stumble in their pursuit of excessive realism, forgetting the "fuzzy edges" of art as, according to him, the simplicity and ease of approach in quadraphonics are crucial (Harvey 2021).

It is noteworthy that musicians find the quadraphonic system more understandable, especially in the context of music creation. This perspective raises several questions about how newer surround standards, built around cinematic systems, may carry assumptions about the role of sound and the hierarchy of space and how these invisible structures affect the artistic process. These questions will be revisited in the third chapter of the thesis.

Apart from these few examples that have gained some visibility, the quadraphonic standard has remained firmly in the margins. Despite this, music produced for quadraphonic surround systems is regularly released across various genres. Examples of albums released in the quadraphonic format in recent years include Santana's "Caravanserai" (2022), Kid Arrow's "We Are Satellites" (2022), and Gentle Giant's "Free Hand" (2021).

Many musicians and sound artists are also interested in the various possibilities of surround sound due to new immersive technologies like virtual reality. The combination of virtual reality's binaural audio with musically produced multichannel sound opens up many interesting and unexpected possibilities. Augmented reality systems could also benefit from more multidimensional soundscapes in real space. Perhaps quadraphonic surround will find new ecological niches within these technologies.

While there are no real signs of a mainstream resurgence of the quadraphonic surround standard, quadraphonics has, contrary to expectations, retained its place in the awareness of music producers and sound engineers. Artists from younger generations, unfamiliar with the early challenges of quadraphonics, may also be more open to experimenting with this almost forgotten technology. The future of quadraphonics remains uncertain, but it seems clear that artists working with it will continue to discover something new, intriguing, and special in it.

3 Art in 4 Channels

3.1 Early Findings

This section of the master thesis will describe the author's earliest findings and work relating to quadraphonic surround systems.

I first came across the idea of quadraphonic surround while researching another topic for my BA dissertation. I discovered that one of my favorite albums, *Dark Side of the Moon* by Pink Floyd, was originally created as a quadraphonic, four channel surround recording. This immediately picked my interest as I had heard that album countless times before, but to think that there was another version somewhere that related to a very different idea on how that music was supposed to be listened to, was endlessly fascinating to me. I remember making a mental note about coming back to this idea at a later time.

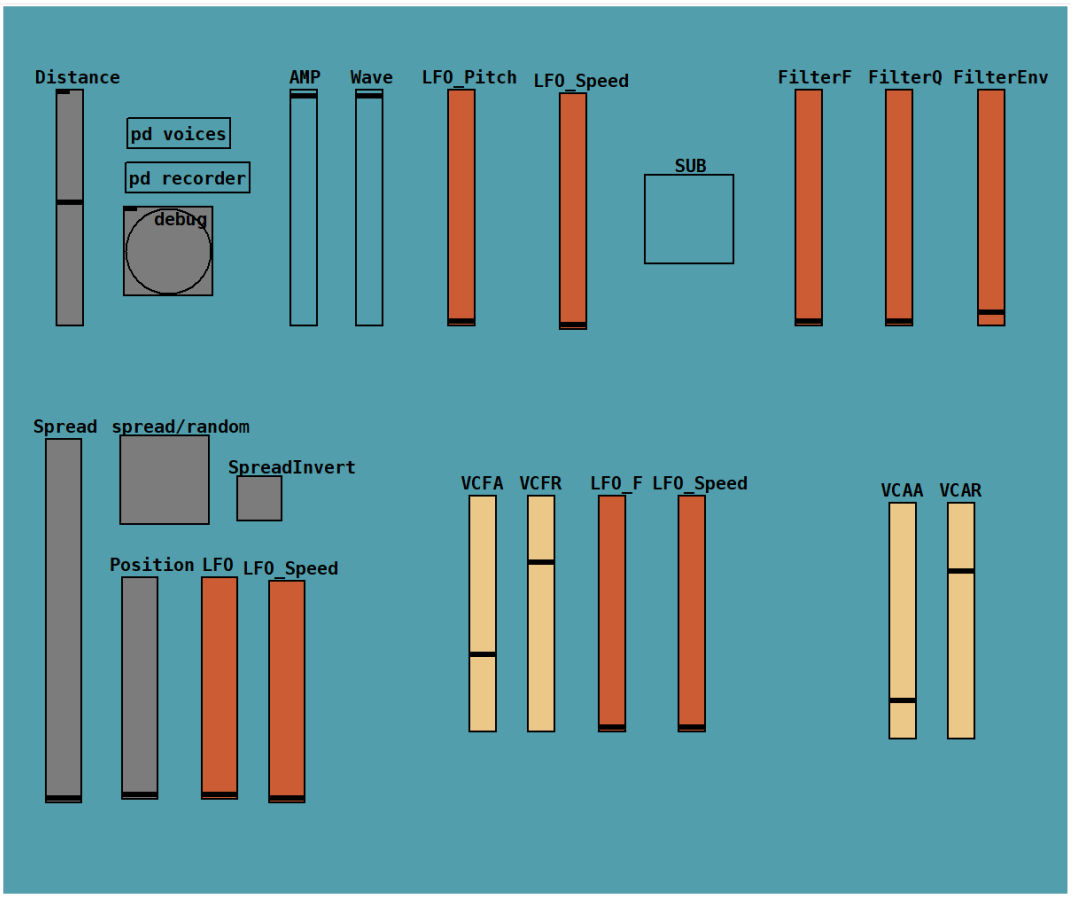
That time came in 2020 when during a course in spatial audio, Immersive Sound D ELEC-E5690, in Aalto University. As the final project for that course, I created my own quadraphonic panning system and a natively quadraphonic synthesizer in Pure Data. The programming of this quadraphonic panning system will be examined in more depth in later chapters.

The idea for the natively quadraphonic synthesizer was simple - each voice of a basic subtractive polyphonic synthesizer could be placed in a unique position in the 360° surround circle around the listener and this position could be manipulated. The spatial manipulation possibilities included in this programming were the following:

1. Variable keyspread ranging from no keyspread to a keyspread going multiple times around the surround circle.

2. Random note position on every note.

3. LFO that moves the notes around as they are playing.



[Figure 3.1A The user interface of the natively quadraphonic synthesizer prototype. Spatial manipulation controls visible on the lower left corner.]

The prototype synthesizer was very basic and definitely had an unrefined sound, but it was still mesmerizing to play with the spatial aspects of it. While I made some binauralized recordings of the synthesizer, they were a pale shadow of the synthesizer played through four channels.

While the synthesizer could be used with a quadraphonic surround system to create some very unique sounds, from the very early stages of development a real complication with quadraphonic surround was encountered - the space requirement. Figuring out a placement for a stereophonic system is quite simple - you can pick an empty wall in your room and place speakers in front of it. On the other hand a quadraphonic system by definition requires real space for the speakers to surround. While this problem is painfully obvious in the author's small apartment, perhaps it had not been so clear to the early researchers and proponents of this technology.

Largely due to this issue of space, the development of the quadraphonic panning system and natively quadraphonic synthesizer were put on hold after the completion of that course project.

The next stage of my quadraphonic surround research came in 2021 when my sister Saara Alhopuro invited me to do a joint art exhibit at Hotel Punkaharju during that summer. Saara's art consists of illustrative arrangements of various found objects, most often plants and mushrooms, photographed in natural forest settings. I was interested in working with a quadraphonic system again, but due to the natural themes present in Saara's art, I chose not to use the natively quadraphonic synthesizer, but instead to combine the quadraphonic panning system with a randomly self-arranging granular sampler that I had previously created programmed in Pure Data.

[Figure 3.1B *Would You Follow* (2021) by Saara Alhopuro (Alhopuro 2021)]

A long audio sample compiled of a set of natural sounding samples of various origin was created for the granular sampler to randomly roll through. The idea was to blur the lines between real sounds and synthetic sounds with the aggressively transformative granular sampling. There were some synthetic sounds, digital and analog drum machine samples and a few location recordings that had been recorded either with a handheld recorder or a spaced omnidirectional microphone pair.

As many of these samples were stereo samples, the chosen approach was to route the two channels of the self-randomizing granular sampler to two different, constantly and randomly shifting positions in the quadraphonic surround field. Here it was noted that some stereo sounds, especially those recorded with the spaced omnidirectional microphone pair, had some unexpected spatial qualities to

them. They sounded almost as if parts of the sound were moving further away or much closer to the listener and even exhibiting spatial qualities that seemed to escape the physical boundaries of the surround system. It was theorized that these effects were caused by varying phase differences in the sounds in the stereo samples, which were amplified by the microscopically magnifying nature of granular sampling and the extended spatiality of the randomly shifting quadraphonic panning.

While working on my piece for this exhibit, I was thinking about the relationship between nature, what is natural and the meaning of the action of documentation, rearrangement and reframing of nature and how that has evolved with the dawn of digital technology and communication networks. While now we enjoy an abundance of media like never before, sometimes it feels like the digital reproduction has started taking precedence over the actual experience. In this vein and along the mushroom photography of my sister, I chose to name this quadraphonic surround installation piece *Decay*.

After the summer in Hotel Punkaharju, we were invited to bring our exhibit to Galleria Pihatto in Lappeenranta, where it was shown for three weeks later that autumn.

3.2 Hearing and Space

This section will examine some of the basic ways human hearing works to determine the position of sound sources and their relations to quadraphonic surround systems. This examination will serve as a basis for some of the development choices during the final master thesis project.

If we look at common sound mixer architecture, panning in the stereo sound field is achieved by amplitude difference. For example, amplifying a signal in the left channel, while attenuating it in the right channel, changes the perceived location of the sound towards the louder left side. This works in human hearing as well - a sound source on the left side of the head is generally louder in the left ear than the right one.

The other main way of sound localization is the short delay times between sounds arriving in the ears. A sound on your left side will reach your left ear slightly earlier than your right ear. As these delays are so short, they are often thought of in terms of phase shifts in the waveforms.

These two main types of interaural localization cues are often referred to as interaural level differences, or ILDs and interaural time differences, or ITDs (Blauert 2013). In addition to the main two interaural localization cues there is a complex set of cues made from varying filtering and frequency masking introduced by the shape of the head and the ear lobes of the listener. All of these combined is often referred to as the head related transfer function, or HRTF.

As the more complex localization cues are closely related to and dependent on individual physiology, creating general models that would work for a wide audience has been challenging (Begault 1991). From the perspective of my quadraphonic surround projects, it also feels somewhat unintuitive to model head-shape and ear-lobe filtering for a speaker system. Then again there could be something there to discover, especially since it is thought that these more complex interaural localization cues play an important part in sound localization in the vertical axis.

It was discovered quite early in the research of quadraphonics that introducing phase differences between signals created a variety of localizational shifts in the sound field that was being projected by the quadraphonic system.

> General comments on the effects of excess phase-shift are that the images tend to move across the stage in a large arc, apparently moving further away from the observer as the phase difference increases, and becoming 'nasal' or bass lacking in quality. However for images in a centre-quadrat location further increase in phase shift (>90°) causes the image to become diffuse, and finally results in the familiar unpleasant 'in the head' or 'phasey' sensations usually associated with stereophonic systems in which one loudspeaker has been phase-reversed. (Ratcliff 1974)

These comments reflect the effects I had perceived when running stereo recordings through my quadraphonic panning system quite closely. Interestingly, while these more engineering-minded researchers seemed to look at the auditory artifacts caused by phase shifts as problems in the system to be solved or worked around, what I instead heard was unfamiliar and interesting sound qualities that carried untapped expressive potential.

It is often said that sound localization is significantly less accurate with sound sources behind the listener. While even early research does confirm this to some extent, localization accuracy seems to be highly dependent on the frequency response and transient content of the sound material, and even with less optimal material, accuracy is not completely lost (Ratcliff 1974). Furthermore, some have suggested that this inaccuracy is not indicative of a lack of capacity for accurate sound localization of sound sources in the rear, but perhaps caused by the lack of sight-based localization training in that direction (Ratcliff 1974).

While there has been a lot of further research on surround sound and the techniques and technology have moved forward to more complex ideas of multichannel audio like AMBISONICS and such systems like Dolby ATMOS, this research and development seems to have continued in the vein of earlier research around quadraphonics - focused greatly on the technical sides of surround sound - reproduction systems, accuracy and realism. Meanwhile most music is still being produced for the original 2-channel stereophonic system and it seems like there is an ocean between these two areas. One could argue that quadraphonic surround systems could offer an alluring lower threshold entry point for musicians interested in experimenting with surround audio as most production and mixing techniques from 2-channel stereo translate well to quadraphonic surround.

Author's note:

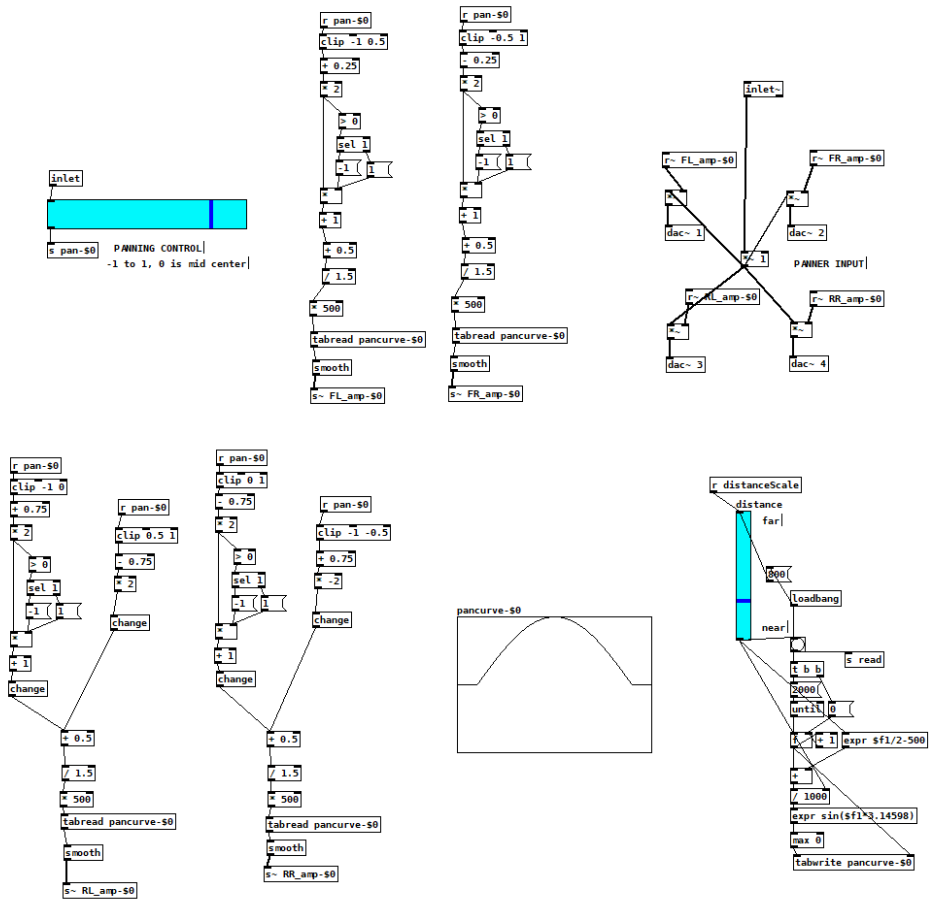
In the following sections of this chapter, pieces of Pure Data programming are indicated with [ ] brackets signifying Pure Data objects or abstractions.

Eg. A [gate] is not a gate, but a Pure Data object.

3.3 Quadraphonic Panning and Beyond with Pure Data

While researching different surround sound systems, I had come to notice that while in the development of many of these modern surround systems a lot of engineering work and scientific research had been invested into developing more accurate, realistic and flexible systems, none of these advancements had had a significant impact on making surround sound any more mainstream in the realm of music production. Surround systems are growing constantly more complex and musicians are still using just two speakers. This made me adopt a less scientific and less engineering-based approach in the development of my own surround system and consequent surround synthesis methods. My focus would be more on discovering simple and easy-to-understand, but powerful methods of using quadraphonic surround sound in a musical context. This section goes through the development of these methods and the related Pure Data programming.

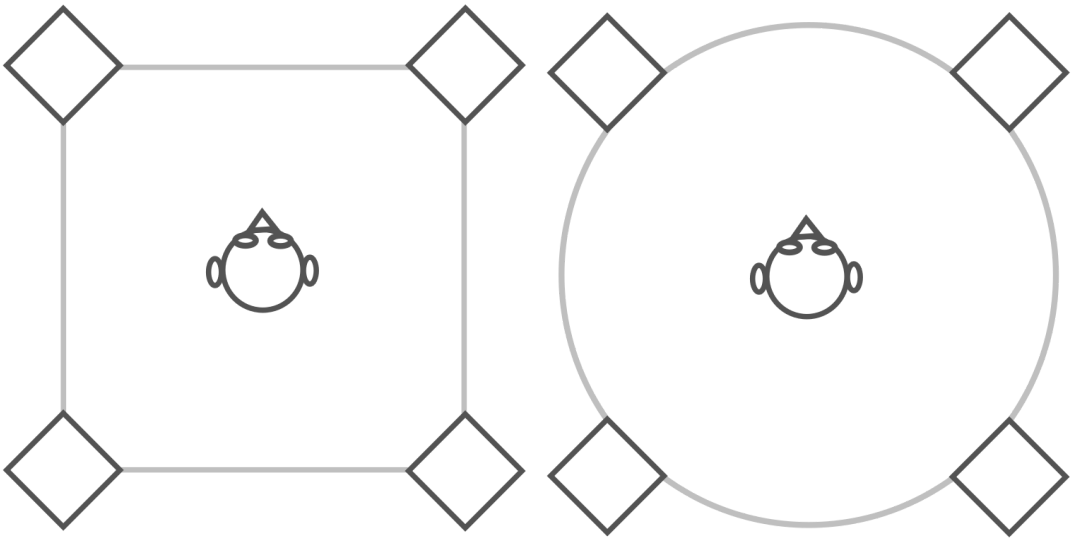
I built the first version of my quadraphonic panner system with Pure Data in late 2020 as a part of the previously mentioned natively quadraphonic synthesizer. As I knew I wanted to continue working with quadraphonic surround in Pure Data, I designed the panner as an abstraction that would work reliably and could easily be used in a variety of further projects. I had named the panner abstraction rather obviously [quadra].



[Figure 3.3A Screenshot of the patching in the [quadra] abstraction]

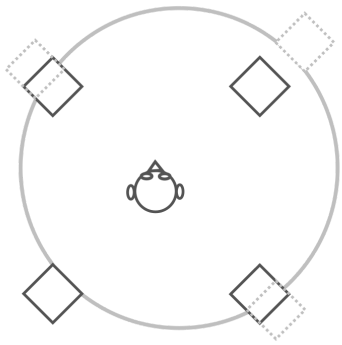
The design of [quadra] is minimal. The left inlet of the object controls the panning and expects values between -1 and 1, 0 representing the front center in the sound field and -1 and 1 both representing the rear center. For movement going multiple times around the surround field, large sweeps of input values can simply be wrapped between -1 and 1 and the abstraction follows reliably. The right inlet of the [quadra] object is the input for the signal which is panned and routed to the first four audio outputs according to the input of the first inlet.

As simply linearly amplifying and attenuating a signal between two speakers might lead to a somewhat square surround field. In order to mitigate this effect, a panning curve was calculated and used to vary the amplification levels between speakers. This curve was set to be variable so it could be adjusted according to the distance between the speakers.



[Figure 3.3B Illustrations on how the volume attenuation between the speakers helps create a circular surround sound field.]

In earlier research, a similar type of amplitude panning method has been described as Vector Base Amplitude Panning or VBAP and ways it can be used in standard surround and even three-dimensional systems have been studied in detail (Pulkki 2017). One of the greatest advantages of this panning method as the basis for a quadraphonic system is the relative simplicity in both programming such a panning environment and also in using it for musical purposes. As this method works as an almost direct expansion of the traditional stereo field, most traditional music recording and production techniques are easily translatable. The only real difference being the larger surrounding area to which sounds can be placed on in the panning.

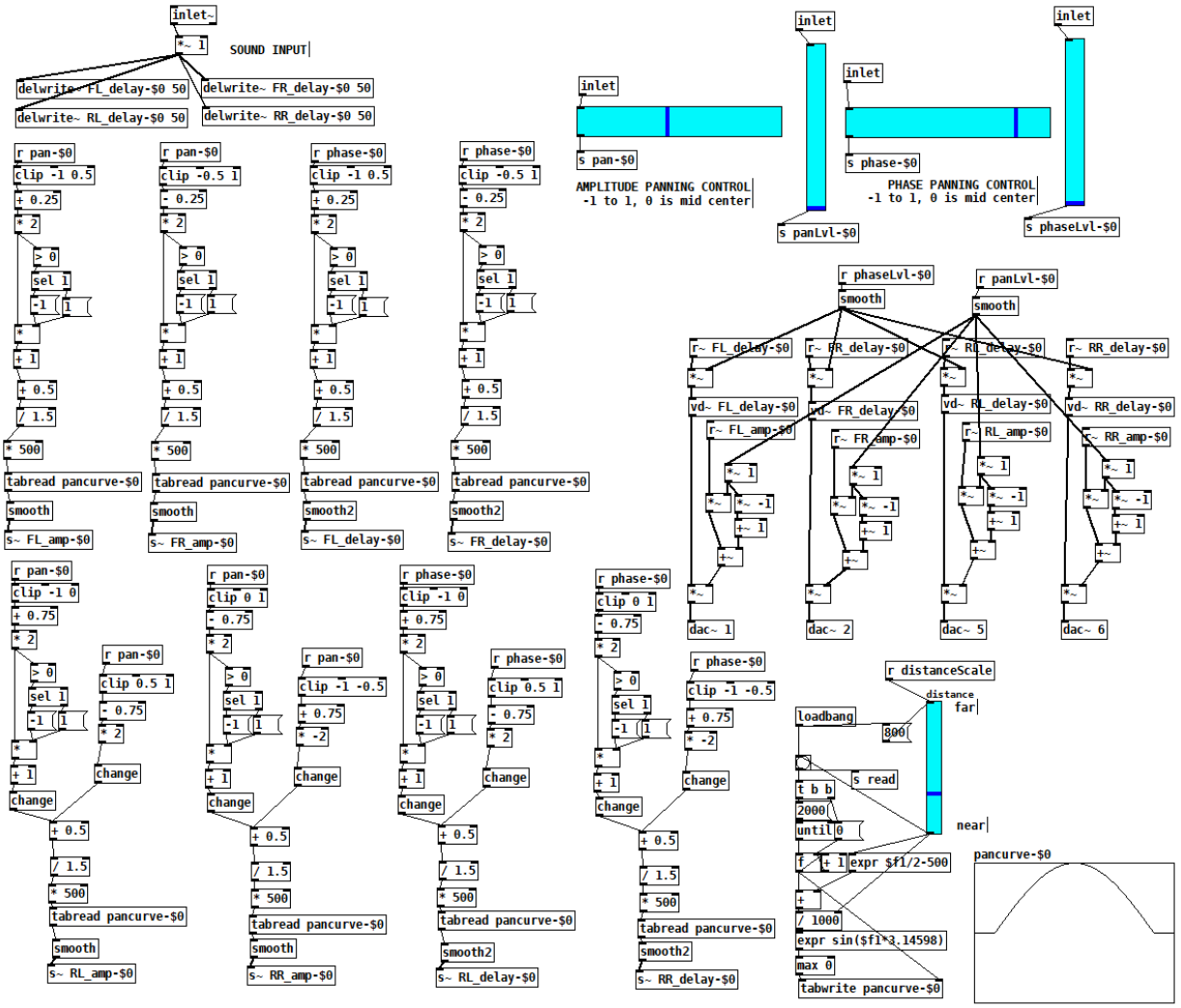


[Figure 3.3C An illustration on how delaying the signal in specific speakers shifts the perceived surround sound field]

The idea for the second method of panning signals in the quadraphonic field came from the previous discoveries with phase shifted signals in the surround sound field. It is a well known and widely utilized phenomenon in stereo mixing that slightly delaying a signal going to the first speaker, will shift the perceived location of that signal towards the second speaker and as noted previously, combining phase shifting with amplitude panning could lead to some interesting, almost illusionary effects relating to the localization of the sound. The next stages of research and Pure Data programming were focused on examining these effects and finding ways to artistically utilize them.

An approach that seemed the most straightforward was to expand on the programming of the previously created quadraphonic panner abstraction [quadra].

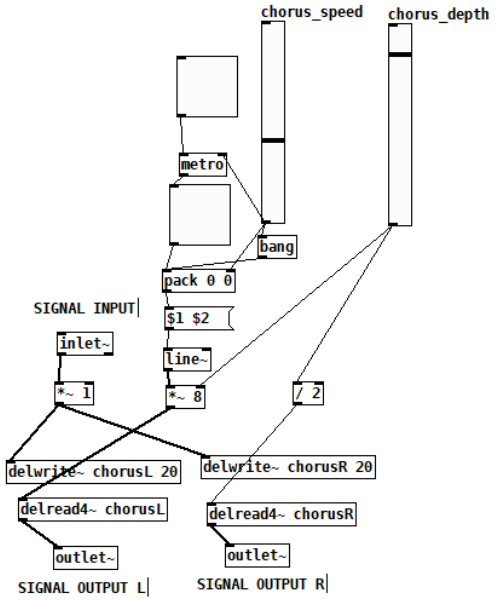
The plan was to incorporate delay-based panning to the amplitude panning system and to have an option to determine the relative strengths of these two effects. This quadraphonic phase-amplitude panner abstraction was named [phaedra]. A preliminary prototype of [phaedra] was created and while it is functional to an extent, certain unresolved bugs limit its wider usability. Work on fixing these bugs and turning this abstraction into a usable and reliable sound tool will continue in the future.



[Figure 3.3D Screenshot of the patching inside the [phaedra] abstraction]

The second approach was to use the Pure Data programming environment to simulate the original situation that had caused these effects to appear in earlier setups. Playing a signal out of two randomly shifting positions in the quadraphonic field, while the two channels were being affected by a stereo chorus proved to be an elegant solution that immediately produced results that closely reflected the interesting illusionary effects that had been previously discovered.

A chorus is essentially a signal that has been routed to two separate paths and while the other path is unaffected, the signal in the other path is being pitch shifted with a varying delay. The resulting effect can be heard in a monophonic setup, but it comes to life in a more spatial sense when these two signals are being played from separate speakers. This is often referred to as a stereo chorus. In order to make this effect more symmetrical, the signal that is not being affected by the varying delay is often also delayed by a static delay, the length of which is half of the maximum amount of the varying delay. This causes the perceived location of the signal to constantly shift between the two speakers while amplitude stays at a static level in both.



[Figure 3.3F A screenshot of a simple stereo chorus Pure Data patch]

As these experiments progressed, several different ideas on using traditional audio synthesis methods in new ways with the quadraphonic surround system were examined.

1. Subtractive and FM synthesis with different oscillator and filter sets routed to varying positions in the quadraphonic field.
2. Additive synthesis where different sets of harmonics are split around the quadraphonic field according to varying rulesets.
3. Karplus-Strong synthesis where multiple interacting resonators are placed around the quadraphonic field.

While early examinations of all three methods produced some interesting results, the simple subtractive and FM synthesis worked especially well as the spatial effects seemed easier to hear. This could have been due to the lesser complexity or perhaps the more minimalistically artificial nature of the source sounds. As ideas for quadraphonic synthesis started to take a more solid form, programming audio effects that would work in the quadraphonic surround was also investigated.

A previously completed reverb abstraction was expanded to four channels and a modified [quadra] abstraction was created that had controllable reverb sends in place for every speaker channel. Essentially this abstraction was a simple single channel reverb with minimal controls for decay, damping and wet/dry, repeated for every speaker. As most gallery spaces are not treated for sound, they tend to be very reverberant as it is and it has often been the case that using an artificial reverb effect is completely unnecessary as the natural echoes in these spaces are so strong and often much more interesting than simple digital imitations. The [reverb] also had a slight effect of blurring the sense of spatiality in the quadraphonic surround

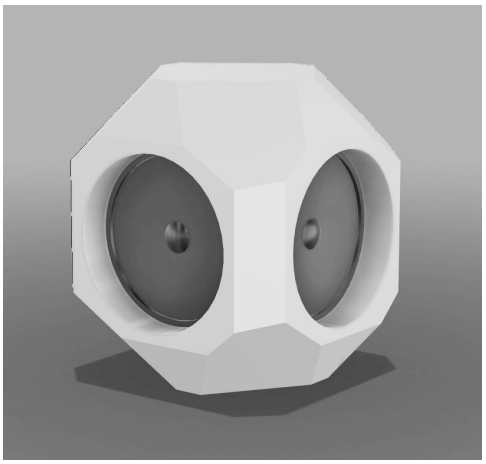
system, but this is something that could probably be improved with a more complex reverb algorithm. Areas of improvement in future development could include adding more reverb channels routed to virtual speakers around the quadraphonic surround field and connecting the different reverb channels with finely tuned feedback networks.

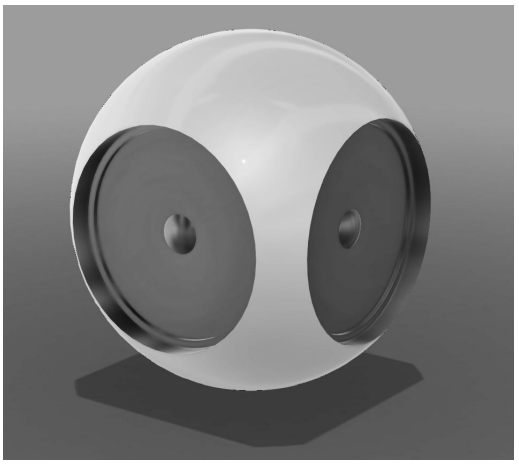
Subsequently, a quadraphonic multi-tap delay processor was also created. Different taps of the delay were routed into different varying positions in the quadraphonic field and were also feeding back into each other. Especially with shorter delay times, this created an intense swirly and swarmy delay effect that seemed to emphasize the spatial qualities of the system. Using delays instead of reverb was more simple in terms of programming and also less processing power intensive. In the art of traditional stereophonic mixing, it is a well known phenomena that using reverb can adversely affect the clarity of the sound, especially in the lower frequency range, while delays can be easier to work with.

Perhaps due to the inaccuracies of the system, it was noted that added complexity in the sound sources sometimes worked to mask some of the more interesting spatial qualities and effects, and these qualities and effects were often more interestingly apparent when the source material was less complex. This delicate balance was something that would be taken into careful consideration during the planning, design and programming of the master thesis exhibit.

3.4 **Designing a Quadraphonic Speaker**

As I was working on my quadraphonic installation *Decay* in 2021, I was simultaneously researching rotary speakers as an interesting motorized 3D-printing project. Somehow these two blended in my head and I had the idea for a kind of digitally controlled rotary speaker, where the speaker would instead be a 4-directional quadraphonic speaker and the sound would be virtually rotated around the speaker with Pure Data programming. I also figured that this would not accurately simulate a real rotary speaker, due to the lack of doppler effect coming from the physical movement of the speaker, but the idea stuck with me. This section goes through the process of designing and fabricating a quadraphonic speaker prototype.



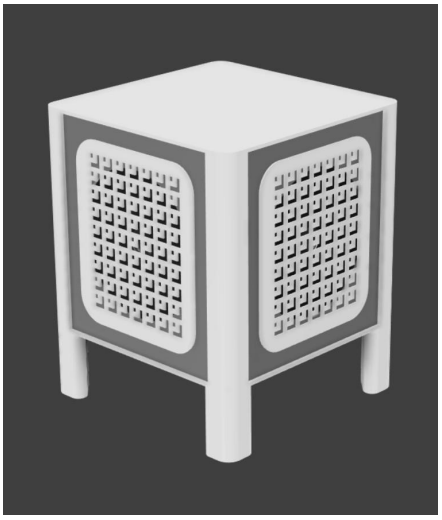


[Figures 3.4A and 3.4B Early quadraphonic speaker design ideas]

A continuing discussion in the realm of sound art is the role of the loudspeaker in a sound art exhibit. While sound is invisible, the loudspeaker stands as a visible symbol of a variety of ideas and, inescapably, as a piece of design in itself. On the other hand, hiding speakers can create a sense of mystery and evoke feelings of a puzzle to be solved, arguably also detracting the listener from the sound itself. I have most often chosen to adopt a position of transparency where, when practical, the electronics are not hidden and everything is left in plain sight, hopefully leaving most of the focus to the sound. Choosing a minimalist design ideal fit this idea of transparency and honesty well. Ideas on aesthetic functionality of design by German designer Dieter Rams were often reflected upon while making these decisions.

> For me, a restrained aesthetic and function that is as optimised as possible have always been important. These qualities lead to long utilisation cycles: The objects do not become visually unbearable after a short time because they have not pushed themselves into the foreground. Certainly, these qualities also act as a constraint upon innovation. (Rams 2017)

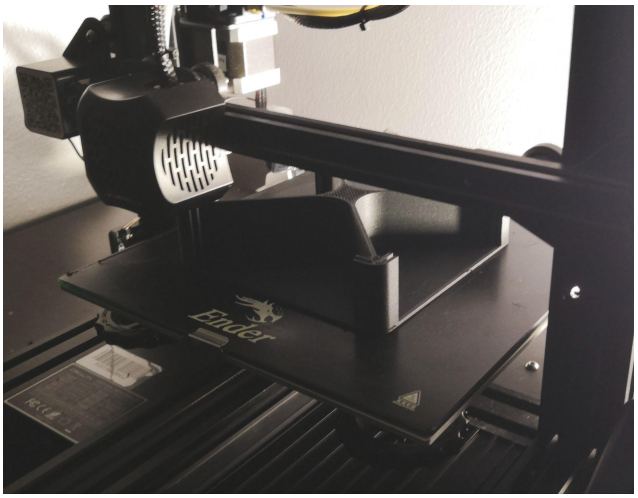
Early CAD designs (Fig. 3.4A, 3.4B) were focused on evaluating different aesthetic approaches, without any thought on practicality or construction. From very early in the process, a clearly minimalist approach was adopted.



[Figure 3.4C First quadraphonic speaker prototype, Fusion 360 CAD model]

The first prototype quadraphonic speaker to get fabricated was a rectangular design inspired by Japanese paper lanterns (Fig. 3.4C). This design was intended to be stylish, unobtrusive and minimal, something one could have on their living room table. Furthermore in a sound art exhibit setting, a minimal design might not detract the focus of the listeners too much either.

Ultimately this prototype proved problematic in some ways. While the prototype was successfully constructed, there were a lot of parts, many of which were relatively complicated shapes to 3D-print. Furthermore, the method of assembly where the speaker elements were attached to plates that slide into sockets (Fig. 3.4F) required a great amount of accuracy in manufacturing tolerances, in order for the plates to stay in place firmly without rattling, but still being removable without breaking.



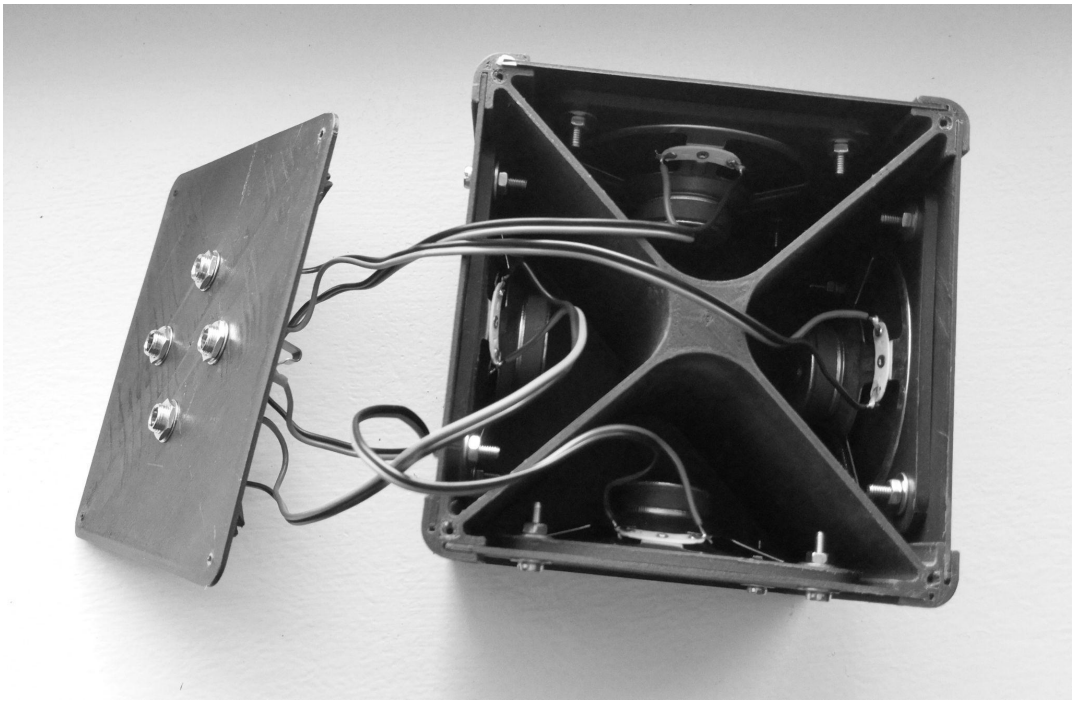
[Figure 3.4D Photograph of the process of 3D-printing the first speaker prototype]

This issue of tolerances was made more problematic by the fact that all the 3D-printing was done on an old Creality Ender 3 V2 printer, which has no automated bed leveling. This made working with tight tolerances hard as setting the starting position of the printer had to be adjusted manually and very slight variance in the thickness of some parts could make them too loose or too tight. Getting the tolerances very accurate was further complicated by the usage of 3D-printing filament made from recycled plastic, which can be somewhat varying in quality and texture.

The final assembly of the first prototype was functional, but did not feel very solid or reliable. As it had been originally designed to be placed on a table, the ways it

could be displayed or used in a gallery setting were also somewhat limited. Even with its limitations and issues, this first prototype was functional enough to serve as a proof of concept and so it was used to test several early pieces of programming.

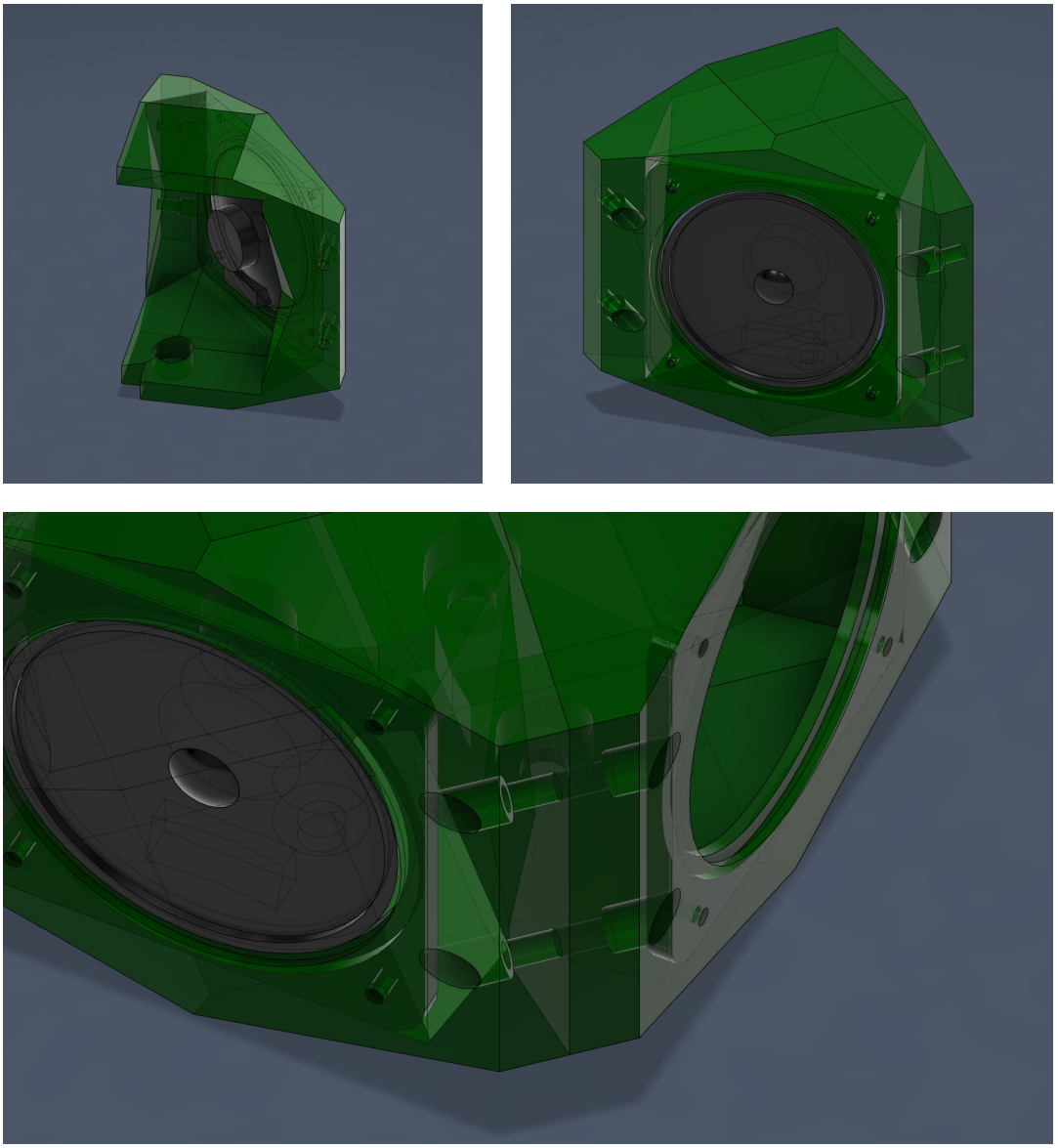
[Figure 3.4E First quadraphonic speaker prototype, tolerance test print on the left, assembled speaker on the right]



[Figure 3.4F First quadraphonic speaker prototype, assembly and wiring]

To address these issues, a new design was created. This design was quite reminiscent of the early cubistic design idea seen in figure 3.4A. This new design was sturdier, easier to 3D-print and used fewer parts in the assembly than the first

prototype. It also fit the idea of having minimal design interfere with what is supposed to be an experience of sound. While the aesthetics of the speaker were taken into consideration, there is a functional reason for every shape of the design. Choices in the angular structure were carefully made to facilitate fast and reliable 3D-printing and to save as much material and time as possible. Some sharp angles in the internal geometry were shifted as sharp angles tend to cause unwanted acoustic effects.



[Figures 3.4G (top left) 3.4H (top right) 3.4I (bottom) Close-up images of the design of the second prototype speaker modeled in Fusion 360 CAD]

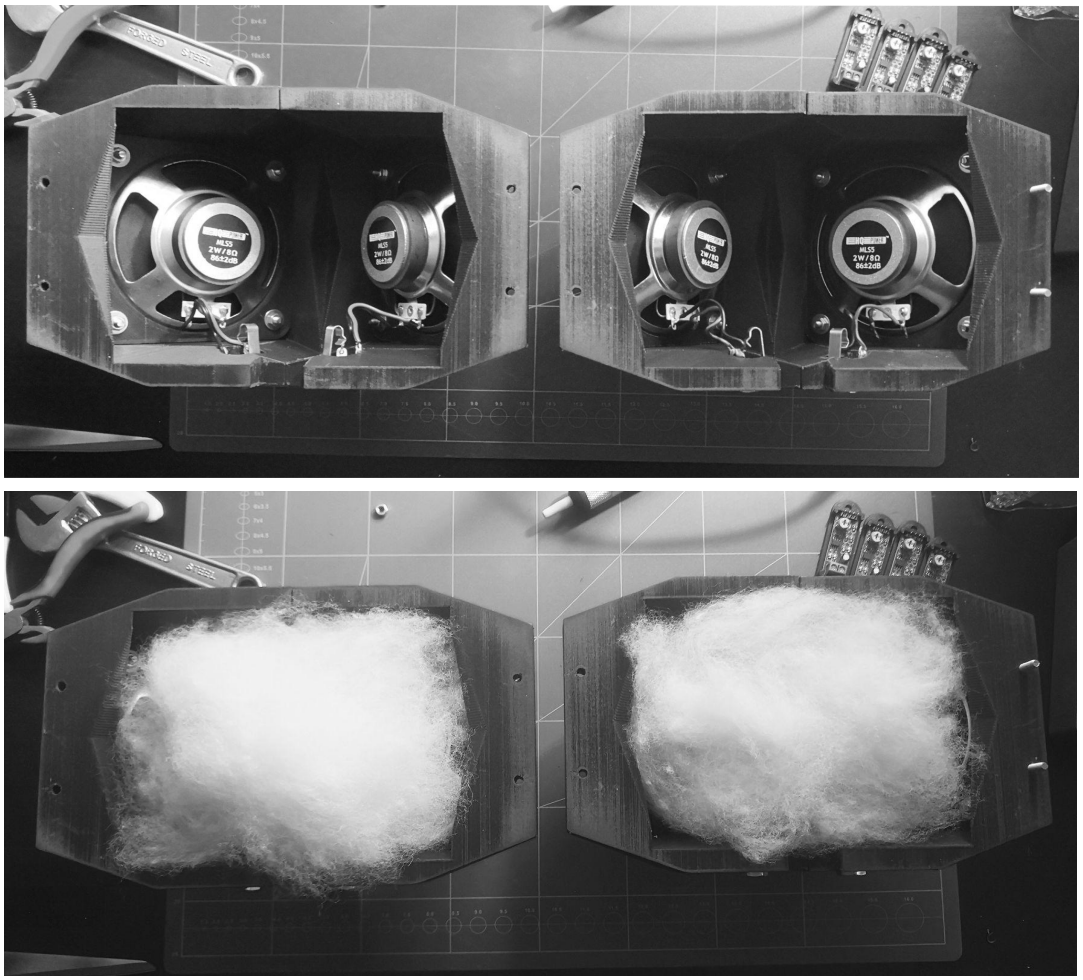
The second speaker assembly consists of four symmetrical pieces that connect to each other with bolts in 45° degree angles tightly locking the pieces together. The speaker elements are attached to these four pieces with a minimal attachment

frame and further sets of nuts, bolts and washers. A round hole for the 6.3mm TS jack was placed on the bottom and a rectangular shape was cut from the middle facing corner of each piece, so that a square mounting hole would be left in the bottom middle of the assembled speaker.

The main disadvantage of this design, compared to the first prototype, was the lack of an internal wall structure between the speaker elements. This might allow the speakers to play each other and bleed through each other with the varying internal air pressure of the speaker, interfering with the separation of the 4 different channels. While some rigid internal wall structure designs were in early design stages, ultimately a simple solution of filling the internal cavity with a generous amount of polyfill was selected (Fig 3.4K).

Another theorized way of preventing interference between the channels was to program a sort of noise-cancellation between the speaker elements, where the main signal going into one speaker element, would also be routed to the other elements, but attenuated, phase reversed and with the correct amount of delay to completely cancel out internal signal bleed. While this method was never developed further, it could prove to be an interesting avenue of further research.

The construction and assembly of this speaker was also successful and it proved to be a much sturdier and functional design. A mounting connector for the square hole in the bottom of the speaker was fabricated and a microphone stand connector was press-fitted into it with additional heat from a soldering iron, melting the connector into the plastic, solidly joining these two elements.



[Figures 3.4J (top) and 3.4K (bottom) Photos of the second quadraphonic speaker prototype being assembled and filled with polyfill]

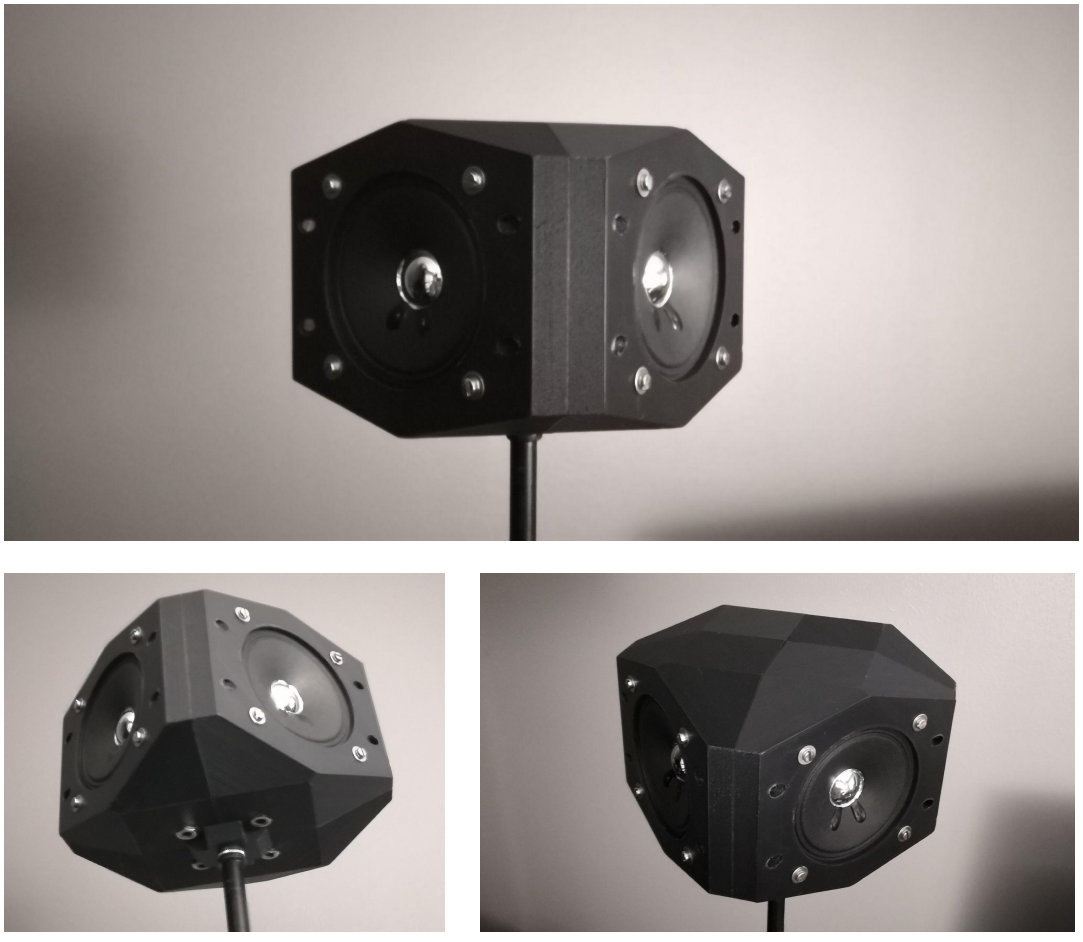
The construction and assembly of this speaker was also successful and it proved to be a much sturdier and more functional design than the previous. A mounting connector for the square hole in the bottom of the speaker was fabricated and a microphone stand connector was press-fitted into it with additional heat from a soldering iron, melting the connector into the plastic, solidly joining these two elements.

All through this project, careful consideration was put into the materials that were being used, with environmental impact especially in focus. While plastic might not intuitively feel like an environmentally friendly material, one could argue that using recycled waste plastic to create functional and lasting design is an ecologically good thing. There are currently many ongoing efforts and enterprises focused on the idea of turning unrecycled plastic waste collected from various sources into 3D-printing materials.

All 3D-printing in this project was done with recycled material and while arguably more sustainable than new plastic materials, it does have some issues. Recycled 3D-printing materials tend to vary more in quality and texture, causing some

difficulty in setting reliable 3D-printer settings and therefore making it more difficult to work with tight tolerances as noted before. On the other hand the coarse texture of the filament does somewhat mask the layer lines indicative of the 3D-printing process and some might consider the coarse surface texture a desirable effect.

While working with 3D-printing it is common to use various surface finishing processes in an effort to mask the 3D-printing layer lines, one could argue that there is something interesting in being able to see this specific construction process in the material. After all, 3D-printing is such a rapidly evolving technology that it is easy to see how layer lines will eventually disappear, and perhaps pieces of design made during this relatively short moment in history where this fabrication method was taking its first steps will be interesting for that visible feature especially. The layer lines can also reflect light in interesting ways, emphasizing certain shapes in relation to the orientation they were printed in. This effect can be seen in figures 3.4L, 3.4M and 3.4N.



[Figures 3.4L (top) 3.4M (bottom left) 3.4N (bottom right) The assembled second quadraphonic speaker prototype]

In early testing the assembled second quadraphonic speaker prototype proved to be solid and reliable, even withstanding an accidental drop to the floor from

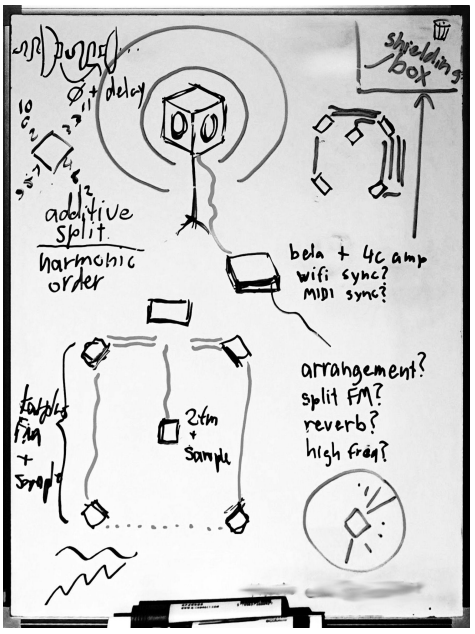
table-height. The polyfill was also deemed an adequate internal baffling solution as the speaker conveyed spatiality well enough for the effect to be clearly present. The microphone-stand mount was also functional. This second prototype speaker was completed just in time for the *LOST DIMENSIONS* - master thesis exhibit and was exhibited there as a central element of the surround sound installation carrying the same name.

3.5 *LOST DIMENSIONS* - Master Thesis Exhibit

LOST DIMENSIONS - A sound installation utilizing a 4-channel quadraphonic surround system in addition to the 4-channel quadraphonic speaker, the [quadra] quadraphonic panner Pure Data abstraction, the [phaedra] quadraphonic phase-included panner Pure Data abstraction and a set of real time algorithmic composition and multichannel synthesis Pure Data patches. This section will look at my artistic process of creating the *LOST DIMENSIONS* - sound installation piece.

The first motivation for setting up this exhibit was to create and exhibit a master thesis project that brought together some of the most interesting skills, techniques and perspectives I had gathered during my studies in the Sound in New Media master's programme. While I already had a strong background in music and sound production in general, during my master's studies I focused a lot on improving my skills related to design and fabrication of instruments and audio electronics. On the other hand Pure Data has continued being a connecting thread through all of my studies and research in sound and music, and continues providing possibilities and opportunities I would have never considered.

Secondly, as I was interested in breaking standards and swimming against some inherent hierarchies of modern surround sound systems, I chose to disregard the idea of an objective directionality in the surround sound system, and instead think about it as a neutral circle where all directions are of equal importance. In addition to this, as the phase shifting programming shifts the virtual surround circle around the listener as seen in figure 3.3C, I also decided to disregard the idea of an optimal listening position and instead embrace a decidedly unreal space, strangely shifting around the listener.



[Figure 3.5A Photo of some early plans on a whiteboard]

A Bela mini prototyping platform with an expander for outputting multichannel audio was chosen for running the sound engine of the quadraphonic speaker. To drive the speaker, some simple LM386 - chip based amplifiers were prototyped, but they were ultimately deemed

unnecessary as the headphone amplifiers of the multichannel expander of the Bela mini platform were actually enough to drive the speaker elements at a workable volume. A simple box was 3D-printed to house the Bela and the appropriate audio jack connectors. The surrounding speakers were active, so an old laptop with a soundcard with enough outputs was all that was required to use them.
The two audio system were not synchronized in any direct way, but as they used a lot of the same programming, with almost the same parameters, it was predicted that connections between the sounds of the two systems would be perceived inevitably. The pieces of programming that were chosen for this installation included:

1. A quadraphonic FM-synthesis voice consisting of two identical, but detuned low frequency FM-sounds that are routed to two randomly shifting positions in the quadraphonic surround circle with [phaedra].

2. Several simple high frequency FM-voices that are routed to a quadraphonic multi-tap delay described in Chapter 3. Section 3. that uses [quadra] to place the taps around the surround circle.

3. Multiple voices of filtered noise split into further phase shifted channels using a programmed stereo chorus routed to various randomly shifting positions around the surround circle with [quadra].

4. Three granular voices, each using a stereo sample consisting of various digitally synthesized sounds, with a stereo chorus baked into the sample itself and the two outputs of each voice routed to various randomly shifting positions around the quadraphonic system with [quadra].

These pieces of programming were chosen because they were simple and relatively inexpensive in terms of processing power, something that was important for running them on the Bela platform. They were also suitable because they seemed to work well in demonstrating the intended spatial effects. The minimalist digital nature of these sounds also reflected the minimalist design ideas that were considered while designing the quadraphonic speaker.

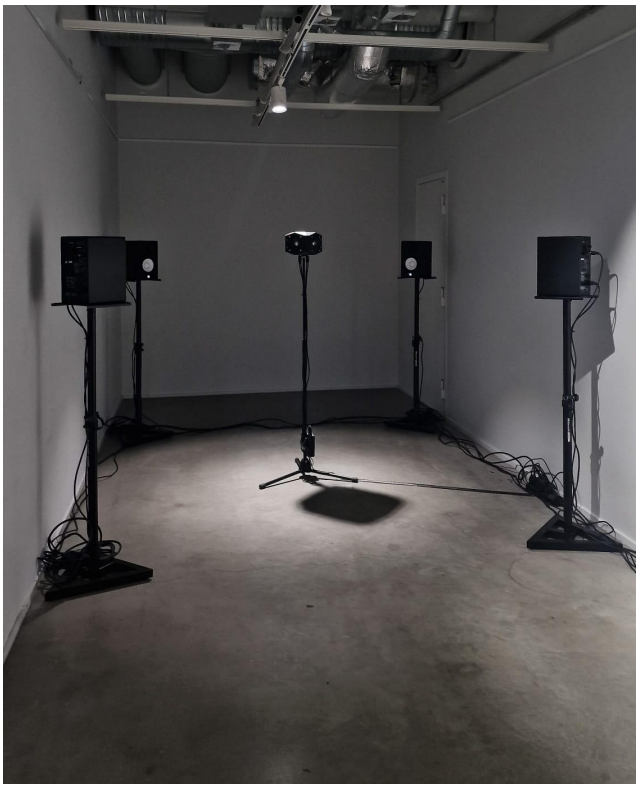
A recording of the sound output of this set of programming has been attached to the thesis. LOST_DIMENSIONS_4_channel.wav is a 44.1khz 4-channel WAV audio file with a FL, FR, RL, RR channel order and requires a system with four separate output channels for accurate reproduction.

Multiple different generative sequencers using algorithm models varying from random to chaotic were built to sequence these voices. They were finely tuned to play little enough to leave space for each other and even for silence and moments of anticipation. While researching algorithmic sequencing with the Pure Data programming language is also a continuous focal point in the author's work, it is unfortunately out of the scope of this master thesis.

Speaker placement was something that was carefully considered. Placing the quadraphonic speaker in the middle of the installation directly interferes with the idea that an optimal listening position in a surround sound system is somewhere right in the middle, instead inviting the listener to walk around and explore the space that the sound occupies. A conscious choice of making the quadraphonic speaker play sounds slightly quieter than the surrounding speakers was also made. The intention behind this was to pull the listener in towards the small speaker, in part for them to better hear the spatial effects that it produced, but also because listening intently to something quiet is a fundamentally different experience than hearing something loud played at you.

A substantial amount of audio and power cables were required to make the installation work, but as this setup had been mapped out and planned well in advance (Fig 3.5A), putting them in place was quick work. A generous amount of black stage tape was used to secure the cables to the floor anywhere people might walk across.

Thematically*, LOST DIMENSIONS* is about lost technology and forgotten futures. On another level it intends on discussing the perspective and memory shaping forces of digital technology and how these technologies are slowly pervading our collective consciousness, shaping our behavior and the world. There is an obvious love for modern technology present in the warm brutalism and unashamed digitality of the installation, but also a looming dissonance. There is danger ahead.



[Figure 3.5B Photo of the LOST DIMENSIONS master thesis exhibit in Väre V2-gallery]

From a musical perspective, *LOST DIMENSIONS* is a minimal ambient piece that refuses to be ignored. While there are moments of harmony and tranquility, there is also an obvious tension and a pressure, specifically brought in by the somewhat dissonant detuned low-frequency FM-voices. The shifting parameters of the FM voices are also the one element that breaks an otherwise clearly structured and static diatonic harmony. While the minimalistic digital sound design works well in a practical sense to demonstrate the possibilities

of the quadraphonic system, it also functions as a reflection of the theme of forgotten alternative futures through referencing retrofuturistic sci-fi aesthetics. While it is easy to hear references to the work of previously mentioned artists Ryoji Ikeda and Mika Vainio, one can also perceive a connection to the adventurous futuristic experimentalism of earlier electronic musicians like Tod Dockstader.

The *LOST DIMENSIONS* - master thesis exhibit opened on 6.11.2023 in the V2-gallery of the Väre building at Aalto University in Espoo and ran without any issues up to the planned closing on 24.11.2023.

While I was quite happy with the final sound installation and the exhibit in general, as the project had been so complex and contained so many different interconnected parts, budgeting enough time and starting early enough with the research, development, prototyping and fabrication of these parts was a difficult task. Many of the original construction and assembly plans did not work out and some fundamental hardware solutions had to be re-thought on the night before the opening. This left me feeling like many parts of the process could be improved on.

Fortunately the final quadraphonic speaker has proven to be a reliably functional tool and doesn't need to be redesigned or remade for now. Furthermore, as the exhibit has closed, the speaker can now again be used for further research and in the testing and development of novel surround sound techniques.

4 Conclusions

The history of quadraphonic sound is an illuminating perspective on the chaotic process of how new technologies are adopted or forgotten. While there are certainly lessons there to be learned for anyone trying to introduce new technologies as products to the mass market, another intriguing thought is the question of how many great ideas have been forgotten and buried, not because they were not great ideas, but because they were failures as specific commercial ventures. As sad as that might sound, it also introduces the exciting possibility that the history of technology is filled with unfound treasures, great ideas wrongfully assumed to be failures.

While it can be easy to disregard the ideas of the past, strangely enough it seems almost easier to disregard what is beautiful and interesting in our time right now. It is easy to see the worth in a decades old photograph depicting your hometown as it once was for only a moment, but it is harder to appreciate how the view of the street outside your window right now is just another fleeting moment like that, history of the future. A digital sound that was once described as cold and artificial has been warmed up by the passing of time and piling layers of nostalgia. How long will it take for 3D-prints to look retro?

For the time being, quadraphonic surround seems to be tightly locked in the margins of music, but perhaps in the future through further research and through developing and publishing low-threshold-of-entry tools for working with quadraphonic surround, some new interest could be sparked. As money made from record sales has plummeted due to the rise of digital streaming services, live performances have become an increasingly important aspect of the work of many musicians. Utilizing quadraphonic and other multichannel systems could provide musicians with new ways of making live performances a more interesting and unique experience, something distinct from what is available for home audiences. Especially as multichannel systems require more space and setting up than what is convenient for most people in their homes. As more live music venues, especially ones specializing in electronic music, have started implementing possibilities for multichannel playback, the threshold for utilizing multichannel audio in a live music setting is constantly being lowered.

One could argue that there is something fundamentally unique and beautiful about the symmetry and simplicity of the quadraphonic system. While accuracy and realism have always been a point of focus in the development of audio technology, it has been seen again and again that actually the inaccuracies and imperfections of old systems have become something considered musically beautiful. While it is possible that e.g. the perceived warmness of tape recordings or the inaccuracy of the tuning of an electric guitar have become sounds that are widely appreciated due to simple cultural exposure and the effect of musical nostalgia, it still serves to indicate that musicality and artistic possibilities of any system might not be measurable in purely scientific terms.

Researching these possibilities and developing new tools for possible future publication is something that is worth looking into and will continue being in the focus of the author. Perhaps the story of quadraphonic surround is not finished yet.

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