# *3D Spatialisation Technologies and aesthetic practice within electroacoustic composition: A journey through Listening, Composition and Performance*

Brona Martin

## *1. Introduction*

Spatial audio is used within a variety of media such as electroacoustic composition, gaming, virtual reality and film. Within the contexts of film and gaming this practice is well documented with many artists sharing their knowledge and tools disseminated through the use of podcasts, YouTube videos and journal publications. However, there is little documentation on spatial audio workflows and how this technology influences creative outcomes within the genres of electroacoustic music and sound art. How do these technologies affect the way we compose and listen? How do we use these tools as both instruments and compositional tools? As composers what do we learn as we work with these technologies?

## *2. Channel-based audio spatialisation*

As an electroacoustic composer I have created multi-channel compositions which have been composed for 5.1 and 8.0 (a ring of 8 loudspeakers) to create immersive listening experiences.

*A Bit Closer to Home* (Martin, 2014) is an 8-channel soundscape composition composed at NOVARS Research Centre, University of Manchester. The piece focuses on the soundscape of my hometown, Banagher located in the middle Ireland on the River Shannon, combining field recordings from the area and interview excerpts which discuss sounds from the past. The piece explores the listening experience of the composer while reflecting on sounds from the past that no longer exist which are discussed in the interview. For this work, field recordings were made using an H4n Zoom recording device and DPA 4060 omnidirectional condenser microphones. These highly sensitive microphones capture the fidelity of sounds and sense of space acting as a microscope between the ear and soundscape. A variety of field recordings were captured including birdsong, a thunderstorm, water lapping and machine noise from the local mill.

In order to replicate the original listening experience of the composer and the environmental context, an 8-channel loudspeaker configuration facilitated a realistic version of the original sound environment.

Musica/Tecnologia, 17 (2023), ISSN online 1974-0050, ISSN print 1974-0042, pp. 69-94
DOI: 10.36253/music_tec-15197 – http://www.fupress.com/mt

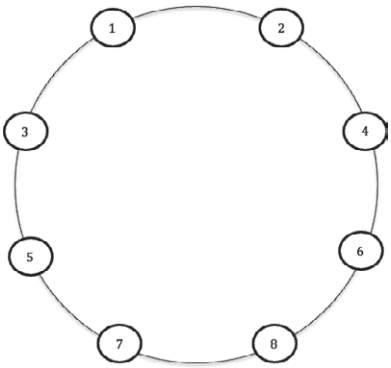


Figure 1. SEQ Figure * ARABIC 1 8-Channel loudspeaker layout.

Even just eight channels of discrete source material create a convincing soundscape where composed sounds can be localised in the manner experienced in acoustic environments. (Truax, 2008, p.105)

Discrete localisation of sounds such as birdsong and people's voices combined with layers of ambient field recordings are effective in creating a realistic immersive soundscape, where the 8-channel setup is treated as eight mono speakers, four pairs and an 8-channel ring.

Within this composition I worked with stereo sound files. Spatialisation was achieved by layering sound materials across the 4 pairs of loudspeakers i.e. (1+2, 3+4, 5+6, 7+8). Panning occurred between these pairs, moving sounds from left to right and vice versa. Some tracks were also routed to 4 auxiliary sends, where each send was assigned to a pair of loudspeakers. This made it easier to send a copy of one sound source to other speakers using send automation so sounds could easily be moved from front to back.

Granular processing of some of the field recordings in Cecilia[1] resulted in the creation of textural sounds, dividing the sound into much smaller segments known as grains. The use of this processed material can be heard in the beginning of the piece where traffic sounds on a wet day are panned left and right on the front speakers. The distinct sounds of water drops falling from a drain on to concrete begin to emerge at 00'25 (Sound Example 1)[2] seconds and can be heard in the foreground. Once the cars pass at 00'54, granulated water drops emerge and are spatialised across the ring of 8 loudspeakers enveloping the listener within these delicate sounds.

To replicate discrete localised birdsong, these recordings were panned to one speaker. The spoken word within the piece was placed on the front loudspeakers 1 and 2 to create the illusion that the narrator is sitting in front of the audience. Additional layers of field recordings were added and spatialized. For example, at 2'46 a rain/

[1] http://ajaxsoundstudio.com/software/cecilia/

[2] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

thunder scene begins (Sound Example 2).[3] The sound of closely recorded water drops from a drain return and are placed in one speaker with the gradual addition of rain and thunder recordings. Changes in perspective are created by using EQ to gradually enhance the bass frequencies so that the thunder appears louder and closer while increasing overall amplitude resulting in distant thunder rumbles coming closer to the listener, enveloping them within the soundworld.

In this example, composing for a ring of 8 loudspeakers allows the composer to enhance, intensify and embellish the field recordings resulting in an immersive listening environment where the listener can localise various sound events weaving between elements of real and imaginary soundscapes. It also allows the composers to keep various elements of the soundscape separate, placing the listener in the centre e.g. the traffic remains in the front, birdsong is placed in single loudspeakers while the rain is placed all around the listener.

As mentioned above the spatialisation for this piece was implemented by layering sounds across different pairs of speakers in combination with send and panning automation. For this piece I didn't use a panner and the spatialisation of materials occurred after I had organised my sound materials. Therefore, the creation of space within the work came afterwards. However, in later works listed below the use of a panner such as SpatGris to spatialise materials throughout the ring of 8 loudspeakers was much easier and resulted in the space being composed within the work simultaneous to the organisation of sonic materials.

## *3. Object based audio approaches*

> When working with object-based audio system mono and stereo sounds can be defined as objects. These objects can then be panned throughout the 3D space. When working with object-based audio "all sounds are distributed independently, which are mixed only during reproduction."[4]

### *3.1 SpatGRIS – VST Panner*

In 2018, I composed an 8-channel soundscape piece, *NightEscape.* This piece explores a night-time field recording, from Atlantic Center for the Arts, New Smyrna Beach, Florida recorded during a residency with composer Jonty Harrison in 2014. The piece was composed at EMS Stockholm in March 2018. For this piece I explored some new spatialisation and sound processing tools. SpatGRIS[5] (Université de Montréal) was used to spatialise the audio in 2D on a ring of 8 loudspeakers.

[3] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

[4] Fonseca, N. 2020. *All you need to know about 3D Audio*. Sound Particles Lda, p. 10.

[5] https://sourceforge.net/projects/spatgris/

> The *SpatGRIS* is a plugin (Mac AU/VST and VST Windows format) designed to compose multichannel space. It allows the user to spatialize the sound in 2D (up to 16 speakers) or in 3D (up to 128 speakers) under a dome of speakers with the ServerGRIS (Normandeau et al. 2018, p. 291).

Working with this panner made it much easier to spatialise the audio with a choice of movements and different trajectory systems while there are also different ways of linking sound sources together. This resulted in a broader range of spatial movements within the piece. SpatGRIS facilitated the movement of a single sound source through the space, 'dissociating sound source's localisation from the loudspeakers position" (Ledoux and Normandeau, 2018, p. 3).

> The composition of space must be concurrent with the composition of time in the general process of development of the work. The space is not an added flavor, a color sprinkled at the end of the course when the work is already finished on the temporal plane. It is an integral part of the electroacoustic work of the 21st century, it is even the most original and exclusive component. For these two reasons, we decided to develop not a new sound spatialization software – there are already many – but rather a plug-in that integrates with the daily work tool of composers (Normandeau et al., 2018, p. 291).

For this composition each track had 8 channels and the SpatGRIS VST plugin. Within the plugin the input mode and output modes were determined e.g. 2 in 8 out.

As a result of the SpatGRIS panner I began to see the ring of 8 loudspeakers as a complete spatial image where sound objects could move through the space and beyond the speaker periphery no longer restricted to loudspeaker position.

8-channel spatialisation also facilitated the division of the night-time cricket

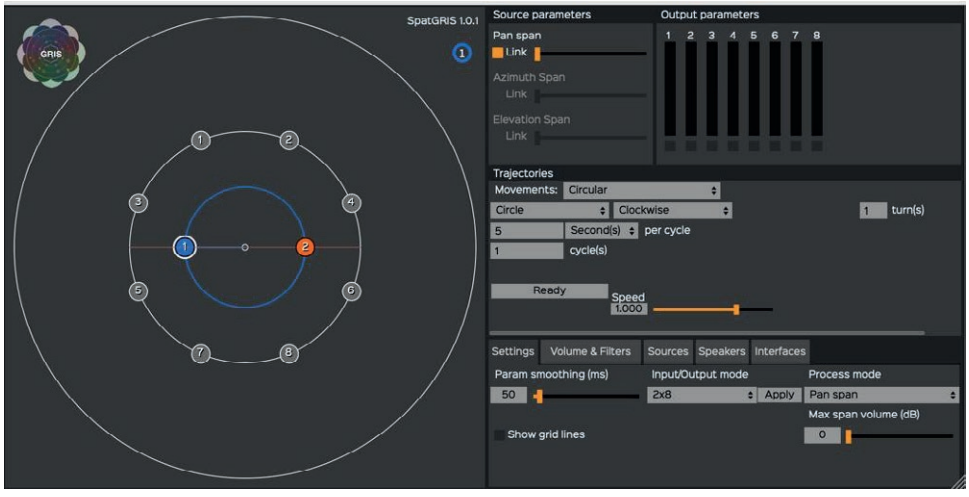


Figure 2. SpatGRIS VST with a stereo sound source.

sounds into different frequency bands (Sound Example 3).[6] These bands were placed in different locations within the space rather than being mapped to a specific pair of loudspeakers. As a result, it is a combination of all of the speakers which are producing the sound. Barreiro calls this spectral diffusion:

> Spectral diffusion happens when the spectrum of a mono or stereo sound is sliced in several frequency bands (called bins), which are then spread over the several channels. One interesting aspect of this technique, at least in conceptual terms, is that the resulting sound is produced by all loudspeakers working together. The sound is not placed in one loudspeaker or between two loudspeakers, but scattered all over the multichannel array. The result (although this depends on the spectral characteristics of the original sound) is that the listener is enveloped by the multichannel sound (Barreiro, 2010, p. 291).

Within this piece I also worked with 8-channel sound files. BEASTtools[7] was used to process and transform stereo sound sources into 8-channel files. For example, Granul8 facilitated 8-channel granulation where stereo sound sources were granulated and spatialised across the 8 loudspeakers. Similar to most granular processing software the user has control over grain position, grain duration, envelope type and pitch. It also includes octave and fifth harmonisation. This type of processing facilitated the diffusion of the sound across the loudspeaker array enhancing the sense of immersion as micro divisions of the sound source enveloped the listener.

> The granulation of sampled sounds in multichannel systems produces multichannel sounds through the placement of several grains among the loudspeakers. The results obtained with such a technique are largely dependent on the characteristics of the sound being granulated and the parameters used in the granulation process. In general terms, however, the results tend to be diffused, although localised, sonic images that can move in the space or be static (Barreiro, 2010, p. 291).

As a result of working with these new technologies the 8-channel workflow was easier and much more intuitive. It had an impact on how I composed space within my music working with the space has a whole rather than being restricted by the position of the loudspeakers. The composition of space develops along with the composition. This was also the first time where I used sound processing tools, where the processed output was an 8-channel sound file specifically spatialised for a ring of 8 loudspeakers. The use of BEASTtools resulted in the composition of space being included at the sound processing stage, whereas previously I had always worked with stereo processed sounds.

[6] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

[7] https://www.birmingham.ac.uk/facilities/ea-studios/research/beasttools.aspx

### *3.2 L-ISA Studio (L-Acoustics) and the Ocean Loudspeaker System*

In 2019 I composed *Frogland* commissioned by the University of Greenwich with funding from the (HEIF) Higher Education Innovation Fund. This was a collaboration between the University of Greenwich and L-ISA (Immersive Sound Art) technology designed by L-Acoustics, led by Dr. Andrew Knight-Hill.

*Frogland* explores the soundworld of Frogs recorded in Florida, USA and Brisbane, Australia. Some of these field recordings were recorded around New Smyrna Beach during the residency at Atlantic Center for the Arts. Composer Rick Nance[8] also attended the residency and kindly allowed me to use some of his frog recordings within the piece.

I used the L-ISA object based panning system to spatialise the audio on the Ocean Loudspeaker System located in their Immersive Sound Art studio in Highgate, London. This 18.1.12 loudspeaker system consisted of "18 Syva scene and surround speakers and 12 Syva Sub speakers."[9] L-ISA have developed their own software, L-ISA Studio which features a 3D controller interface:

> With L-ISA Studio, interaction designers can design and test their interactive environments at the earliest stages of a project simply by connecting the L-ISA Controller to game engines, tracking systems, or other creative solutions via the Open Sound Control (OSC) protocol. The entire design can be tested and presented on a laptop.[10]

L-ISA Studio software included source control plugins and their L-ISA controller application. This allowed us to set up the panning for our work which we would later refine in the studio.

*Frogland* was mixed in Reaper, where each track had the L-ISA VST plugin. Each of the L-ISA plugins has a source ID which is mapped to a source within the L-ISA controller. The plugin allows you to control 3D spatial audio parameters such as Pan, Width, Distance and Elevation. You can also write this automation to the reaper project by moving the sound objects within the L-ISA controller. The L-ISA plugin within Reaper communicates with the L-ISA controller application using OSC. I used mono and stereo recordings within the work where sound sources were placed on fixed points within the space or spread across multiple loudspeakers. 360 degrees panning further facilitated and enhanced movement and gestures within the work.

Once I got to the L-ISA studio I was able to load my saved L-ISA controller session on to their studio computer where I could then refine the spatial mix. A L-ISA technician assisted with the setup where the L-ISA controller was on a touch screen. This of course meant I could move objects through the space with my fingers rather than using a mouse.

[8] Rick Nance Bandcamp Page https://acousmaticart.bandcamp.com/album/inquiet

[9] L-ISA Ocean Sound Spaces specification sheet, https://creations.l-acoustics.com/uploads/2022/07/Ocean_SPS_EN_1.4.pdf (Accessed 29th November 2022).

[10] https://l-isa.l-acoustics.com/create/studio/ (Accessed 29th November 2022).

Similar to working with SpatGris, the affordances of working with object-based audio resulted in a detachment from a specific loudspeaker layout. With channel-based audio I was mainly thinking about how much of the sound signal should go to one or more speakers. With object-based audio, the focus became more about the placement of sound objects within the space. I started to think about the division of the overall soundscape in terms of smaller sonic events perhaps influenced by the L-ISA interface and the movement of sound objects.

Since I knew that the audience would be moving through the space during the performance the spatialisation of the materials was not symmetrical i.e. working with layers of stereo pairs, with the listener in the centre. This had a direct influence on the spatialisation of the work. I focused on composing smaller soundscapes within the piece which were spread throughout the room, which merged together to create the overall soundscape.

The performance of *Frogland* was featured in a concert of works at the L-Acoustics Studio in High Gate, London. The concert featured works by Dr. Andrew Knight Hill, Paula Fairfield and University of Greenwich students. There was no seating and the audience moved freely through the space, experiencing my composition perhaps as they would a real-world natural environment – free to walk about and listen to the soundscape. Others stood still and closed their eyes. I enjoyed walking through the space during the performance positioning myself within different parts of the virtual soundscape, no longer tied to the mixing/playback console which was in a studio next door. As I moved through the space, I felt I was stepping into different smaller soundscapes made up of multiple sound objects within the overall space. This was considerably influenced by the use of L-ISA's object based panning software and the ability to visualise sound objects within the space thanks to the specific interface.

Back in 2019 L-ISA Studio software would only work with hardware such as the L-ISA processor II[11] which was required to create immersive playback, capable of rendering up to 128 outputs in a 2D or 3D layout.[12] Therefore, the performance of *Frogland* was restricted to the L-ISA studio which had the processor. Due to this restriction, in September 2019 during a residency at EMS Stockholm I remixed the piece using ambisonics so that the piece could easily be adapted to different loudspeaker configurations without using L-ISA Studio software.

## *4. Ambisonic workflows and aesthetic*

> The basic approach of Ambisonics is to treat an audio scene as a full 360-degree sphere of sound coming from different directions around a center point. The center point is

[11] This has changed now, and the L-ISA studio will work without the processor. A very recent review of L-ISA studio can be found here: https://www.mixonline.com/technology/l-acoustics-l-isa-studio-review

[12] L-Acoustics L-ISA Studio 2.4 – A Real- World Review, Part 1 - mixonline.com/technology/l-acoustics-l-isa-studio-review (Accessed 6th December 2022).

> where the microphone is placed while recording, or where the listener's 'sweet spot' is located while playing back.[13]

> Ambisonics is a system of sound reproduction based on the spherical harmonics of the sound field. The more spherical harmonics, or in other words the higher the order of representation (high order ambisonics, or HOA), the greater the spatial resolution over a larger listening area (Barrett, 2010, p. 3).

My journey into ambisonics began in 2016 when I was an artist in residence at Atlantic Center for the Arts,[14] Florida where I had the opportunity to work with composer Natasha Barrett.[15] During these three weeks we explored ambisonic formats and tools, composition workflows and sound field recording. Much of my knowledge and research about ambisonics has come from Barrett who has been working with ambisonics since 2020 and has published extensively about her practice. Over the years I have heard Barrett's work diffused over different loudspeaker arrays and I was always impressed with how she composed and performed with three-dimensional soundfields.

> The simulation and recreation of three-dimensional sound fields (with ambisonic or wavefield synthesis) results in spatial clarification doing away with the ambiguous phantom imaging and allows the direct transmission, without performance interpretation, of spatial information to the listener (Barrett, 2007, p. 245).

During my residency at EMS in 2019, I had the opportunity to revisit ambisonics and everything I had learned from Barrett at ACA. For me the first step was to understand ambisonic workflows in order to create an ambisonic version of *Frogland*. This involved duplicating the *Frogland* reaper session and then replacing L-ISA Source control plugins with IEM[16] ambisonic stereo encoder plugins on each track. Each track was then set to 16 channels as I decided to work in 3rd order ambisonics. All tracks were routed to an Ambisonic Bus which was then routed to 2 different tracks. 1 track had the IEM binaural decoder which facilitated headphone mixing. The 2nd track had the IEM ALLRADecoder which decoded the mix to a specific loudspeaker layout. Since I was working in Studio 2[17] at EMS, the mix was decoded to a 15 genelec loudspeaker array with 9 loudspeakers at listening level, 5 in the ceiling and 1 subwoofer. EMS supplied the JSON file which had the azimuth and elevation co-ordinates for the loudspeakers. This file was imported into the ALLRADecoder which then uses this file to calculate the decoder. ALLRAD can be used to decode any ambisonic order. Now that I had an ambisonic mix of *Frogland* I could use the ALLRADecoder to decode the mix for any loudspeaker layout once I had the coordinates of that loudspeaker array.

[13] https://www.waves.com/ambisonics-explained-guide-for-sound-engineers

[14] https://atlanticcenterforthearts.org/

[15] https://www.natashabarrett.org/

[16] https://plugins.iem.at/

[17] https://www.elektronmusikstudion.se/work/studio-equipment

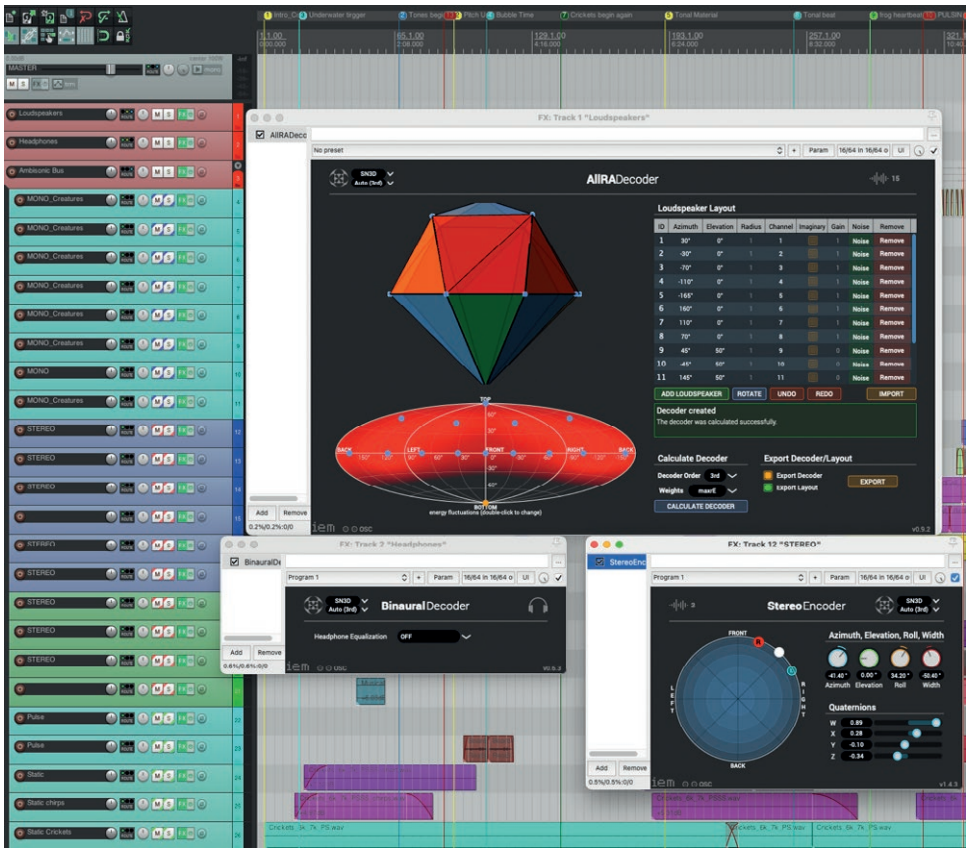


Figure 3. 3rd Order Ambisonic workflow in reaper using IEM Plugins for encoding and decoding.

While I was composing space within a 2D loudspeaker configuration such as a ring of 8 loudspeakers I always thought about space in terms of distance and amplitude. I have previously divided sound materials into different frequency bands where these bands are gradually layered back together slowly enveloping the listener in the original sound. By starting with the higher frequency content and gradually introducing the other layers, ending with the lower frequencies the soundscape is brought closer to listener. However, composing 3D space using ambisonics offers a more realistic interpretation and recreation of specific soundscape. We now have the ability to spread the layers of the soundscape vertically as well as horizontally. We can spatialise the spectrum of sounds within the soundscape vertically along the loudspeaker array i.e. low frequency content on the lower speakers and high frequency content on the higher speakers. This allows us to create a sense of height and depth within our works.

### *4.1 Performance and Adaptability of Ambisonic formats*

In May 2021 *Frogland* was performed at Klingt Gut! 5th International Symposium on Sonic Art and Spatial Audio in Hamburg Germany. For this performance I increased the track channels from 16 to 64 to create a 7th Order Ambisonics mix which created a very large rendered sound file, about 8GB in size. For this online event *Frogland* was played in the 33.2 dome, decoded by the Klingt Gut! team using the ALLRAD decoder and streamed live using the Neumann KU100 which facilitated binaural listening. As organiser Thomas Görne said streaming created "more of the 'being there' effect rather than direct binaural rendering of the HOA files".[18] As I listened to the live streamed concerts, I could hear the paper shuffling as the person was introducing the different pieces. Despite not being there in person I was amazed by the size of the performance space which was occupying my headphones. There were times when I kept looking towards the door of my room as I was hearing sounds almost two metres away.

As a result of this experience, I feel that working with ambisonics makes it easier for composers to adapt their work for different loudspeaker configurations as we take our compositions to different studio and performances spaces. Klingt Gut! proved that despite not experiencing the compositions inside the dome, we could still appreciate the composed space within the works in a binaural format.

## *5. IKO – icosahedral loudspeaker – inside out*

There is a significant amount of work that goes into setting up a high-density loudspeaker array/loudspeaker orchestra/sound diffusion system. So, imagine having one speaker which can project a 3rd order ambisonic sound field. This was my first thought when I was introduced to the IKO[19] icosahedral loudspeaker at the University of Greenwich in 2021. Finally, the idea of setting up a spatial audio concert was a little easier – 1 speaker, 1 speaker stand, 1 amp, 5 reflector panels. The reflector panels are used both in the studio/composition space and the performance space.

> For concerts, the artistic practice evolved to set the IKO up together with reflector baffles. A recent study investigated their effect on the perception of moving transient and stationary sounds. The baffles obviously reduce the signal-dependency by contributing more additional reflection paths, contrasting the direct sound. (Zotter and Frank, 2019, p. 166).

The portability of this speaker means it can be easily set up in a variety of locations such as churches, markets galleries or installation spaces. It is also an example where

[18] Email exchange with Thomas Görne, 21st January 2023.

[19] For more information about the design and research of the IKO visit the OCIL (Orchestrating Space by Icosahedral Loudspeaker) webpage. https://www.researchcatalogue.net/view/385081/958807

the loudspeaker setup remains the same for composing as it does for performance. Of course, the difference lies in the acoustics of the performance space.

> The icosahedral loudspeaker (ICO) is a compact playback device that uses acoustic algorithms to project sound beams into freely adjustable directions, also wall reflections leading to the listener. 'Orchestrating Space by Icosahedral Loudspeaker'(OSIL) aims at increasing the practical and theoretical understanding of electroacoustic sound phenomena in computer music that are defined by their sculptural-choreographic nature, i.e., exhibiting localization, motion, and extent (Sharma et al., 2015, p. 2).

> THE IEM ICOSAHEDRAL LOUDSPEAKER (IKO) consists of an icosahedral housing carrying 20 individually driven loudspeakers and has been built in 2006, originally with the idea to holographically mimic musical instruments (Sharma and Zotter, 2014-2019).

> While surrounding Ambisonic loudspeaker arrays play sound from outside the listening area into the audience, compact spherical loudspeaker arrays play sound into the room from a single position (Zotter and Frank, 2019, p. 153).

## *5.1 Listening to the IKO*

As a Research Fellow at the Sound|Image Research Group, University of Greenwich I had the opportunity to take part in some workshops where we were introduced to the IKO (June 2021). Listening exercises and ear training led by Dr. Angela McArthur played an important role in developing an understanding of how sounds behaved within the space. The IKO possesses a dominant presence within the room often located in the centre. Therefore, it is very clear that the sounds are coming from it. It is important to spend time exploring the space and listening from different positions in order to detach ourselves from the commanding visual presence of this loudspeaker and focus on the movements of sound objects. Closing our eyes really helped while listening to sounds and compositions focusing our attention on the behaviour of the sounds within the space.

Studies carried out by those who designed the IKO have shown how both static and moving auditory objects are perceived by the listener:

> Static Auditory Objects: "The experiments used stationary pink noise and could create auditory objects nearly 2m behind the IKO, which corresponds to the distance between the IKO and the front wall of the playback room. The maximum distance of auditory objects created by the IKO is strongly signal-dependent. Experiment showed that the auditory distance of pink noise bursts decreased for shorter fade-in times, while the fade-out time had no influence. A transient click sound was perceived even closer to the IKO. This can be explained by the precedence effect, that favors the earlier direct sound over the reflected sound from the walls. While this effect is strong for transient sounds, it is inhibited for stationary sounds with long fade-in times" (Zotter and Frank, 2019, p. 164).

> Moving Auditory Objects: "The studies extended the previous listening experiments towards simple time-varying beam directions, such as from the left to the right, front/back or circles. To report the perceived locations of the moving auditory objects, listeners used a touch screen that showed a floor plan of the room, including the listening position and the position of the IKO. They had to indicate the location of the auditory object's trajectory every 500 ms. The perceived trajectories depend on the listening position, but they can always be recognized" (Zotter and Frank, 2019, p. 165).

## *5.2 Composing for the IKO*

As a result of Arts Council England 'Developing your Creative Practice' funding, I had the opportunity to compose a new piece for the IKO in 2022. I also reworked an existing ambisonic piece which allowed me to explore ambisonic workflows while listening and contrasting binaural and IKO (3rd order ambisonic) mixes.

When working with the IKO I really felt like I was composing the space within my work. It takes a lot more time to spatialise the sounds within the space – to create an immersive experience. A lot of my sounds just seemed to sit on the loudspeaker. In contrast, when working in 8.0, if I wanted a sound to come from a particular location, I would pan the sound to that speaker while using eq and sometimes reverb to create a sense of distance and perspective.

This new composition *Aisling* (2021) was part of an AV piece. The visuals created in Unity Game Engine, depicted a virtual soundwalk by the sea and a wooded area with a small river and campsite. The composition was a direct response to the visuals. Sound materials included field recordings of the sea, water lapping, a campfire and forest sounds. Usually, I would restrict myself to a sound library of field recordings which were recorded from a specific place. However, some of the field recordings which included broad band sounds like the sea for example were quite difficult to work with on the IKO. After experimenting with eq and panning, I discovered that slow movement of sea sounds in a circle on the azimuth created the illusion of water lapping and moving across the space. To create a sense of distance away from the speaker, I added some synthesised sound materials which occupied a narrower band within the spectral space. These more detailed sounds such as granulated twinkling water sounds (01'00) (Sound Example 4),[20] birdsong (4'22) (Sound Example 5)[21], musical bamboo-like sounds (03'50) (Sound Example 6)[22] and rain drops (05'53) (Sound Example 7)[23]

[20] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

[21] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

[22] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

[23] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

Figure 4. The IKO with reflector panels at St. Alfege's Church, Greenwich, London.

recorded from Haken Audio's Continuum fingerboard.[24] The addition of these nature-like synthesised sounds really helped to expand the space around the IKO adding detail to the soundscape.

As a result, the piece *Aisling* uses a combination of synthesised sounds and field recordings. With the IKO, I have found it easier to work with synthesised sounds. The combination of both field recordings and synthesised sounds worked very well and removed my purist idea that 'I must only work with field recordings to create this soundscape'.

Of course the spatialisation journey does not stop here. When you take the IKO out of the studio and take it to a church such as St. Alfege's Church in Greenwich, London for example – a reverberant space with lots of reflections. The transition from composition space (studio) to the performance space results in a new listening experience due to the changes in acoustics and our proximity to the loudspeakers. The performance of my piece on the IKO in the church resulted in an overall enhancement and embellishment of the composed space within the work. I heard sounds that I had not heard in the studio. The piece became more immersive as sounds travelled further away as they moved through the big reverberant space of the church. Sounds could be heard about 3 metres in every direction away from the IKO. The composed space

[24] https://www.hakenaudio.com/slim-continuums

Figure 5. IKO with Video project – Performance of AV piece Aisling.

within *Aisling* which had been slowly and carefully sculpted in the studio became bold, brave and more intense within the church as sounds reflected off concrete walls, wooden benches, tiled floors, the glass windows of the church and the reflector panels. It was during this concert that I really heard the potential of this loudspeaker.

## *6. Composing with layers of different spatial formats*

On the 14th of September, 2019 I heard PA Tremblay's acousmatic work, *Bucolic and Broken*[25] at Convergence, International Conference/Festival of Music, Technology and Ideas at De Montfort University, Leicester. The concerts for this conference/festival were held in the PACE Studio 1, a space especially designed for multi-channel diffusion concerts. Within *Bucolic and Broken,* there were many different layers of sounds such as ambient field recordings, piano, tonal materials, delicate rhythmic mechanical textural sounds and synthesised sounds. Some sounds seemed to occupy the whole room, enveloping the listener while others retained their own space within the piece. This was a similar experience to some of Barrett's performances of her work e.g. enveloping soundscapes but with detailed focused points within the piece (*Innermost* ICMC, University of Limerick 2022 *and Speaking Spaces no.1: Heterotopia*, Sonic Cartography Conference, 2022) and I wondered if Tremblay had used ambisonics to spatialise his sounds. I emailed Tremblay to find out more. In our interview style correspondence[26] Tremblay provided detailed answers to my questions, and I discovered that his piece was a hybrid of different types of spatial formats.

> On a different plane, at which technology and aesthetic inform each other, the piece offers a novel way to utilise three competing multi-channel paradigms (third-order ambisonics, cinema 7.1 and classic acousmatic loudspeaker orchestra), where the aesthetic and technical strengths of each implementation are exploited, in the context of allowing the portability of music written for large loudspeakers arrays. Since these are more frequently seen [these days], and that various cultures (cinema, videogame, etc) have started embracing high-count multichannel, this piece offers one proposed avenue to reinvigorate and critique traditional multichannel fixed media, both in the commercial world and in the experimental one (Martin and Tremblay, 2020).
>
> Whereas the precision of point-sources of the classic cinema setup is used to allow full-range, articulated protagonists to dialogue, the more mobile and diffuse sound of the TOA is used to give breadth to these elements, as well as auditory context and fluidity. The use of a quadraphonic real distant loudspeakers, directly from the GRM tradition, allows to give further distance than the other two paradigm which are anchored on a hemisphere, to allow the composition of a depth of field difficultly affordable otherwise. The final work has therefore only 28 channels and has been successfully decoded on systems varying in loudspeaker count, from 12 to more than 100 (Martin and Tremblay, 2020).

Tremblay spent a lot of time composing this piece and testing it in different studios such as "in the SPIRAL (Spatialisation and Interactive Research Lab) of the University of Huddersfield (UK) and in the hemisphere studio of Notam (Olso, Norway), with road tests and mixing in the spherical studio of the University of Hull (UK)".

[25] https://electrotheque.com/oeuvre/41658

[26] https://www.bronamartin.org/spatialaudiointerview1_pat.html

(Tremblay, 2016-17). Tremblay's extensive experiments and research paid off since this is a piece of music that stands out in my mind where I really remember the performance. I have yet to create a piece which uses a hybrid of spatial audio formats. Even working with one format such as ambisonics requires patience and time to develop an understanding of how our pieces might sound when they are taken out of the studio and into different performance spaces with different loudspeaker arrays and configurations. However, it seems this hybrid of formats works in order to achieve a variety of spatial attributes i.e. point source, diffused sound, depth of field.

## *7. Sound Diffusion and Performance: sonic transformations beyond the studio*

Transferring the work from the studio to a performance space offers even more possibilities for the replication and simulation of the original soundscape environment.

> Sound diffusion facilitates the transition of the work between *composed space* and *listening space*. This new listening space, the *diffusion space*, further enhances the illusion of the original soundscape experienced by the composer (Smalley, 1991, p. 123).

> By combining speakers placed at different distances and angles from the audience, loudspeaker orchestras furnish performers with complex possibilities to project and enhance spatial contrast, movement and musical articulations. The performer draws on spectral and spatial changes in the music, loudspeakers of diverse frequency response and power, room acoustics, and how changes in the precedent effect and directional volume influence our perception of the spatial scene (Barrett, 2016, p. 55).

Many of my works have been performed within concert halls on sound diffusion systems such as MANTIS[27] (Manchester Theatre in Sound, University of Manchester), BEAST[28] (Birmingham Electroacoustic Sound Theatre, University of Birmingham) and MAAST[29] (Music and Audio Arts Sound Theatre, University of Kent). This is an opportunity for the composer to perform their work where 'the same type of physical gestures that were used to shape material during the process of composition should be used again in performance to enhance further the articulation of the work's sonic fabric.' (Harrison, 1999, P. 118). We can create even more tension and intensity during the performance as textures gradually become louder as layers are added and diffused throughout the space. This can be achieved by gradually increasing the volume of sound being sent to loudspeakers that are outside of the original studio loudspeaker configuration for which the piece was composed as stereo and 8-channel images are replicated across multiple pairs and rings of 8 loudspeakers.

[27] https://www.novars.manchester.ac.uk/connect/mantis-festival/

[28] https://www.birmingham.ac.uk/facilities/ea-studios/about/meet-beast.aspxs

[29] https://blogs.kent.ac.uk/maast/2019/06/04/maast-introduction/

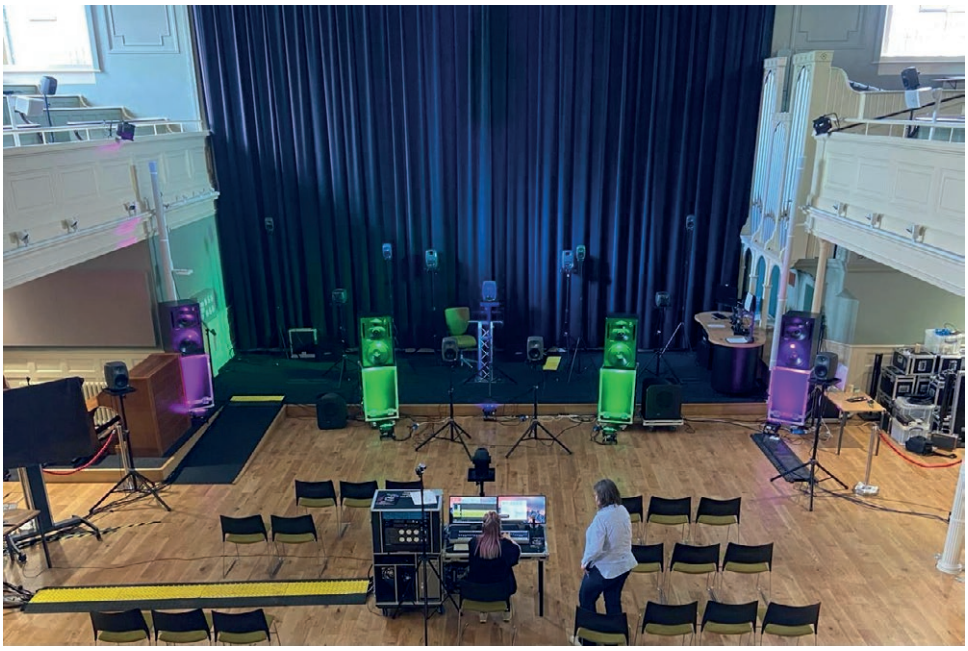

Figure 6. The MAAST System in the Dockyard Church at Chatham Historic Dockyard with loudspeakers located in the balconies. This picture was taken during a diffusion workshop by Dr. Louise Rossiter followed by a concert (https://blogs.kent.ac.uk/maast/2022/05/13/maast-chase-concert/).

### *7.1 Creating a sense of height within the work*

We also have the opportunity to create a sense of height within the work which may not have been possible while composing in the studio on a 2D plane i.e., Stereo, 5.1, 8.0. Depending on the performance space, loudspeakers can be placed in balconies or on very high loudspeaker stands with a high pass filter applied which creates the illusion of sounds rising and moving above us. This can be experienced at a MAAST concert, directed by Dr. Aki Pasoulas, University of Kent. For example, loudspeakers are placed on the balconies within the Dockyard Church at Chatham Historic Dockyard. A high pass filter is also applied to these speakers, adding height and distance to the work as the higher frequencies within certain sounds are enhanced. If there are no balconies within the space, loudspeakers can also be placed on tall speaker stands or ceiling speakers can be used to create a sense of height within the work.

Some sound diffusion systems such as BEAST and BEASTdome[30] at the University of Birmingham have special tweeter tree canopies which create a sense of height within the work. Unlike speakers located in balconies or on higher loudspeaker stands, these tweeter canopies are located directly above the audience. As part of the BEAST

[30] https://beast.cal.bham.ac.uk/offspring/beastdome/

Figure 7. The MAAST System in Slip 3 Mezzanine, Chatham Historic Dockyard for the Sonic Cartography Conference, 2022 (https://research.kent.ac.uk/sonic-palimpsest/sc2022/). Loudspeakers are located on tall loudspeaker stands.

system these speakers are attached to a truss which is then hung above the audience from a lighting grid. Loudspeakers are also placed in balconies when performances are in the Bramhall Concert Hall, University of Birmingham but these do not have a high pass filter applied.

The BEASTdome also includes a ring of tweeter speakers. Some of the speakers are permanently located within the dome itself. This includes an upper ring of 8 loudspeakers (genelec 8040s), Keystone (4 x 8040s) and Tweeter horn speakers in a ring of 8. For concert performances in the Dome, more loudspeakers are added such as, a mains stereo pair (2 x Genelec 1037) and a lower ring of 8 (8 x Genelec 8040).

## *7.2 Diffusing NightEscape on the BEAST System*

At BEAST FEaST 2018, I performed *NightEscape* (2018)[31] in the Bramhall Concert Hall. For me, this performance stands out as one of my most memorable as the soundscape was free to explore and react to the acoustics of this large concert hall. It became

[31] https://beast.cal.bham.ac.uk/beast-feast-2018-featured-artist-brona-martin/

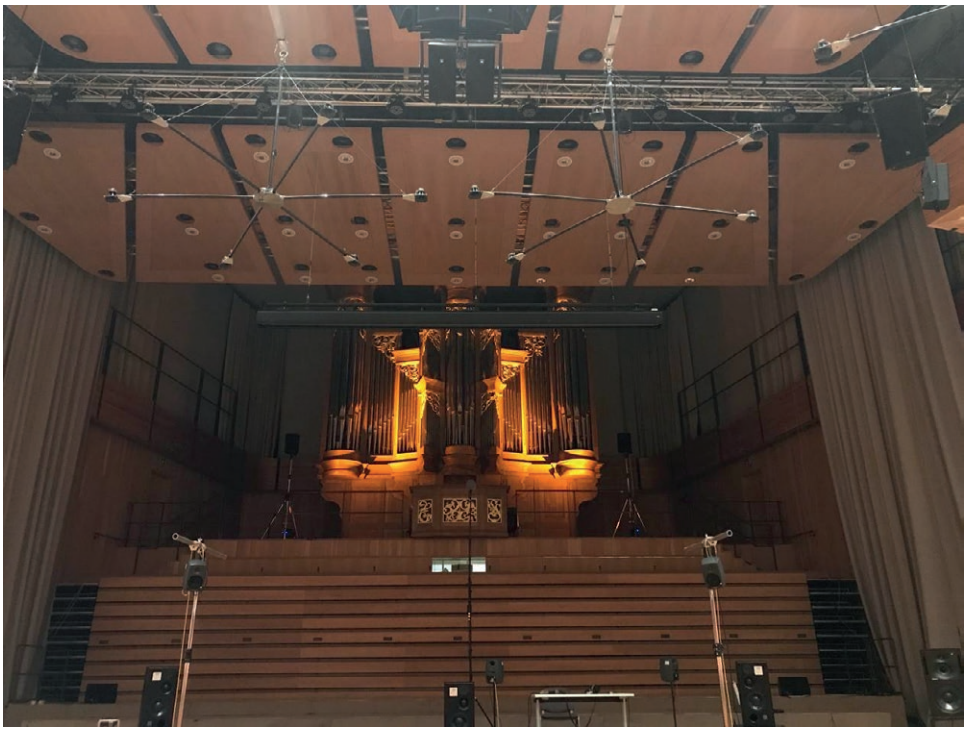

Figure 8. BEAST Tweeter Canopy in the Bramhall Concert Hall, set up for BEAST FEaST 2018 (https://beast.cal.bham.ac.uk/beast-feast-2018/).

even more enveloping as layers of sound were diffused around the audience, some from very distant speakers and some in close proximity to the listeners. Composed for a ring of 8 loudspeakers on a 2D plane, the addition of height and depth enhanced the overall immersion of the piece as sounds could be localised further in the distance such as planes flying overhead creating the illusion of being within a much bigger soundscape.

Within this piece a gradual climax begins (04'24) (Sound Example 8)[32] as a result of tonal material derived from the sound of the plane being pitch shifted upwards creating a sense of expectation. This sense of moving upward was enhanced by placing the sounds in the tweeter canopy above the audience and the speakers in the balconies creating a sense of being elevated within the sound.

## *7.3 Sound Diffusion and Spoken Word*

*A bit closer to home (2014)* has been performed on the 48-channel MANTIS (Manchester Theatre in Sound) diffusion system, at NOVARS Research Centre,

[32] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10252743

Figure 9. BEASTdome concert setup.

University of Manchester and also at the Sonic Lab[33] (Sonic Arts Research centre, Queen's University, Belfast). During the first diffusion of this work on the MANTIS system, I quickly discovered that since channels 1 & 2 were mapped to other loudspeakers including those on the ceiling, I would lose control over the location of the spoken word. This would disrupt the illusion of the narrator sitting in front of the audience, telling their story. In the last few years, I have composed many works which include spoken word such as interview and archival materials. As a result of my diffusion experience, I always create two versions of a composition, one for sound diffusion for performance and one normal playback. The diffusion mix includes a separate render of the spoken word, which will be mapped to a stereo pair at the front (fig 2) resulting in a 4-channel mix, if the piece is stereo and a 10-channel mix if the piece is 8-channel. This ensures that the narrative component does not get lost within the diffusion, ending up on the roof speakers for example.

[33] https://www.qub.ac.uk/schools/ael/Discover/facilities/soniclab/SonicLabSpecs/

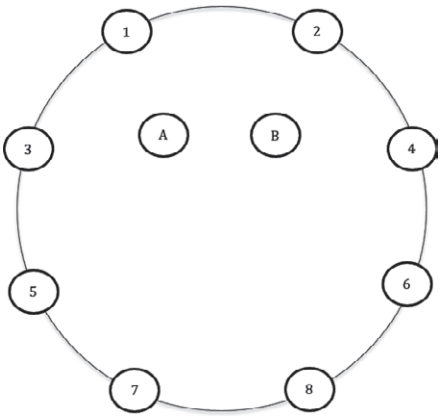


Figure 10. Speaker layout for 8-channel works with spoken word fixed on loudspeakers A&B, while the ring of 8 is diffused over an array of loudspeakers.

## *7.4 Sound Diffusion – Moving sounds below us*

For some diffusion systems such as the MANTIS system the lowest point for a loudspeaker is on the floor, the same level as where the audience are seated. Often smaller loudspeakers such as Genelec 8030As are placed under the seats of the audience so listeners can experience sounds within their 'proximate space'.[34]

The Sonic Lab, at SARC (Sonic Arts Research Centre)[35] University of Belfast is an example of a 'permanent high-density loudspeaker array'.

> Although loudspeaker orchestras, stereo diffusion, and more recently hybrid performance techniques remain alive especially in Europe, there is a trend towards fixed installation, high-density loudspeaker arrays, which I will call permanent-or P-HDLAs to differentiate from loudspeaker orchestra HDLAs (Barrett, 2016, p. 35).

In the Sonic Lab, the audience are placed 4 metres above a ring of 8 loudspeakers and 2 subwoofers. The current system at the Sonic Lab is unique in that "audiences and researchers enter the lab at ground floor level and walk out onto an acoustically transparent, modular grid floor suspended 4m above the structural floor of the lab located at lower ground floor level."[36] There are four layers of Meyer and Genelec loudspeakers – High, Mid Height, Ground and Basement with the audience seated on the ground level.

In 2015 *A Bit Closer to Home* was performed in the Sonic Lab as part of the Sonorities Festival. For this performance the spoken word remained on a main stereo

[34] Proximate space: Space closest to the listener (Smalley, 2007, p. 36).

[35] https://www.qub.ac.uk/sarc/

[36] Sonic Lab Specs, https://www.qub.ac.uk/schools/ael/Discover/facilities/soniclab/SonicLabSpecs/, accessed 5/12/22.

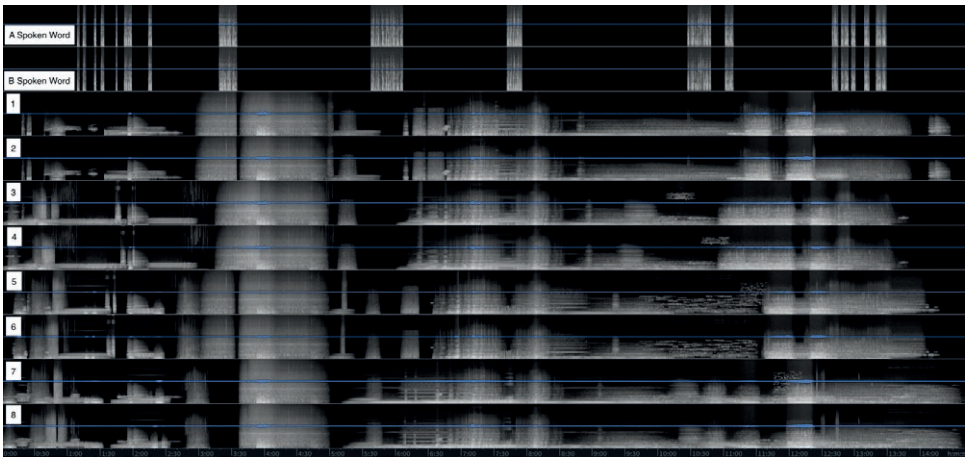


Figure 12.

pair. The rest of the material was diffused throughout the space. This was the first time I had the opportunity to diffuse sounds below me and really explore distance where usually I have focused on diffusing sounds above the listener to create a sense of height. For example, during the 'thunder scene' mentioned above in section 2, sounds were placed in the upper ring of eight loudspeakers. In order to change the perspective from 'distant' to 'close' the amplitude was slowly increased on the mid-high loudspeakers and then on the floor level loudspeakers bringing the sounds closer to the listener gradually enveloping the audience. Sounds of rain were placed in the high ring of loudspeakers while sounds of lapping water were placed in the floor level speakers surrounding the audience. The diffusion of this piece at The Sonic Lab[37] emphasised the spatial characteristics within the piece while enhancing and embellishing the sonic material creating an extended and more realistic soundscape.

## *7.5 Sound Diffusion Aesthetic*

Before a MAAST concert[38] in the Dockyard Church in Chatham Historic Dockyard on May 13th 2022, I had the wonderful opportunity to participate in a Sound Diffusion Workshop facilitated by award winning composer and former winner of the L'espace du son international spatialisation competition (2012), Dr. Louise Rossiter[39]. Rossiter discusses her approach to Sound Diffusion:

> The idea of scenes comes from both my listening and my compositional practice and in particular diffusion practice. So, if I'm listening to a piece of music for diffusion, not

[37] Since my performance at the Sonic Lab, there have been some changes to their speaker layout to accommodate a Dolby Atmos Configuration.

[38] https://blogs.kent.ac.uk/maast/2022/05/13/maast-chase-concert/

[39] https://louiserossiter.com/

> just my own music but also other people's, quite often I spend a long time listening to that music and drawing a diffusion score. The main purpose of that process is to learn a piece but also to pick out the main scenes which I feel are the most important. For example, if you've got a plane in a piece, you would expect that to fly overhead. My job is to make that sound as realistic as possible. Then I have to think about the sounds that go on around the plane. It's about looking at the source of that sound, how that sound has materialised and developed to being there and then fitting those sounds around the main object in that scene to make it make sense. The diffusion score quite often won't have a drawing of a plane in it, but it will have something like 'plane overhead' and that will be higher up vertically on the score. Then you might have some gestural material happening underneath.
>
> When I am rehearsing for diffusion that's when I start to write my directions, what direction things are going to be coming from. The loudspeaker orchestra or collection of loudspeakers are there to facilitate the composers sounds and it's my job as the diffuser to make that work in the best way possible.
>
> In terms of compositional practice, I also do pre composition scores because I'm using image quite a lot as inspiration. The way my mind works, I need to write those ideas down in abstract image form. If you compare the pre composition score to the diffusion score it's built up in scenes so the main gestures and sound sources will be in there. The idea of scenes is almost like a map for diffusion or a map for composition because it not only makes it easier for me to understand but also for the audience. (Martin and Rossiter, 2022)

Rossiter's use of a diffusion score provides a visual breakdown of the piece into various scenes. The scenes will remain the same, but the diffusion will always be dependent on the loudspeaker array and will therefore be different for every performance. I have never used a diffusion score for performance as I feel I have enough to do in listening and managing the faders. However, I feel it is an extremely useful tool in ensuring specific scenes are diffused in certain way which have been planned out in the rehearsal. This is especially useful when we have the option of using over 50+ loudspeakers within the diffusion performance which can sometimes be overwhelming especially if rehearsal times are short.

## *8. Conclusion*

This paper explores the author's experience of composing with a range of spatial audio formats. It also examines the impact of working with new technologies and their influence on the creative process and compositional explorations through space. The application of different tools results in the composer exploring different compositional workflows while examining how these tools both compositional and performance, enhance the composition of space within the work.

From my experience of working with these systems I have found that creating immersive works using ambisonics is an adaptable format for performance since the piece can be decoded for different loudspeaker arrays while retaining the composed

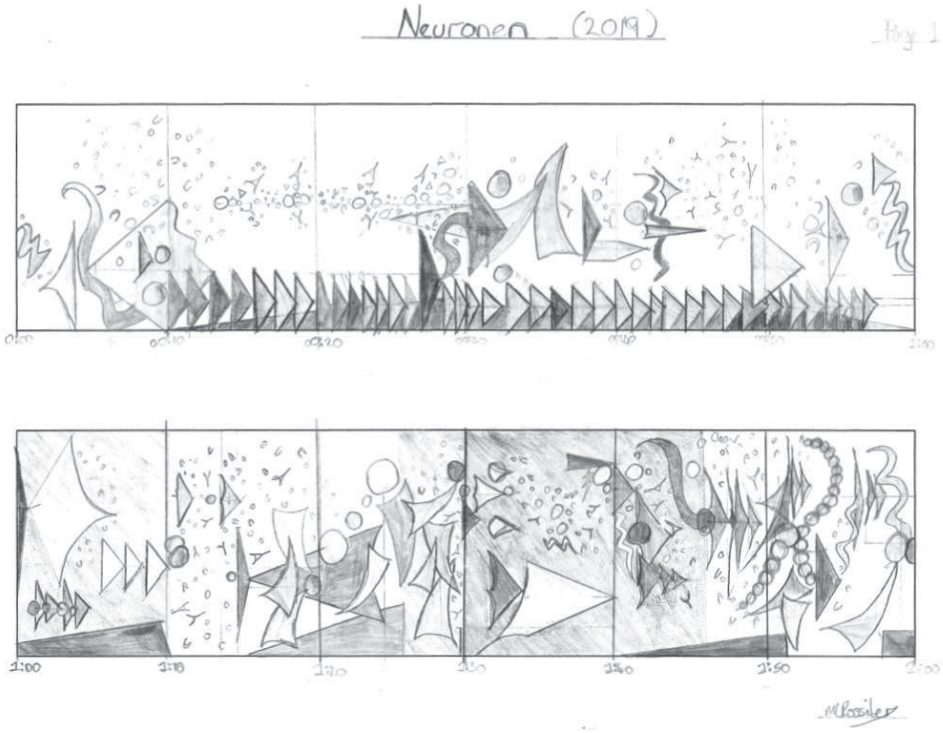


Figure 12. Rossiter's Diffusion Score for Neuronen (2019).

spatial image. Issues such as blurring may arise if the piece is encoded to higher order and then decoded to a lower order of loudspeaker 'due to the reduction of spatial resolution.' (Carpentier et al., 2016, p. 17). However I worked mainly in 3rd order ambisonics so this was not an issue.

The various interfaces used for spatialisation also had an impact on how I positioned my sounds within the space and created the spatial image, placing sounds within a hemisphere rather than along a 2D plane. As a result, I spent much more time composing space compared to creating works for an 8-channel setup. The creation of space developed along with the composition. For example, while composing with the IKO I spent a lot more time spatialising materials to create movement and spatial trajectories while using EQ automation to create a sense of distance. A lot of time was spent positioning sound sources in precise locations. I also began to explore different types of sonic materials other than field recordings which I was not intending to use. Synthesized sounds were easier to work with and spatialise resulting in the addition of detailed sonic gestures which weaved in and out amongst soundscape materials.

Sound Diffusion also allows us to adapt our pieces for different spaces and where the composer has the opportunity to enhance physical gestures and spatial motion within the piece in real-time. However, despite the piece being fixed, this type of performance allows the composer to continue to interact with the sound material outside of the studio. Musical events can be further shaped and embellished while dynamics

within the piece can be enhanced facilitating the adaption of the work for a larger reverberant performance space. Sound diffusion allows me to play with my piece within the space where the sounds are no longer restricted to the confines of the studio.

Regardless of how we perform and spatialise our work, we will continue to learn from each performance. Despite all of this wonderful technology, listening is fundamental in developing our understanding of how sounds behave in space. Alongside listening it is also important that we continue to create opportunities where we can discuss music and compositional aesthetic e.g. in a workshop scenario so that we can learn from each other while engaging with a language that helps us to discuss and listen to works composed for different spatial audio loudspeaker configurations.
Since all performance spaces are different in terms of size, acoustics and loudspeaker setup no performance is the same. With every performance we learn something new about our compositions in relation to the composed space within the work and the spectral content of our sounds.

*Bibliography:*

Barreiro, D. (2010), Considerations on the handling of Space in Multichannel Electroacoustic Works, *Organised Sound*, *15*(3), pp. 290-296.

Barrett, N. (2007) *Trends in Electroacoustic Music. In The Cambridge Companion to Electronic Music*, in Nick Collins and Julio d'Escriván (Eds). Cambridge: Cambridge University Press.

Barrett, N. (2010) Ambisonics and acousmatic space: a composer's framework for investigating spatial ontology. *Proceedings of the Sixth Electroacoustic Music Studies Network Conference Shanghai, 21-24 June 2010.*

Barrett, N. (2016). A musical journey towards permanent high-density loudspeaker arrays. *Computer Music Journal*, *40*(4).

Barrett, N. (2016) A 3D future for Loudspeaker Orchestras Emulated in Higher-Order Ambisonics. *Proceeding of the International Computer Music Conference 2016. Utrecht, Netherlands.*

Barrett, N. and Jensenius, A.R. (2016) The 'Virtualmonium': an instrument for classical sound diffusion over a virtual loudspeaker orchestra. *Proceedings of the International Conference on New Interfaces for Musical Expression NIME'16. Brisbane, Australia*.

Carpentier, Thibaut, et al. (2016). Holophonic Sound in IRCAM's Concert Hall: Technological and Aesthetic Practices. *Computer Music Journal*, *40*(4), pp. 14-34.

Harrison, J. (1999). Sound, space, sculpture: some thoughts on the 'what', 'how' and 'why' of sound diffusion. *Organised Sound*, *3*(2), pp. 117-127.

Ledoux, D. and Normandeau, R. (2018). An Immersive Approach to 3D-Spatialized Music Composition: Tools and Pilot Survey. In *Audio Mostly 2018: Sound in Immersion and Emotion (AM'18)*, September 12–14, 2018, Wrexham, United Kingdom. ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3243274. 3243300

Martin, B. and Tremblay, P.A. (2020). *Spatial Audio: Poetics and Workflows: An interview with composer Pierre Alexandre Tremblay, February 2020 about his piece, Bucolic and Broken*. https://www.bronamartin.org/spatialaudiointerview1_pat.html

Martin, B. and Rossiter, L. (2022). *Sound Diffusion Techniques: Email exchange*, December 2022.

Normandeau, R. and Bélanger, O. et al. (2018). SpatGRIS/ServerGRIS, Creative tools for 2D and 3D sound spatialization. *Proceedings of International Computer Music Conference, 2018, South Korea.*

Sharma, G.K, Zotter, F. and Frank, M. (2014-2019). *Orchestrating Space by Icosahedral Loudspeaker [OSIL].* https://www.researchcatalogue.net/view/385081/958807 (accessed 19th January 2023).

Sharma, G.K, Zotter, F. and Frank, M. (2015). Towards Understanding and Verbalizing Spatial Sound Phenomena in Electronic Music. *Proc. of inSONIC2015, Aesthetics of Spatial Audio in Sound, Music and Sound Art, Nov 27–28, 2015, Karlsruhe, Germany.*

Smalley, D. (2007). Space-form and the Acousmatic Image. *Organised Sound*, *12*(1), 35-58.

Smalley, D. (1991). Spatial experience in electro-acoustic music. In *L'espace du son II*, pp. 121-124. Ohain: Musiques et Recherches.

Tremblay, P.A. *Programme note for Bucolic and Broken, 2016-17*. https://electrotheque.com/oeuvre/41658 (accessed 19th January 2023).

Truax, B. (2001). *Acoustic Communication*, 2nd ed. Connecticut/London: Ablex Publishing.

Truax, B. (2008). Soundscape Composition as Global Music: Electroacoustic Music as Soundscape. *Organised Sound*, *13*(2), pp. 103-109.

Zotter, F. and Frank, M. (2019). *Ambisonics A Practical 3D Audio Theory for Recording, Studio Production, Sound Reinforcement, and Virtual Reality*. Switzerland: Springer.

## *Discography*

Barrett, N. *Innermost* (2019) https://www.natashabarrett.org/Innermost.html

Barrett, N. *Speaking Spaces no.1: Heterotopia* (2021) https://www.natashabarrett.org/Heterotopia.html

Martin, B. *A bit closer to home*. (2014). https://soundcloud.com/brona-martin/a-bit-closer-to-home?in=brona-martin/sets/new-works

Martin, B. *NightEscape* (2018) https://issta.bandcamp.com/album/tides

Martin, B. *Frogland* (2019) https://soundcloud.com/brona-martin/frogland?in=brona-martin/sets/works-2011-2013

Martin, B. *Aisling* (2022)

Rossitter, L. *Neuronen* (2019) https://louiserossiter.com/pages/Neuronen.html

Tremblay, P.A. *Bucolic and Broken* (2016-2017) https://electrotheque.com/oeuvre/41658