Multispatial Sound

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Sound Pavilions

Electronic music, sound and contemporary architectural innovations may seem like unusual partners, but there has been a long history of collaboration between architects and composers seeking to articulate ideas through the combination of these substantive and transitory media. Landmark projects such as the Philips Le Corbusier Pavilion for the 1958 Brussels World's Fair, designed by Iannis Xenakis, the spherical concert hall of the German Pavilion at Expo 70 in Osaka by Fritz Bornemann, Toru Takemitsu's Osaka Iron and Steel Pavilion and Xenakis's extraordinary Diatope installation for *Légende d'Eer*, created to mark the 1978 opening of the Centre Pompidou in Paris, have all combined forms, shapes, lines and contours in both sound, structures and space. These projects united the electronic music aesthetics of the day with architectural thinking, often through links between the abstract geometries used in both fields, common theories or metaphors, but significantly and perhaps most surprisingly, in the spatial presentation of sound and the desire to create architectural sonic constructs.

From a contemporary perspective, and a culture whose iconic technological developments include the MP3 and home surround-

sound cinema, it might seem extraordinary that these early structures inspired composers to work with spatial sound. To me, it's even more extraordinary that the patrons, promoters, curators, and architects also had the foresight and vision to support such an aesthetic investigation over fifty years ago; particularly in light of the enormous technological challenges which had to be overcome to realise these projects.

Relationships between music and architectural spaces stretch far back in history as the construction of our acoustically rich religious buildings testify. Notions of spatial music, or spaces constructed to enhance the presentation of music, are not new. But for electronic music, the monophonic spatial trajectories of Edgard Varèse's five-channel audio for *Poème électronique* diffused into the Philips Pavilion, Osaka's groups of loudspeakers, arranged in a sphere to distribute Karlheinz Stockhausen's *Spiral*, and the seven-channel simultaneous sound tracks of Xenakis's *Légende d'Eer* allowed their composers to move beyond the simple presentation of their work towards a sonic articulation of space. These were not static, frozen forms, in the way that Schelling related architecture and music, but a new ephemeral sound architecture, modulating and changing in the time domain.

Creating the sound systme for *The Morning Line* has been a wonderful opportunity to take forward this legacy and to

employ twenty first century technologies, theories and experiences to facilitate a new sound pavilion for 2010; a platform for new spatial audio art works to be developed, exhibited, heard, experienced and presented in public spaces throughout the world.

Technology

Spatial audio control is technologically challenging and is the subject of intense research in Universities and corporations throughout the world. The most complex spatial audio reproduction techniques (such as Wavefield Synthesis or High-Order Ambisonics) have some way to go before they can leave research labs and become widely applied. These types of technology promises true 3D projections of sound using hundreds of loudspeakers, just as holographic image projections promise 3D film and television. Yet, although these possibilities are some way off, technology has developed sufficiently to create tremendous possibilities for artists to work with spatial sound using large-scale multispeaker arrays.

Clichéd as it sounds, the time of spatial audio has arrived. In addition to the groundwork laid down by early pioneers in the field, recent developments in basic technologies have also made spatial productions possible, and have produced more activity than ever before in this area. This has allowed it to flourish, move away from institutions and one-off

presentations and into the public domain. Surround sound is now expected in many concerts, broadcasts, film theatres and on DVD, is disseminated over the internet and can be reproduced using plug-ins for popular software media players. Advanced computer systems, large file stores and sophisticated, mathematical processing of digital audio by super-fast computers and audio chips, have played their part in this coming of age, but other perhaps less obvious technological developments, have also been important. The professional and domestic desire for surround-sound has inspired loudspeaker manufacturers to consider multi-speaker solutions and new forms of engineering to make smaller, lighter and, importantly, easier-to-position loudspeakers (though someone still has to find a solution to the miles of cable which accompany them). The two monolithic speakers that were the hi-fi alters of 1960s, 70s and 80s listening environments have been transformed into five or more slender surround sound speakers and a discrete sub-bass frequency box.

And if miniaturization wasn't enough, Meyer have recently developed full range, powerful, loudspeakers and amplifiers, shrunk them into a 10cm cube and weatherproofed them for outdoor use - the perfect technology and, in fact, a turn-key development which enables the 47 channel *The Morning Line* sound system to exist.

Spatial audio perception

A desire for spatial sound has existed for centuries, the means and aesthetic concepts have been demonstrated for decades in electronic music and the technological resources to facilitate surround sound are widely available. But, the means and desire to make spatial audio works doesn't necessarily produce a convincing spatial sound experience. One element is missing from this equation – people.

Much of my research (e.g. [1] and [2], published with my former PhD student Dr. Peter Lennox, now of the University of Derby, UK) has shown that having the motivation, spatial audio encoding technologies, speakers, ideas, the means to move a sound from speaker to speaker, to 10 speakers, 100 speakers, 1000 speakers, doesn't necessarily result in sound environments which can be perceived to be spatial, in the way we understand spatial sound.

There are many, many reasons why this is the case, but I'll illustrate it here with one example that was an important consideration in *The Morning Line* sound system design:

Many researchers seeking to understand our perceptual mechanisms have investigated how we use and process information from our various sense organs to make sense of the world. Older models of our perceptual systems were based on

an understanding that our ears, for example, were stimulated by air movement, this was converted into electrical signals which were then fired through a nerve to the brain, where some unknown mechanism untangled the information and calculated out what was heard. This is called a “bottom -up” model of perception.

As our understanding of the brain developed, it transpired that it was impossible for it to process the hundreds of thousands of pieces of information that resulted from our eyes, our ears, skin, nose and mouth simultaneously. Ongoing perceptual research also suggested that more complex mechanisms than the “bottom up” model were at work.

Contemporary models now suggest that our perceptual mechanisms also use information we have learnt, models of behavior and of activity which we hold in our head - referred to as “top-down” information. This can be used to inform not only the interpretation of what we sense, but also *how* we perceive and how we use our sensory systems. Both “bottom-up” and “top-down” information seem to continuously combine in ever changing proportions, uniting experience, prediction and sensory stimuli.

Jarvilehto’s *Theory of the organism-environment system* [3] suggests that the environment and the perceiver should also be

considered as a holistic system – i.e that one cannot isolate perception from environment in which perception is taking place. James Gibson's *Ecological Theory of Visual Perception* [4] also suggests that environmental interaction is important:

> "We are told that vision depends on the eye, which is connected to the brain. I shall suggest that natural vision depends on the eyes in the head on a body supported by the ground, the brain being only the central organ of a complete visual system. When no constraints are put on the visual system, we look around, walk up to something interesting and move around it so as to see it from all sides, and go from one vista to another. That is natural vision..."

Much information about our environment appears to be uncovered through our exploration of it, and audio spatial perception appears to behave in a very similar way to the visual model described above. Unrestrained listening is similar to Gibson's ambulant viewer.

Our work suggests that this not just a useful observation, but that it is vital for us to apprehend spatial audio information *at all*.

When we hear sounds, our attention is drawn to them, we move closer, listen from different positions, are drawn to a

distant sound, compare the relative positions between a close sound and a distant sound. Our relationship to the audio world we perceive is also an exploratory and interactive one.

Anomalies often occur where our ability to predict a situation is compromised by the information we observe. Jeff Hawkins [5] has proposed a memory-prediction framework theory describing how our brains predict subsequent events. Some researchers attribute this ability to “mirror neurons” in our brains (discovered by Gallese et al in the 1990s [6]), a specialised neuron specifically evolved to “simulate” actions we have observed. Prediction is also important “top-down” information that can be used to guide and prepare our sensory systems to act efficiently.

Most sound reproduction systems surround the listener with loudspeakers on the periphery of their listening environment. Like stereo, they have a magic seat. This is located in front of the speakers, with your head exactly at the center point and where a centrally positioned sound produces a strong illusion of a “phantom” sound appearing in thin air between the loudspeakers. This is referred to as a "sweet spot.”

A limitation of surround sound systems predicated on a “sweet spot” is that our inquisitive nature often urges us to uncover information about the environment by moving. Our natural

mechanisms prompt us to move our ears, adjust our point of view to gather extra information that could inform apprehension. This is particularly true where we encounter spatially ambiguous information. Fixed perspectives can produce such anomalies which don't conform to our previous experience or our predicted "simulations" of a situation.

Those familiar with Zucker, Abrahams and Zucker's 1984 film "Top Secret" will know of an exaggerated visual illustration of this. One scene features a perspective spoof where a foreground telephone becomes gigantic when put to someone's ear; the illusion is that the telephone is large because it is very close to the camera and the person who answers it is small because they are distant. Our assumptions are foiled because the telephone is gigantic at the same distance from the camera as the person. This illusion only works when the camera is in a fixed position, forcing us to see the scene from a fixed viewpoint. A small movement of this viewpoint would resolve the ambiguity and allow us to understand that there is no distance between the two objects; otherwise we assume, because of our knowledge of the relative size of people and 'phones, that the size anomalies are caused by visual perspective.

Often, our perception of spatial audio anomalies can be quickly resolved by a small movement of our head.

Unfortunately all surround-sound systems provide less information or, worse still, contradictory spatial information when we move from their “sweet spot”. Our natural explorations to seek more information are consistently thwarted.

This was a concern I was interested to address when designing the sound system and computer control for *The Morning Line*. My aim was to create a system where it would be possible for listeners to explore sound and for artists to present sound that might appeal to our spatial audio perception mechanisms. One that would, through exploration, reveal more spatial information rather than less.

***The Morning Line* sound system**

The multispatial sound system of *The Morning Line* consists of a series of audio zones. Each audio zone can contain a large number of sounds, all potentially located or moving independently. The zones are distributed throughout the structure projecting both inwards and outwards. Matthew Ritchie’s open architectural design allows sound to flow throughout. Since sounds are not presented only from a peripheral speaker system, but from many different multilayered speaker configurations, moving around the structure does reveal more information about the spatial distribution of sounds. It is possible to determine spatial perspectives, and sounds which are foreground, background,

close, distant, up, down, near, far, over there, or over here can all be detected. Relative movements of sound, against some background or in relation to the movements of other sounds are also possible, creating a potential for complex spatial interactions and distinct constructs of sonic architecture.

To date, artists have approached the system in a variety of ways: as an opportunity to establish static audio presentations from multiple loudspeakers, to support patterns of geometric sound movements around the structure, as a way to move sound through complex spatial trajectories or to choreograph polyphonic sound movements. Some have re-created natural environments by developing multizone audio soundscapes for listeners to explore.

The software engineering team at the University of York's Music Research Centre (MRC York, UK)* worked with me to develop the computer system which controls all the sound spatialisation and reproduction of these works. The software is built on the commercial Max/MSP platform and controls all aspects of the audio system, from exhibition schedules to specially designed creation tools which allow artists to make and control the spatialisation of their work. The software reproduces multiple sounds, creates surround-sound environments, and can control the simultaneous movements of hundreds of sounds throughout *The Morning Line*. Several audio

technologies have been combined to make this possible, including Ambisonics, Vector Based Panning technologies (originally developed by Ville Pulkki at Helsinki University of Technology), and a series of bespoke panning algorithms developed by the MRC York team specifically for *The Morning Line*.

Many of the spatial audio creation tools connect with the act of drawing, a feature of *The Morning Line's* conception, and can realize lines, curves, and paths as trajectories or distributions of sound.

Walking through spatially polyphonic sound fields is a powerful experience. Listeners' relationships to music and audio materials are now not so far removed from the complex audio world that surrounds us. This creates a potential to explore and to engage intimately with audio art.

I'm delighted to say that the ambulant listener, suggested by our theories of spatial audio perception, miraculously appeared during the preview of *The Morning Line* at the Seville Biennial of Contemporary Art in 2009. Listeners were observed walking, strolling or marching round and around *The Morning Line*, drawn from one sound space to the next, hearing something interesting in the distance, approaching it, moving away, listening from near and far, from inside the work and

from outside, within a the piece or observing the resulting audio architecture from a distance. It was very exciting for me to see people engaging with sound projection in this way, and as artists become more and more familiar with the complexities and new possibilities afforded by multispatial sound systems, I hope we'll see the development of ever more engaging and complex works of spatial audio art in the future.

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