MULTI-DIMENSIONAL SPATIAL SOUND DESIGN FOR 'ON THE STRING'

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ABSTRACT

"On the String" is an installation-performance scored for sound sculptures, real-time synthesis, musicians, light display and an immersive sound diffusion system. The composition, inspired by String Theory, called for the design of an immersive sound design that could be flexibly adapted to different diffusion situations. The software design aimed to realise a concept of sonic objects moving in four-dimensional space. The paper describes loudspeaker setup and software implementation of the work. Other aspects of the work, such as composition, sculptural elements, real-time synthesis, staging and light design, have been described in [4]. A DVD is available [3].

1. INTRODUCTION

"On the String, theatre of music" is an installation-performance with sound sculptures, virtual instruments, *pipa*, harpsichord, string ensemble, light display and an immersive sound diffusion system consisting of more than 60 loudspeakers (Figure 1). By 'theatre of music' we refer to a narrative structure based on theatrical devices, yet firmly driven by musical motivations. Meaning is primarily construed through sonic and musical objects, and not through the conventional mechanisms of theatre. The concept is discussed in [6] and has been explored in our earlier works such as [5] and [7].

Figure 1. Stage shot of "On the String" at Esplanade, showing the two sound sculptures, "Corridor" and "Canopy", featured together with *pipa* and harpsichord.

2. A MULTI-DIMENSIONAL METAPHOR

Edward Witten uses musical metaphors to explain the notion in String Theory that,

> particles in the universe are composed of loops of vibrating strings. Like a violin or piano string, one of these fundamental strings has many different harmonics. In string theory, harmonics correspond to different elementary particles. If string theory proves correct, electrons, photons, and neutrinos are different due to changes in the vibrations of the strings. [12]

The description of one-dimensional tiny vibrating loops of energy conjured up an aural image of multiple strings in microtonal movement, evoking a fantasy of what the fundamental building blocks of the universe can sound like. What sort of sounds would vibrations of one-dimensional objects produce? We decided to work with notions of scale, time and spatial dimensions. Both by subject matter and compositional material, "On the String" is a journey from the tangible reality of everyday soundscapes towards events on subatomic scales. The 9 movements let the audience listen in on molecules, leptons, quarks, dark matter, and the vibrating strings at the heart of String Theory. The 6th movement, "Graviton Dance", draws on a concept of 4 'large' and 6 'curled-up' dimensions of space. Metaphorically, the 'sonic gravitons' are moving in mathematical Calabi-Yau space. Over the last 3 movements, the process is reversed, and the listener is brought back to the human-sized world.

3. SPATIAL SOUND DESIGN

The composition called for the design of an immersive audio system that could be flexibly adapted to different diffusion situations. Paralleling the designs of sculptures, staging and lighting, our spatial imaginings started with 'virtual sonic sculptures' as 3-dimensional structures (see Figure 2) into which sonic activity and movement of sources could be injected.

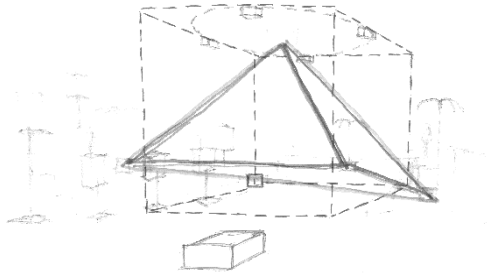

Figure 2. Early draft of 'virtual sonic sculptures'.

We then developed ways of morphing between sonic sculptures, using various gestural interfaces or algorithmic spatialisation. Simultaneously with the composition and diffusion design, we developed the physical loudspeaker setup, first in a full-scale rehearsal venue, then finalised at the performance Black Box theatre. The audience was seated in a horseshoe formation, on three sides of a central stage. In order to realize the idea of a 'fourth dimension of space', we created an immersive audio environment with overlapping 'Global' and 'Local' zones, and the possibility to morph between them.

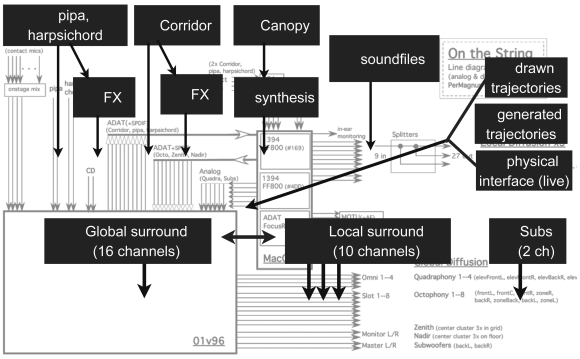

Figure 3. Audio flowscheme for "On the String".

The 'Global surround', enveloping the whole space, comprised of 16 channels: low octophony, elevated quadraphony, central nadir and zenith points, and two subwoofers. The layout is shown in Figure 6. The speakers of the low octophony were placed 30cm off the floor at the corners and sides of the room. As Kendall has pointed out, "[o]nly very low-frequency narrow-band signals localize below the floor and only very high narrow-band signals localize at the ceiling." [2] Signals to the low octophony were gently filtered (highshelf -4 dB at 2.5kHz) to strengthen the perception of sounds emanating 'from below'. The elevated quadraphony was flown from a ceiling grid. Again, signals to these speakers were filtered, and it was found that in this case, more filtering was needed for the overall vertical image to be satisfying (highpass -12 dB at 50 hz, 6dB/octave). As can be seen in the layout, the quadraphony speakers were placed halfway between the corners of the square stage area and the corners of the room, facing inwards and tilted towards a central 'sweet spot'. The quadraphony is thus narrower than the octophony, the overall Global shape approaching a pyramid. This turned out to be the optimal compromise after testing several different possibilities; an important consideration was the need to maintain consistency between all audience positions. Obviously, no listener occupied the sweet spot, and the effect produced by spatial movement within the elevated quadraphony (e.g. circles) heard at the audience seats was described as 'panning' between a 'remote, elevated *left*-right' pair, coupled with a 'close, overhead *right*-left' pair, the latter having a 'muffled sound' due to the cabinet masking effect. Nevertheless, it was possible to create satisfactory spatial images and movements with the quadraphony, in particular when the larger and audience-enveloping octophony was also engaged. The nadir-zenith pair was succinctly described as a 'pillar'. It allowed for virtual sonic images to seemingly emanate directly from scenic action, and be dispersed upwards or downwards; this was used at the end of the performance. Both points were clusters of 3 loudspeakers each, facing the three audience zones, with appropriate filtering applied. The two subwoofers received low-passed signals from the 'left' and 'right' halves of the octophony, and had independent gain control that was used in the live diffusion at certain points.

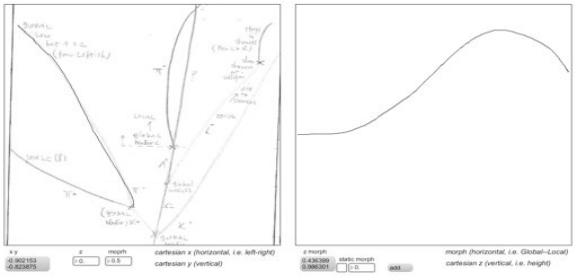

Figure 4. Patcher to draw spatial movements. To the left is the source's trajectory in the plane. To the right are its *elevation* and *morph* parameters.

The 'Local Surrounds', enveloping each of the 3 audience zones, were also conceived for fully immersive diffusion and used 10 channels. The idea was to create something of an 'extended home theatre'. In the plane we placed 7 full-range monitor speakers approximately evenly distributed along the periphery of a slanted oval. Below and behind the raised last row of seats, a speaker was placed lying down, facing the stage and tilted upwards at a 45° angle.

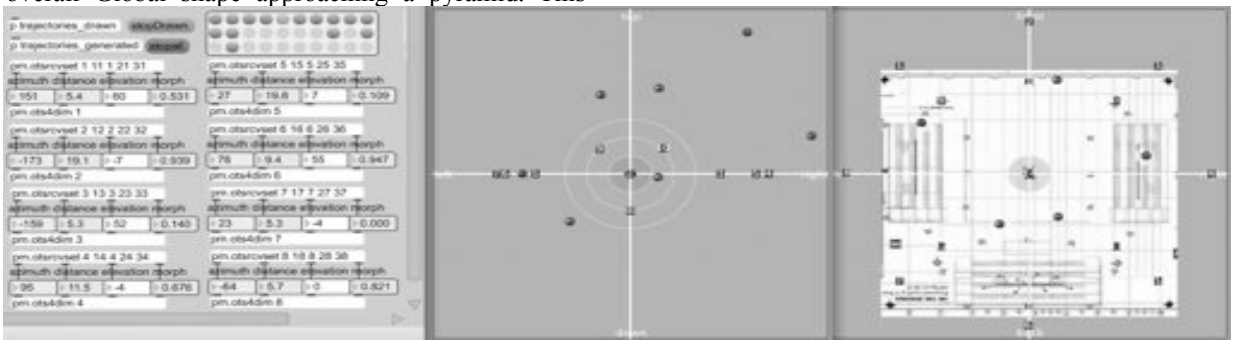

Figure 5. Spat~ interface with 4-dimensional position data for 8 live sources.

Above each zone we hung a set of 'Shower speakers', each being a custom-made array of 8 small loudspeakers, covering approximately 3m x 1.5m. Similar installations have long been part of loudspeaker orchestras, e.g. the *Acousmonium*. The Showers were fed 2 channels of audio, and each loudspeaker was set at a fixed left-right panoramic corresponding to its position, so as to create the effect of a diffuse 'overhead left' and 'overhead right'. As Stefani and Lauke point out,

> small loudspeakers can be placed underneath seats or very close to the audience without risk of ear damage to create dramatic invasions of personal space and to contrast large spatial gestures with small, intimate sonic events. [10]

We employed such effects at different points in the performance. The 3D Local surround thus comprised of a 7-point surround in the plane together with a 'standing triangle'.

The software part of the diffusion design connected the two surround systems in a concept of 'four-dimensional spatiality'. The main MaxMSP patcher employed two *Spatialisateurs* [1] in parallel: one for the Global, and one for the Local surrounds. The two spaces were defined, respectively, by fixed loudspeaker positions and reverberation characteristics (that changed over the course of the piece). The position of each sound element (source) was given by 4 parameters: the usual *azimuth*, *distance* and *elevation*, plus a fourth called *morph*, determining the amount of crossfade at the input to the two *spat.spat~* objects. VBAP [9] was used as spatialisation method, and the reverberation parameters, changing for each movement, were tuned to further the impression of sources 'morphing' between a large, global space and the small, local spaces. The setup made it possible to position a sound object between Global and Local surrounds while keeping its 3D directionality, thus emulating a fourth spatial dimension. In all, the real-time spatialisation engine received 8 live sources and 8 channels of pre-recorded soundfiles, and distributed them over 26 output channels towards 65 separate loudspeakers. An overview is shown in Figure 3.

The performance's third movement was based on the idea of elementary particles moving and colliding, as captured in bubble chamber images. To create 'sonic particles' of different strands, we made recordings of friction sounds, such as scratching on *guqin* strings. We mapped the particle trajectories directly onto the immersive environment, aiming to give the listener an illusion of being inside a bubble chamber. We developed a MaxMSP patcher, shown in Figure 4, to draw (e.g. with a Wacom tablet) particle movements directly on top of a bubble chamber image. Data for a number of four-dimensional trajectories were stored in *coll* files. During the performance, the files were triggered together with a soundfile, and the spatialisation data were automatically adapted to its duration in order to recreate the movement in space.

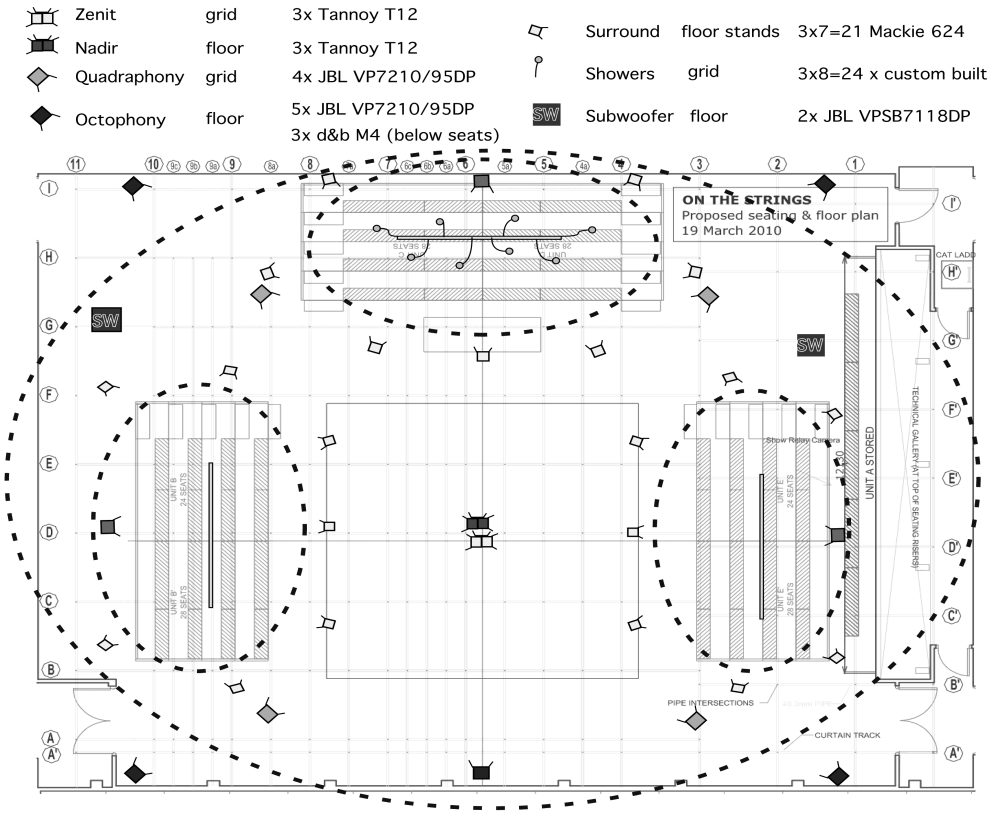

Figure 6. Top view of the loudspeaker layout, showing the 3 Local (audience) surrounds and the Global surround. The central square is the stage, measuring 8m x 8m.

For the "Graviton Dance", we developed another patcher to generate spatial trajectories algorithmically in real-time. To maintain compositional consistency between frequency and spatial parameters, it used the same data for the spatial movement as for the underlying sound synthesis.

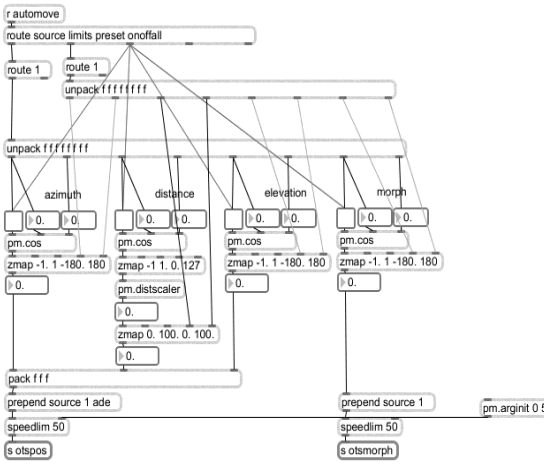

Figure 7. Patcher for automatic generation of source spatialisation.

4. CONCLUSION

The multi-dimensional spatial design in "On the String" echoes the multidimensionality of String Theory. The software and physical loudspeaker diffusion system enables metaphorically a concept of 4-dimensional space. The number of loudspeakers to use is a question of spatial resolution. Sound is what we perceive as space; space is primarily understood through the medium of hearing. In our daily existence, auditive space perception is largely subconscious. By contrast, in the context of an art piece, we can lift this kind of sensation to the surface of consciousness, and let it be infused with meaning.

Trevor Wishart has described musical processes in some of his works as unfolding in multiple dimensions of 'dreamspace' (e.g. [11]) with sound as a vehicle for a journey into a psychological drama of conditioned associations. "On the String" offers another kind of journey, this time into musings and metaphors around theoretical speculation on the relationships and workings of the tiniest conceivable specks of matter, the vibrating one-dimensional units of energy expressed as strings. What are these objects? The mathematical formulae might be beautiful approximations with as yet unknown factors, and presenting the theory in simple terms is hard, though [8] is in parts approachable. Some have called String Theory a purely speculative construct, while others maintain the possibility of testing its predictions in experiments. Be that as it may. For musicians, the paradoxical is a fertile terrain and we thrive on exciting difficulties. We challenge ourselves to imagine the music of a ballet choreographed for unobservable, mysterious sound objects wrapping themselves in six curled-up dimensions of imperial clothing while travelling four limitless dimensions of space, their dance somehow enabled through the innards of time.

5. ACKNOWLEDGEMENTS

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