Compositional Approaches to Spatialisation with the speaker.motion Mechatronic Loudspeaker System

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Abstract

This paper describes compositional approaches to working with the new speaker.motion mechatronic loudspeaker system. The spatial affordances that come with the new loudspeaker system require new compositional ideas to explore the dynamic use of spatial attributes in electronic music. The speaker.motion system is first introduced and the communication protocols that composer use to control the system are discussed. The paper then continues with two case studies describing site-specific compositions that have been developed for the speaker.motion system each of which uses the spatial affordances of the system at the fore-front of their creative output. In assessing the compositional strategies of the system the paper also includes discussion provided by other composers who have utilized the speaker.motion system and their thoughts on the new ways it affords spatial performance and composition approaches. The paper then concludes with the future directions of both the system and the development of compositions for it.

Keywords

Mechatronic Instruments, Spatial Performance, Interface Design, New Loudspeaker Systems.

Introduction

The speaker.motion system allows dynamic directionality changes of four loudspeakers. The new approaches and affordances of the speaker.motion have been explored through the composition of new musical works with dynamic spatialisation as a key aspect of the piece, as well as through a user study completed by composers utilizing the system. The new spatial affordances of the speaker.motion system have catalyzed new compositional approaches to dynamic spatialisation in particular in regards to the composer/performers active engagement with the physical properties of the performance space.

The concept behind this new instrument is the development of a tool to further allow composers and performers to actively manipulate the way sound travels through a performance space as a part of their piece. speaker.motion is a mechatronic instrument that has been designed to allow real-time manipulation of the sound projection vector of a loudspeaker. By dynamically manipulating the directionality of the loudspeaker, the composer/performer is able to use the way sound travels through and reflects around the physical area of the performance space, which affects the way that the audience perceives it.

Spatial Composition

Spatial composition has a long tradition within the development of electronic art music. Composers such as Schaeffer, Stockhausen, Cage, Xenakis and Tudor have embraced spatial relationships in their works. Throughout these early spatial experiments in electroacoustic music, a number of avenues for spatial expression can be identified. These avenues continue to be the basis for contemporary spatial explorations.

Spatialisation has also been considered by many scholars as a way to further add layers of structure, emotion and meaning in electronic music. Denis Smalley, Natasha Barrett, and others make a clear distinction between the intrinsic and extrinsic qualities of a sound (Smalley, 1997), (Barrett, 2002), (Kendall & Ardila, 2008). They argue that the intrinsic qualities of sound are those that are inherent within the sound itself, such as, its timbre, dynamic qualities, or spectrum. Similarly, the extrinsic qualities are the sound's ability or tendency to point the listener's mind towards a real-world equivalent to the sound. This might be something with which the listener is familiar that could possibly produce the particular sound, or a sound similar enough for the listener to immediately create an association in his or her mind. Composers are often aware of both the intrinsic and extrinsic qualities of sounds in their pieces, and they exploit and manipulate these associations for aesthetic or structural reasons (or sometimes both). These same

intrinsic and extrinsic properties are also evident in the spatial domain. The intrinsic spatial aspects of a sound are the individual resonant properties of a sound source as well as the compositional creation of a spatial illusion. The extrinsic spatial aspects would then be a spatial allusion where the intention is not to have the listener believe that they are physically in the space being alluded to, but to have a tendency to point the listener's mind in that direction. In the same way, composers can use the knowledge of the effect of spatial intrinsic and extrinsic qualities of sound in order to create friction (by specifically rejecting what is expected spatially) or resolution (by adhering to the listener's expectation of a spatial quality).

Many scholars of spatial theory have focused on distinct spatial locations in sound spatialisation practice. In 'On Sonic Art', Trevor Wishart extends this to the idea of spatial motion in composition, arguing that, in fact, many sound sources are in need of some spatial motion in order to be recognised (Wishart, 1996). A static bee humming, for instance, will often not make the listener think of a bee, but when it appears to be moving around a space, the listener is more likely to associate it with the image of a bee. The spatial metaphor of frequency (high frequencies come from above, and low frequencies come from below) often gives composers the ability to either compliment or contradict what can be expected, and therefore can be used to create conflict and resolution within a piece. The tenth chapter of 'On Sonic Art', 'Spatial Motion', proposes many possible potential sonic trajectories and discusses how they may be used to deepen the portrayal of meaning and emotion in music. However, in practice, many of these potential spatial trajectories are difficult to achieve. One of the major motivations for the research presented in this paper is therefore to create ways for composers to more easily generate advanced spatial trajectories, particularly in real time. With the speaker.motion system affording the added element of dynamic manipulation of the directionality of loudspeakers, composers can add a further layer of decipherable intention to their work, as conceptualized by the scholars mentioned above.

A number of extensions to traditional loudspeakers have been made over time. For Kontakte, Stockhausen placed a loudspeaker on a turntable and recorded the sound of the speaker whilst it was in motion (Maconie, 1990). More recently, Dan Trueman and colleagues developed hemispherical loudspeaker arrays as a way of simulating, in electronic instruments, the complex acoustic radiation patterns created by acoustic instruments (Trueman, Bahn, & Cook, 2000). These hemispherical loudspeakers also allow electronic musicians to create the same point source localisation when collaborating on stage that would be experienced through localising sounds to specific instruments in an acoustic orchestra. The hemispherical arrays have been used extensively in laptop orchestras and robotic music ensembles. While not necessarily the original intention, the shape of these loudspeakers does allow musicians to conceive of spatial trajectories by creating specific panning patterns throughout the individual cones of the loudspeaker unit.

The spatial elements of hemispherical loudspeakers have been explored in more depth by Gerriet Sharma and colleagues, who have used their icosahedral loudspeaker system as a way of spatialising sound (Sharma, Zotter, & Frank, 2014). This is accomplished through the creation of complex spatial trajectories with the individual cones of the icosahedral loudspeaker as well as by positioning thespeaker array in the room in particular ways to allow the composer to manipulate room reflections.

Speaker.motion System Design

speaker.motion is a system of four mechatronic loudspeakers (Johnson, Norris, & Kapur, 2016). Each loudspeaker can rotate in either direction infinitely and can also simultaneously tilt. The *speaker.motion* system includes four identical units that can be used individually or daisy-chained together.

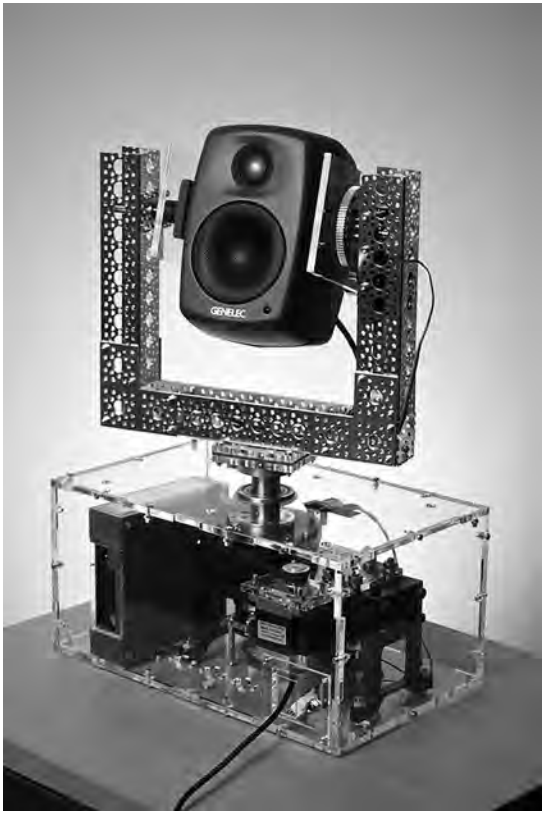

Figure 1. The speaker.motion mechatronic loudspeaker

Each unit features a Genelec 8010A loudspeaker mounted in a purpose-built mechanical structure. The loudspeaker itself is mounted inside a gimbal -like cage structure that gives the loudspeaker the desired azimuth and elevation control. A miniature servomechanism mounted on one side of the cage drives the loudspeaker's tilt, and a stepper motor drives the rotation of the entire cage. By rotating the full cage structure, *speaker.motion* is able to adjust both the tilt and the rotation simultaneously. Where possible, the moving parts are all mounted inside the enclosure underneath the cage. This design helps with structural stability, protection of the mechanical parts, and safety concerns by limiting access to moving parts. The design also contributes to the visual aesthetic component of the system that draws attention to the loudspeaker itself as the gesturally active object.

Compositional Approaches

The unique qualities of the speaker.motion system allows composers to interact with space in new ways. To fully explore the spatial potential of the system a range of new compositions were developed with not only cite specificity in mind but also instrument/loudspeaker specificity. The creation of these works involved an adjustment of the compositional process to better incorporate the instruments novel capabilities. This new process and the resultant works are discussed in the subsections below. The observations about the spatial affects in the following compositions were made through the author's observations and personal listening experience. Due to the unique spatialisation techniques utilized in the pieces, audience members at varying physical locations throughout the performance venues would have experienced these spatial effects differently.

Music for Mechatronic Speakers

The piece is composed entirely of mechanical sounds made by the speaker.motion units. Any recorded audio consists of recordings of the speaker.motion mechanisms. The main technique deployed in developing the audio element of the piece was an Alvin Lucier-inspired re-recording process. The relationship between the speaker.motion system and the sonic material was evident and iterative from the beginning of the compositional process. This differs to the traditional approach to composition of electroacoustic music which would usually involve first the composition of the sonic material, and then the inclusion of spatialisation techniques and processing for cite specific and system specific aspects of the composition.

In Music for Mechatronic Speakers the speaker.motion unit's spatial movements were first composed and then, as the speaker.motion unit played through these movements, the mechanical sounds resulting from the physical movements were recorded. This recording makes up Audio Track One. Audio Track Two comprises of a recording of Audio Track One's audio played back through the loud-speaker while the unit is in motion. Due to this process of recording the audio emanating from a spinning loudspeaker, the audio levels fade in and out as the loudspeaker spins closer to the microphone. This creates the dynamic pulse that is evident throughout much of the piece. The pulse creates a natural flow to the drone textures produced by the motor's mechanical noises being layered on top of each other.

Audio Track Three continues this process, working through third and fourth layer abstractions of the audio recordings. The only manipulation in any of the audio tracks is in Track Two (where a slight edit has been made to the section of silence 5 minutes into the piece). A recording of the servo has been cut and moved slightly forward so that the listener hears the movements of the servo just before they see the servo move. This gives the impression that the mechanics are responding to the audio, and further emphasizes the lack of distinction between the mechanical sounds and recorded audio.

The piece, which is outlined in Figure 3 begins with only the front two loudspeakers ramping up their speeds to quickly move through a number of pitches sounded by the motor itself to create a melodic line. The audio heard at this stage is the mechanical noise of the system performing the composed movements: no audio is played through the loudspeakers themselves at this point. The speaker.motion units then continue their rotation at a slow rate, with one loudspeaker slightly faster than the other to create a denser harmonic spectrum by the variation in pitch produced by the differing motor speeds. At one minute into the piece, the third and fourth speaker.motion units also begin to slowly rotate, adding further density to the drone being created at this stage by all four mechanical systems.

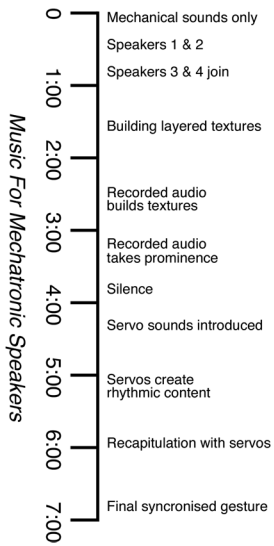

Figure 3. Spatial Structure for Music for Mechatronic Speakers

The physical movement of the loudspeakers implies movement in the timbre of the drone created, and thus is perceived as a subtle pulsing to the drone. At around 1.30, the first hint of any audio being played through the loud-speakers is introduced this is the first shift away from mechanised space. This aims to build the timbral density for just a few seconds and quickly fades back out. At around two minutes into the composition, the recorded audio fades back in, now coming through both front loud-speakers at a louder volume with additional layers on top of each motor that sound as the loudspeakers slowly change their speeds of rotation to continue the melodic change. Though this shift in and out of the mechanised space is present, mechanised space is implied throughout the entire piece as all recordings come from the mechanical elements of the system in their origin. The unique mechanical properties of the speaker.motion system afford this relationship between actual mechanised space and implied mechanised space to be explored throughout the composition.

The mechanical sounds of the *speaker.motion* system were at first considered 'noise' (an unwanted sound). However many composers have chosen to extend and explore this element of the *speaker.motion* system. The fact that the mechanical sounds are created through physical motion (the moving of mechanical parts) gives an ability to infer such motion in any sonic material that occurs at the same time. The MIDI implementation allows such motions to be synchronised with specific sonic material of the composers choosing to explore relationships between the space and motion that is bonded with the sonic material of the piece, and that which is inferred by the physical motion of not only the loudspeaker, but the motor and servo as well. These relationships between mechanised space and implied mechanised space created new ways to explore and manipulate the perceived source and space bonding of the sounding object given that the sounding object was not always clear, and was often implied through a mechanised space, as much as it was through both physical motion (of the loudspeaker) and spatial motion (of the trajectory).

A video and recording of Music For Mechatronic Speakers is available here: http://bridgetdjohnson.com/speaker-motion

Snow All Around

Snow All Around (outlined in Figure 4) was the piece

written by the author for the speaker.motions concert. The compositional process in some ways, followed a more traditional compositional approach, however there was still consideration of the reflective aspects of the performance space and the ability for speaker. motion to project sounds at varying vertical angles. This particularly influenced the development of the rhythmic material in the piece. The rhythmic material was developed in a way that would allow the reflections of the space to varying the intonations of the phrasing, and at times where the speaker.motion system was Snow All Around used an acoustic guitar as the original sound source and digital signal processing to create rhythmic and timbral effects on the piece. The piece used minimal spectral processing to use the room itself as the main signal processor. Reversed guitar strikes were used to create evolving gestural content that resulted in a drone-like effect. The layers of varying drones were created to bring out room resonances of the space and to use the long reverberant nature of the space to add depth to the composition. The introduction of the piece evolves over two minutes. The first major structural change in the piece comes from the introduction of more rhythmic material at two-and-a-half minutes.

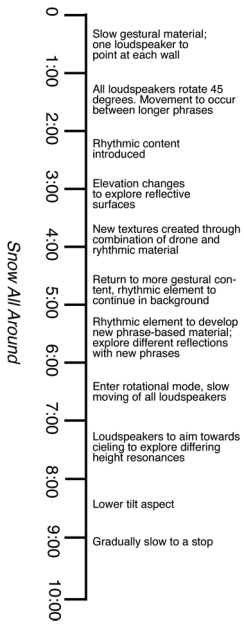

Figure 4. Spatial structure for Snow All Around

This rhythmic material bounced off the walls of the space in different ways depending on the directionality of the loudspeakers, drawing attention to the reflective nature of the space. From the upper floor of the gallery, the rhythmic material was so spatially processed that it merged with the more drone-like material to create layers of gestural content. From the lower levels, the more distinct rhythmic events held their character separate to the drone sounds beneath them. The same audio files played from all four speaker.motion units. The motions of the loudspeakers were subtle and directional rather than programmed for more dynamic motion. Each of the loudspeakers was in positional mode until six minutes and forty seconds into the piece. Throughout this first half of the piece, each loudspeaker had only moved on its horizontal rotational angle four times, each time pointing to a new wall in the space. Such pointing to different walls was intended to allow sufficient time for the acoustic properties of each surface to be explored through varying acoustic material. The vertical tilt parameter was also uniform across all four speaker. motion units, with the loudspeakers largely pointing in variations of upward directions. The aim of this was to explore the variations in the height of the room with the varied acoustic material.

In the second part of the piece, all four speaker.motion units slowly spun in the same direction. This action was taken for further exploration of the acoustics in a more dynamic way. The speed was kept slow so that as differences in the acoustics emerged through the change in loud-speaker directionalities, there was time for these to be explored and the differences between them to be observed.

Figure 5. Performance environment for Snow All Around. The speaker. motion units can be seen in front of the audience

Composers Comments

Six composers of electronic music completed the user study, each of whom had performed with the speaker.motion system. The composers all came from a back-ground in electroacoustic composition and had all performed with other custom-built instruments before. After performing with speaker.motion, the composers completed a user study that asked a range of questions about how they utilized the system and the aesthetic considerations they made both spatially and through their wider compositions. They were also asked questions about their experience as audience members participating in concerts utilizing speaker.motion. The user study was conducted with ethics approval from Victoria University Human Ethics Committee. The user study was conducted in the week following the public performance of new works for speaker.motion and participants responses were anonymous. A total of six composer participated in the concert all of whom had written and performed site-specific pieces for the speaker.motion system.

The response from the user study was positive. All of the composers felt that speaker.motion had changed the way they that thought about space in their compositions and that, having used the speaker.motion system, a heightened level of spatial engagement would now continue in their future compositions. Selected composer statements in response to questions about this area include:

Spatial elements have been a strong element in my compositional process, but what speaker.motion affords is a more complex, dynamic and controllable interaction and intention within the spatial parameters of ideas.

Even without speaker.motion, I feel that I have now been made more aware of the great potential afforded by using non-traditional speaker configurations.

It is possible that the physicality and visual phenomenon of seeing the loudspeaker actually rotate helps to draw attention to the spatial elements of a piece and their compositional intent. These comments suggest that having deepened their spatial awareness through their use of the speaker.motion system, the composers will now continue to think about the spatial aspects of their music in that depth, even when they are not using the speaker.motion system.

All of the composers felt that there were aspects of their piece that they would not have been able to achieve with-out the speaker.motion system. All of the study participants also described ways in which they used the speaker.motion system to engage with the physical space in which they performed, which validates a key design goal of the system. Some composer comments related to this include:

I was able to aim the speakers specifically at the various reflective surfaces in the space. I also found that, by aiming at the more absorbent audience, I could affect timbral change.

By having two symmetrical pairs of rotating speaker, which rotated in different phases, some very interesting phasing effects were created (with the same source sent to each pair).

Five out of six composers also felt that the speaker.motion system drew their attention to spatial attributes as a listener or audience member.

The way composers used space as a compositional tool was much more evident then traditional speaker setups.

The visual coupling led me to consider their use of space more than with a traditional loudspeaker array.

The speakers were brought to life as a very important aspect of the composition, so was the space itself.

When given an opportunity to suggest changes to the system, all of the composers felt that they would like to see the system explored with larger loudspeakers; this is an avenue that will be explored in subsequent iterations. Many composers also suggested that they would like to see further dampening of the mechanical sounds created by the system, another aspect that is intended to be addressed in future versions of the system.

Conclusions

The design of the speaker.motion system was driven by a compositional desire to be able to constantly change a loudspeaker's direction. The intuitive nature of this system was an integral part of ensuring that new spatial aesthetics were not only available to the researcher but also to other composers and artists. *speaker.motion* affords new approaches to spatial composition and performance through its intuitive and novel approach to spatial engagement.

The *speaker.motion* system has now been used by a number of composers in concerts at different physical locations, many of which were described in this chapter. The ability to dynamically adjust the directionality

of the loud-speakers has afforded the composers a new range of ways to interact and engage with the physical space of the concert venue. The physicality of the moving loudspeaker has also proven popular from the audience's perspective. The spinning gestures of the moving loudspeaker can at times appear to be choreographed in a more dance-like fashion, and the character that becomes the loudspeaker has incited a great level of curiosity from the audience members. While variation in spatial attributes may be achieved through synthesizing variation in filter frequency and amplitude within any concert hall, the physical motions of *speaker.motion* effectively make the room itself both a signal processor and an expressive instrument.

Throughout this research a range of experienced electronic musicians used the new *speaker.motion* loudspeaker system. In the user study conducted, a majority of users felt that the system afforded new ways to interact spatially in performance. So far, only a relatively small number of pieces have been written for the system, meaning that there is still a great deal of room for composers to write new musical works that use the *speaker.motion* system and to explore how the directionality of a loudspeaker might be used for aesthetic purposes. Future work exploring compositional approaches with the speaker.motion system includes further user studies that explore not only the specific use of the system but the ways in which the use of such a novel system might impact the compositional process.

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