

There will always be a you: Experiences with Game of Life's mobile Wave Field Synthesis system

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Abstract

In Wave Field Synthesis, wavefronts produced by small speakers in linear arrays are combined in order to physically reconstruct sound fields which are virtual 'images' of arbitrary sound fields. Despite the growing body of technical and theoretical knowledge surrounding Wave Field Synthesis and the growing number of compositions which exploit it, the cost and complexity of the technology have restricted its use to academic or corporate researchers, and its practical and qualitative implications from the point of view of the artist have not yet been widely discussed. Drawing upon experiences working with the mobile Wave Field Synthesis system maintained by the Game of Life Foundation during the development of my piece, *there will always be a you*, this paper will provide insight into the production process and describe how an empirical approach tends to problematise the gap between technical idealisations and the qualitative performance of the technology. Some changes to the software which would allow the artist to manipulate the WFS environment more concretely are suggested.

1 Introduction

Born (1995) and DeNora (2000) have shown how the kind of normative, unproblematic discourse often used by technicians with reference to their work stands in contrast with a critical understanding of the ways that music technologies are used and lived with. But what impact can an idealised technical view of technology's role in music making have on practical use itself? In this paper I begin from the premise that, in the case of sound projection with Wave Field Synthesis (WFS), where a certain enhancement in realism has become one of the main motivating factors in its application, the prevalence of an idealised technical discourse enforces a gap between an artist's 'vision' and the real-world results.

The goal of the research presented in this paper is to develop a way of working with WFS which confronts and closes the gap between theory and practice. I will discuss some of the qualitative consequences of an artistic approach which deals with WFS in a grounded, empirical way, based on the pragmatist notion that art making is primarily an empirical and experiential mode of activity (Dewey 1934). I will also discuss the ways that such an approach tends to problematise the abstract, representational modes of interaction commonly offered to users of WFS control software, and describe strategies for adapting the software which would allow the user a more direct grasp of the actual performance of the system. I will begin by describing the historical context within which my research was conceived and carried out.

2 A Brief History of Wave Field Synthesis

Wave Field Synthesis is a sound projection method in which wavefronts produced by small speakers in linear arrays are combined in order to physically reconstruct sound fields which

are virtual 'images' of arbitrary 'virtual' sound fields. While a detailed technical discussion would be beyond the scope of the current paper, a historical summary will serve to show how the range of applications has changed over time. For extensive technical descriptions, the reader is referred to Berkhout (1988), Berkhout et al. (1993), and Baalman (2008).

WFS was developed by researchers in the department of Acoustical Imaging and Sound Control at the Technical University of Delft in the 1980s and 1990s. Its initial application (as a component of a commercial project known as "Acoustic Control Systems") was in the field of adjustable reverberation for concert halls (Berkhout 1988, Acoustic Control Systems 2009). The use of multiple time-delayed speakers to simulate acoustic reflections in concert halls was not new. ACS was preceded in this respect by the Phillips MCR system (De Koning 1983), and the sound reinforcement system at the Royal Festival Hall (Parkin and Morgan 1970), among others. The difference in the ACS approach, even prior to the invention of WFS, was the attempt to make the simulated reflections spatially coherent.

It has become common to describe WFS as a new theory which was conceived generally for virtual acoustics by applying the Huyghens principle, but it is important to remember that Berkhout and his team had been working in the field of oil and gas exploration for several years when they began to integrate the concept of holophony, previously described in Berkhout's writings on seismic acoustics (1987), into ACS. In its early stages, then, WFS was an application of established seismic acoustic extrapolation techniques to an existing system for adjustable concert hall acoustics. Braasch, Peters, and Valente (2008) have also suggested that the origin of WFS technique may be traced to the theoretical 'curtain of microphones'

proposed by Steinberg and Snow in their foundational work on AB stereo technique, but the similarity between the two approaches is most likely incidental.

The original specification for a WFS array required input from an array of microphones situated on a stage (Berkhout 1988, p. 933), but as research progressed beyond the ACS project during the 1990s, computational techniques began to be developed to model propagation, focusing, and the movement of virtual sound sources (Jansen 1997). Today speaker arrays are commonly used to synthesise virtual wave fields and microphone array technology has developed independently for use in acoustical measurement and analysis. (de Vries and Boone 1999)

The past decade has seen considerable growth in the use and development of WFS technology, especially in Europe. Technical development has been stimulated in large part by the CARROUSO project, established in 2001 as a joint effort of European government, academic, and commercial partners (Sporer et al. 2001). Commercial systems targeting the entertainment industry, such as the Fraunhofer Institute's IOSONO (2009), have also become available. Large-scale research systems have been in development at IRCAM since 2002 and at TU Berlin since 2004. Due to the cost and complexity of the necessary technical resources, the increase in interest among composers and sound artists has largely gone hand-in-hand with the increase in the number of academic installations.

3 Wave Field Synthesis at the Institute of Sonology

The WFS installation currently in use by the faculty and students at the Institute of Sonology was developed by the Game of Life Foundation and is currently housed at the Scheltema arts complex in

Leiden (Game of Life 2009).

The Game of Life Foundation is a group of Netherlands-based composers, headed by Arthur Sauer, which began working toward the acquisition of a WFS system in 2004 after an accident destroyed its mobile octophonic system. As the project developed, the foundation decided to build its own WFS installation, commissioning the assistance of Raviv Ganchrow, who had successfully constructed a small-scale system with control software written in Supercollider as his MA project at the Institute of Sonology in 2004. The Supercollider library and GUI which control the Game of Life system are developed and maintained primarily by Wouter Snoei, another Institute of Sonology alumnus (Snoei 2008). Further technical assistance was provided by Jan Trützschler von Falkenstein, Dr. Diemer de Vries, and by laboratory staff at the Technical University of Delft. When construction was completed, the WFS system had its public debut in concerts at Ghent and Den Bosch during the 2006 November Music festival.

In June 2007, the foundation arranged with the Institute of Sonology to rent a permanent housing of their WFS system, in exchange for which the system would be primarily reserved for student and faculty compositions and research. In 2008, with a quickly growing repertoire and numerous technical improvements, the system toured to festivals in the Netherlands, Belgium, and the UK. To date there have been over 30 finished compositions specifically for the Game of Life system, including some with live musicians, and some using the array in a traditional multi-channel configuration, without the WFS filtering. Training on and use of the system has now been incorporated into the curriculum, and student and faculty concerts are presented on it throughout the academic year. Technical improvements are largely driven by the needs of the students and faculty using the system, the most popular current

drive being towards the development of a stable real-time version of the control software.

4 Technical Overview of the Game of Life WFS system

The Game Of Life WFS system is a mobile, modular loudspeaker array, consisting of 192 loudspeakers which were custom-designed to facilitate transportation and reconfiguration. Each group of eight loudspeakers is mounted on a steel frame which also holds the DACs and amplifiers for the group. Every second group is supplemented with a subwoofer mounted near the bottom of the frame. Smaller speakers are spaced approximately 16.4 cm apart and the height of each group of eight is adjustable between approximately 1 and 2 m. Each loudspeaker group rests on casters to facilitate mobility and configuration. In a normal arrangement, all of the groups are arranged in a 10.2m square around the audience, with gaps of approximately 1m square in each corner.

Audio calculations to control WFS filtering are divided between two 8-core MacPro computers, controlled over LAN by a laptop running the interface software. Interfacing between computers and amplifiers is accomplished using 8 Motu 2408mkIII units and 24 Behringer ADA8000 units. A Supercollider library, maintained by Wouter Snoei, drives the system and provides users with control over source location, directivity pattern (point or plane), movement path, and movement speed either numerically (using a set of Supercollider classes) or graphically (using the built in GUI) (Snoei 2008). Since score files are written in a standard XML format, it is also feasible to generate scores using other software. Position and movement data and sound material must be determined and saved in the proper formats prior to rendering with the WFS system, since the time required to synchronise the computers currently prevents real-time manipulation.

Headphone, 2 channel, or 4 channel auralizations are possible when the library is run in off-line mode (without a WFS speaker array connected).

5 First impressions

My first encounter with the Game of Life WFS system as a listener was at a concert at the system's permanent home in Leiden in November, 2008. The first item on the program that evening was a movement from *Livre du Saint Sacrement* by Olivier Messiaen, played by Winfried Böning at the Dom cathedral in Köln, which had originally been presented as a live broadcast to the WFS system at the Technical University in Berlin and subsequently adapted for the system in Leiden. Multiple microphone positions in the original location were translated into virtual source positions in order to reconstruct the acoustic of the cathedral in the listening room. Listening to this recording revealed a significant gap between the virtual space depicted by WFS and the physical presence of the listener in the listening room.

It is well known that perfect reproduction of WFS is only possible in anechoic or free-field conditions (Berkhout 1988, de Vries and Boone 1999, Corteel 2007). Otherwise, the acoustic characteristics of the listening room play an important determining factor in both physical and perceptual accuracy. Acoustical interference can be reduced by a number of practical methods. Positioning loudspeakers close to, or inside of, the walls of the listening room and dampening the listening room as much as possible can help to passively reduce the interaction of the room acoustic with the virtual acoustic. Active, electroacoustic methods to compensate for room acoustic artifacts have also been devised (e.g., Spors et al. 2004). The Game of Life system, however, is designed for flexibility and mobility, and is effectively agnostic as far as its real-world architectural location is concerned. There is no question of adapting every

possible playback room, and so far there are no systematic adjustments to compensate for room acoustical interference in the software model.

During this first concert, I observed that a common listening behaviour involved adopting a closed position, with the head bowed and the eyes firmly shut, in an apparent effort to complete the holophonic illusion by eliminating visual interference caused by the presence of the speakers. The gap in decay times between the virtual and the real acoustics was always audible whenever an audience member moved or coughed. Since source localisation, if at all possible in the context of such a reverberant environment, would have been just as difficult in the real Dom as it was in the virtual Dom, it appeared that the perceptual effect of the WFS rendering of the Dom's enormous acoustic hinged more on the length of the decay time than on the spatial accuracy of the reflections.

When I had an opportunity to be immersed in the acoustic of the Dom cathedral in 'real life' during a visit to Köln shortly afterwards, I noticed a similar effect. Furthermore, the lighting, the Gothic ornamentation, the smell, the temperature, and the movement afforded to the body by the size of the enclosure, were as important to a spatial impression as the propagation of sound waves. It is clear that hearing and listening are multi-modal activities which are performed with the body, and that purely auditory sensations are not possible (Gibson 1966). The Dom's acoustic, which sounded during the simulation in Leiden like a nebulous wash of reverberation, became completely coherent when experienced 'in context'.

6 Conceptual Overview

By dealing with the WFS system *in situ*, I hoped to couple my design with the actual performance of the system and integrate the sound of the piece with its surroundings as much as possible. The

gap which I perceived between the virtual and the physical in my early listening experiences led me to forgo simulation in favour of an empirical and experimental approach.

The strategy for *there will always be a you* was to situate a single, repeatable action in the room where the WFS system is stored. Each repetition would be recorded from a different position with a single omni-directional microphone. Accumulated recordings would then be distributed in the WFS system as a series of point sources corresponding to microphone positions, and synchronised so that the focal event would occur at the same time from all of the locations at once. No predefined number of recordings was planned.

Aside from being conceptually related to the aforementioned Messiaen recording, the strategy also has historical precedents in art, most notably Robert Morris' 1961 sculpture, *Box with sound of its own making*, a walnut box containing a three hour tape recording of its own construction. The strategy also bears comparison to Gottfried Michael Koenig's *Funktion Gelb* (1968), a four channel piece in which each loudspeaker plays an different iteration of a single algorithm.

Before beginning, I considered many potential 'sound events' for the project. My goal was to sonify the system, the location, and the presence of the various human actors involved, doing so in such a way that the listener might be made critically aware of the interaction of all of these elements. Since I considered becoming aware a temporal process rather than an instantaneous event, and since this suggested a focal point having a certain duration, I decided that my 'event' should be a unified process hinging on the performance of a certain action which could be repeated more or less accurately. The process which I chose, and which gives the piece its title, was to mount the microphone, mark its position on the floor with masking tape, and then use the WFS system to play

back the Donna Summer ballad *There will always be a you* (1979) in 'virtual stereo' (as two plane sources virtually situated in two corners of the array).

My decision to use recorded music, aside from the fact that it would be interpreted by the listener as having a certain predetermined unity, was motivated by a critical interest in the spatiality of music in everyday life. Recorded music is often ubiquitous and 'a-spatial', not attached to a certain time or place, but inherently portable. In a sense, my piece tries to negate the ubiquity which would normally be taken for granted by drawing the music emphatically into the present in which the listener is situated. The ethical and artistic questions opened up by the appropriation of other music in my work are of obvious importance, but beyond the scope of this paper. Suffice it to say that in this context, the act of appropriation serves to situate my work critically with respect to the 'high-low' distinction.

It had occurred to me to work with the song in question approximately a year before in an unrelated context. The decision to use it in the current work was initially intuitive: the strange and alienating kitsch quality of its sound world had a certain dark appeal, as did the outlandish idea of using a relatively obscure disco ballad as if it were a replacement for a sine sweep for measuring impulse response. The results of the experiment revealed to me a deeper level of resonance, particularly with respect to the lyrical content. The repeated title line, addressed personally and intimately to the listener, reminds her again and again of the necessity of her presence. The unashamed sentimentality of a love song stands in stark contrast to the streamlined technical precision of the WFS apparatus.

Most importantly, my strategy was planned to be impossible to carry out without working directly with the Game of Life system in its location. It could be

argued that the piece itself is thus also location-specific. To date, it has not been heard outside of its original location.

7 Production Process

The thirty-three consecutive recordings, sound file synchronisation, and virtual positioning were performed during five afternoons in December 2008 and January 2009 at Scheltema. During the first recording session I was assisted with microphone placement and documentation by Claudia Mannigel, but otherwise I worked alone. Decisions about microphone placement were made *in situ*, usually in response to conditions at the time of recording. Sound insulation in the building is minimal and open doors connect the recording space with adjacent studios which were occupied at various times by sound installations, theatre or dance rehearsals, cleaning staff, and restaurant patrons. Adaptation to these external events played a large role in determining the final outcome of the work.

For each recording, I used the same AKG SE300B microphone with a CK92 omni-directional head cartridge, which I connected to my computer through a portable Edirol FA-66 firewire sound card. The microphone was normally mounted on a boom stand so that the height could be varied between approximately 0,25m and 2,5m. This also allowed recordings to be made in awkward positions where noise and resonance would be emphasised. In four of the recordings, the microphone was removed from the stand to be inserted into ventilation pipes or structural supports. Doors and windows were opened whenever possible in order to introduce noise from incidental activity.

During the first session, I decided to start recording before the microphone position had been marked in order to capture voices, footsteps, and activity that would draw attention to my presence during recording. Eventually I decided to wait deliberately before stopping the recording as well. The

structure of the piece is thus effectively divided into three parts: the set-up before the song, including microphone positioning and false starts; the playback of the song itself; the break-down at the end. Although the duration of the original song is under 5 minutes, the finished work has a duration of 9 minutes and 53 seconds.

Recordings were synchronised off-line using the digital audio workstation software Ardour on Linux (Ardour Community 2009). A prototype synchronisation was done after the first ten recordings in order to evaluate the material and gauge the effect that further accumulation would have. I performed the final synchronisation of the complete series of thirty-three recordings on the last day of recording. After synchronisation, tracks were exported as individual WAV audio files and then sequenced using the GUI in Supercollider. Static virtual source positions on the horizontal reproduction plane were matched to the corresponding microphone positions and the thirty-three synchronised tracks were sequenced to be read simultaneously from the hard disk.

My decision to stop the series of recordings came after this second synchronisation, partly because overall volume had increased significantly, and partly because reproduction began to suffer from timing problems and adding further tracks to the score caused audible glitches. This problem is apparently caused by a known bug in the Supercollider interface which prevents the simultaneous reading of large numbers of files from disk. At the same time, I observed that the combined effect of the recordings produced audible variation at different listening positions, heavy room-acoustical resonance coloration during the middle section, and a delicate and complex texture during the outer sections.

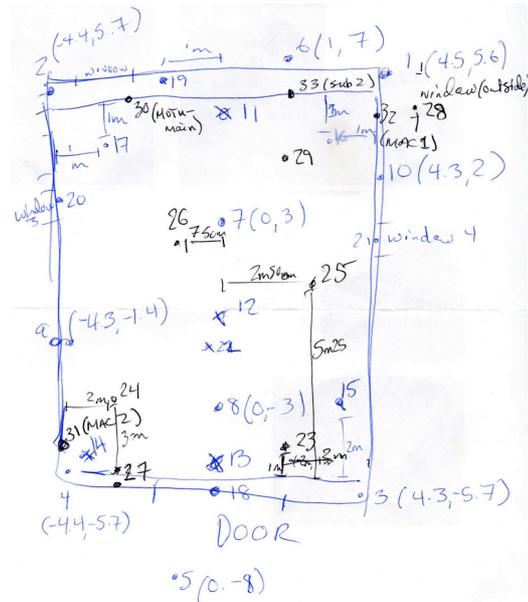


Figure 1. Working map of microphone positions

The first presentation of *there will always be a you* took place in the presence of a small audience at a concert organized by the Institute of Sonology on the 7th of April, 2009.

8 Observations

Listeners have predictably tended to react strongly to the musical absurdity and political audacity of the act of appropriation, but many have also expressed interest in the recording strategy and the resulting perceptual ambiguity. One listener reported having the impression that parts of the piece were coming from adjacent rooms. Another commented that the piece tended to emphasise the 'here and now' of the acoustic situation rather than creating the illusion of another space. My own experience of the piece focused on the fact my own perspective was radically different from that of the audience members. Most importantly, however, I found that certain aspects of the work have brought some of the practical limitations of WFS into focus.

In *there will always be a you*, microphone positions are not sources as such, but openings into the room at different times. Since the sound of the room during listening blends so transparently with the recorded sound, the listener is often unaware of which is which. It is difficult for the listener to hear the positions as 'source locations' at all.

The resolution of human hearing is quite low for detecting source position or following source movement and the detection of distance is normally dependent on qualitative cues (Moore 2003, p. 267). This is especially true when sound perception is considered in isolation from environmental acoustics, cross-modal cues from vision or proprioception, and bodily movement (Zwiers et al. 2001, Gibson 1966). WFS deals with sound projection from a physical rather than a perceptual point of view, and the psycho-physical characteristics of listeners have not been taken into account until relatively recently. Since the virtual WFS sound field is always abstracted from the environment, qualitative and cross-modal cues are often missing, and the purely acoustic accuracy may in fact be lost on many listeners as a result. Recent perceptual testing with WFS systems in blind, anechoic conditions has revealed that listeners are often more likely to hear the source location at the actual speaker than in its virtual position (Wittek 2007, p. 201).

In my work, however, there is no need for an idealised geometrical relationship between listener and point source. The intended effect is rather topological, resulting from the interaction between the sound from each individual aperture (as reproduced by the WFS system) and the sound of the room itself. Overall perceptual ambiguity is intentionally included in the quality of the piece.

Spatial aliasing and irregularity in the dispersion patterns of the loudspeakers could explain some of the ambiguity. Other artifacts might be explained by the Haas effect, since perceived source

position for certain listening positions can depend on whether the reconstructed wavefront or the fragment of the wavefront coming from the nearest speaker reaches the listener first. Distinct 'gaps' are audible in the corners of the synthesis area, an effect of 'windowing' due to the finite length of the array 'aperture' (Corteel 2007). A certain degree of spectral coloration was also observed in the WFS rendering. Such coloration has been shown to effect virtual sources positioned in the near-field in relation to WFS arrays. (Corteel 2007)

The bulk of the spatiality ambiguity, however, does appear to have a qualitative rather than a quantitative explanation. Microphone positions do not correspond to 'object' positions, but are more like holes through which the sound of the entire room is audible. If one encountered such a situation in everyday life, one would be unlikely to interpret the sound as coming from the hole (even if it actually does). Rather one would say that the sound comes from the room beyond the hole.

9 Recommendations

The work was planned in such a way that the software could be used transparently without any alterations or complications. In general, since only basic elements of the interface were employed, no major difficulties were encountered or expected. Nevertheless, certain aspects of the software design presented conceptual drawbacks for the task at hand. As a result, I have identified some changes to the GUI which would allow the artist to manipulate the WFS environment in a more concrete, direct way. Marc Leman (2008, p. 73) has suggested that the role of the mediating level can be understood as a set of hooks extending the artist's body prosthetically into a technologically mediated situation. The Game of Life GUI could be seen as mediating between the artist and the actual wave field produced by the system.

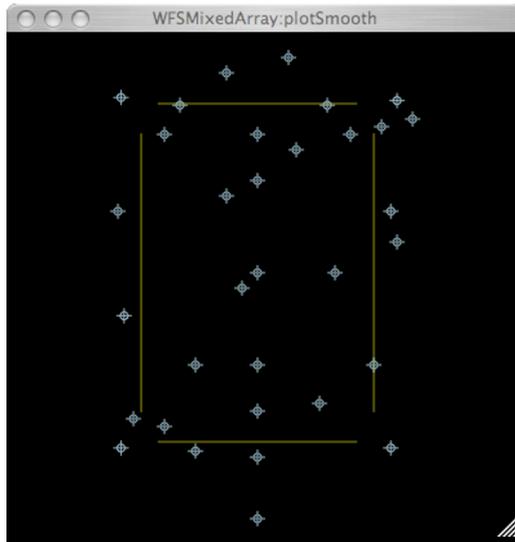


Figure 2. Microphone positions mapped as WFS point sources

In the current GUI, sound is mapped as a set of points which can be moved around a horizontal surface. The physical reality of the wave field, however, is far more complex than the geometrical approximation. The ability to access a topological model would allow the user to understand and manipulate the interaction of the propagation from different sources much more directly. The real-world effects of artifacts and aliasing could also be incorporated into the model, making it possible both to gauge the extent to which these might have a destructive effect on the intended structure, or on the contrary to use these degradations as musical materials.

Although it may be correct at the calculation level to provide the user with a featureless horizontal plane as a starting point, it is detached from both the physical behaviour and the aural result. It also gives the user no other alternative but to think of virtual source positions as 'objects' (Sporer 2004). Allowing users to describe a 'world' or a set of spatial extents and constraints as a starting point might encourage alternative approaches. The *sWonder* system, originally written by Marije Baalman and currently in use at TU Berlin, allows the user to define a room,

with basic architectural features such as walls with definable absorption coefficients, in which to position sources (Baalman et al. 2007). The grid on which sources may be positioned is also variable.

On a practical level, the current mode of visualisation also makes it difficult to distinguish between static points or planes when many of them are viewed simultaneously. Simple labelling or colour mapping would solve this issue. Similar minor readability issues could be identified and dealt with through empirical user testing.

The most important barrier to grounded research with the GOL system is that users are encouraged to develop their work using normal multi-channel systems or headphones. The design of a scaled-down system of 16-32 channels for studio use would have major benefits in this respect. Artists would be able to familiarise themselves with the real-world idiosyncrasies of WFS rendering and adapt their work accordingly.

10 Conclusion

WFS is distinguished from traditional sound projection techniques by its claim to physical accuracy, but this accuracy is largely undermined by the compromises which become necessary when it is put into practice. For practitioners, the disconnection is echoed at the interface level, since planar or spherical source-objects on a featureless plane bear very little relation to the audible results of the spatial synthesis. Founding their work on technical idealisations, artists are invited to an abstract and graphical compositional approach. This could be partly traceable to the conceptual connection between WFS and seismic imaging, but it also tends to be reinforced in the design of currently available software.

In *there will always be a you*, I have adopted an empirical and qualitative approach to working with WFS, situated

closer to 'phonography' or 'field recording' practice than to music as such. Artifacts and idiosyncrasies in the rendering played an integral role in the composition. The role of 'source position' in the overall spatial impression was deliberately undermined in order to highlight the relationship between the listener, the system, and the room.

I have also identified some ways in which the Game of Life GUI could be adapted to facilitate qualitative experimentation. Most of these follow

from the need for direct, concrete access at the interface level, situating WFS effects in the world, rather than in featureless space. These adaptations, in combination with the development of a scaled-down studio system, would be helpful to artists who want to avoid basing their WFS work either on conceptual abstractions or on strategies translated from traditional multi-channel use.

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