

# mono2eN: A Multi-Channel Autospacialisation Performance System

Callum Goddard

Department of Media

Aalto University

School of Arts, Design and Architecture

callum.goddard@aalto.fi

## ABSTRACT

This paper presents the mono2eN system, a multi-channel autospacialisation performance system. Developed through a practice-led research approach, the system was originally developed for a multi-channel solo acoustic bass performance. Central to the system is an autospacialisation algorithm that controls the multi-channel spatialisation parameters of a spatialised mono sound source as well as applying a magnitude freeze audio effect. The behaviour of both the spatialisation and freeze effect is dependent upon the audio content of the signal. The motivation behind the system and a technical overview of the autospacialisation algorithm is provided. Two studies are detailed, a performance case study and a user study. These were conducted to gain insight into and to convey the impressions and experience of practitioners and users of the system. Although some concerns over the audio effect triggering were raised, overall the results indicated a positive response to the system. This suggests that the mono2eN system has potential as an easy to understand multi-channel performance system that is able to spatialise any mono audio source, allowing for its use within a large number of contexts.

## 1. INTRODUCTION

The mono2eN system is a multi-channel autospacialisation performance tool developed through a practice-led research approach. Originally developed to augment a solo acoustic bass performance, it is possible to use any mono audio signal as the input to the system. This allows for it to be used within a large number of contexts. Central to the system is an autospacialisation algorithm that controls the multi-channel spatialisation parameters of a spatialised mono sound source as well as applying a magnitude freeze audio effect. The behaviour of both the spatialisation and magnitude freeze effect is dependent upon the audio content of the signal.

Taking a practice-led approach opens up playful and artistic approaches to the use of technology as well as promoting and encouraging unexpected and innovative applications [1]. The experiential aspect, both in the artefact

produced, and the relationship between researcher and research problem, is emphasised. In many cases practice-led research does not start with an identified problem and “enthusiasm of practice” leads instead [2]. Due to the significance experience has within the work, evaluation must happen through (either direct or indirect) experience of the research [2]. Commonly, work is shared with the appropriate communities of practice. A works’ adoption into practice, further development by users or new inspired works allow for the impact and effect of the work to be measured. [1]

The the mono2eN system has been shared with, modified and used by practitioners of spatial music (see Section 3.1). The code of the initial system<sup>1</sup> has also been distributed to, and modified by others.<sup>2</sup>

This paper presents the development process of the mono2eN autospacialization performance system from a practice-led perspective. The inspiration and intentions relating to the system and a technical overview of the system primarily focusing on the spatialisation control algorithm are given in section 2. An investigation into the system via a performance case study and user study is detailed and results arising from both are discussed in section 3. Finally, conclusions and the direction of further development to mono2eN system are presented in section 4.

## 2. THE MONO2EN SYSTEM

The work leading to the mono2eN system was motivated by a personal desire of the author to create a multi-channel performance for an 8-channel concert.<sup>3</sup> The performance intended to use an acoustic bass, on which a solo improvised composition was to be played. As such, both the acoustic bass part and the mono2eN system needed to be developed to complement each other.

Several design challenges presented themselves in the system’s development. The pieces central identity and aesthetic was an improvised solo acoustic bass performance, thus, any method of enabling multi-channel performance required that the core character of the piece remained.<sup>4</sup> Also, no permanent alterations or augmentations were wished to be made to the acoustic bass as the piece was originally intended as single performance. Any additional controls

Copyright: ©2013 Callum Goddard et al. This is an open-access article distributed under the terms of the [Creative Commons Attribution 3.0 Unported License](https://creativecommons.org/licenses/by/3.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

<sup>1</sup> <http://sccode.org/1-4T6>

<sup>2</sup> <http://sccode.org/1-4T8>

<sup>3</sup> <http://tai-studio.org/index.php/projects/4for8/4for82012/>

<sup>4</sup> That it still sounded like an acoustic bass guitar being played

could also not hinder the playability of the instrument, due to the playing and performance style of the piece.

The acoustic bass would be played and heard along side the multi-channel mix, having the acoustic bass sound spatialised to varying positions around the performance space was found to best complemented the acoustic sound from the bass guitar.

Due to the piece being improvised, having a static or pre-determined mix was not desirable. As the musical content was to be improvised, dynamic and variable, it was wished that the spatialisation also contained these characteristics. This raised the question of how to develop a control method that would allow for the performer to improvise the mixing of the output channels whilst performing.

The solution settled upon was to develop an autospatialisation algorithm that would respond to the acoustic bass's signal (a mono audio signal) and use this to control the spatialisation parameters. This solution accounted for the aesthetic considerations, and provided an adequate solution to the design challenges faced relating to control over the spatialisation.

## 2.1 Spatialisation Techniques

Spatialisation methods have ever increasingly been used within electroacoustic music as multi-channel systems have become readily available [3]. Practitioners today have many potential methods for spatialisation which can be applied to a variety of contexts. Two potential methods of spatialisation which were considered within the implementation of the mono2eN system were Vector Base Amplitude Panning (VBAP) [4] and Wave Field Synthesis (WFS) [5, 6].

VBAP uses changes in the relative volume levels of audio channels to determine the spatial positions of a sound. As this method of spatialisation is based upon altering the amplitude of the sound, is transparency, allowing the performance to retain its sonic character. Spatialisation is however, very dependent on speaker positioning relative to the listener.

WFS attempts to overcome this shortcoming through synthesising the wave front of a sound source [6]. In this respect overcoming the requirement for a 'sweet spot' where accurate spatialisation is heard. There as also been work into interactions with sound sources generated through WFS [7].

## 2.2 Implementation

The mono2eN system prototype was developed using SuperCollider.<sup>5</sup> Being developed through a practice-led approach, the exact algorithm that was implemented has been developed and tuned according to the authors personal preferences. In the process of developing the initial spatialisation algorithm, it was desired that an additional audio effect be added. Inspired by the idea of sound artefacts being left behind as the sound is spatialised, an algorithmically triggered magnitude freeze effect was implemented along side the autospatialisation algorithm.

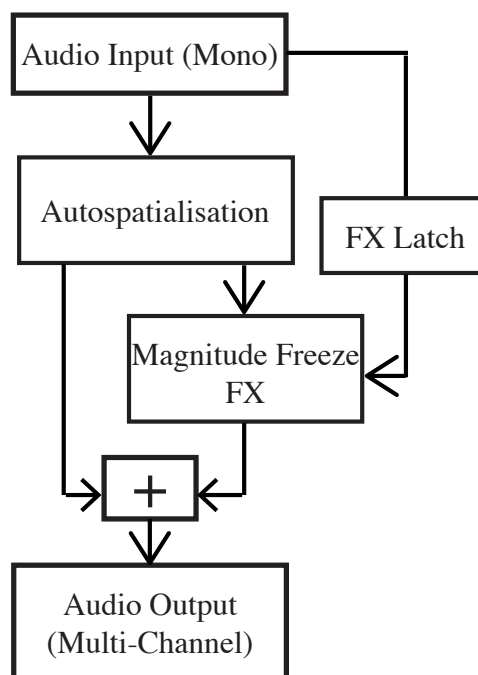


Figure 1. A structural overview of the mono2eN algorithm

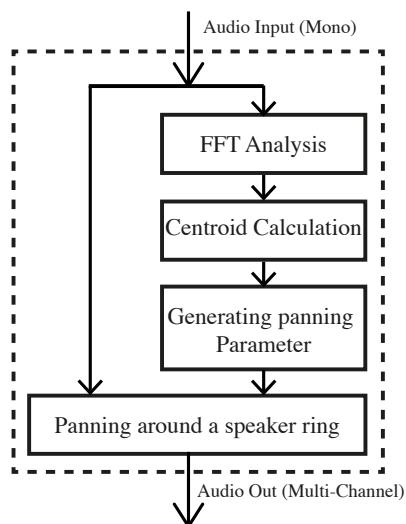
The overall structure of the system can be seen as containing three parts: the autospatialisation, the FX latch and the magnitude freeze FX. The overall structure of the mono2eN system can be seen in Figure 1.

### 2.2.1 Autospatialization

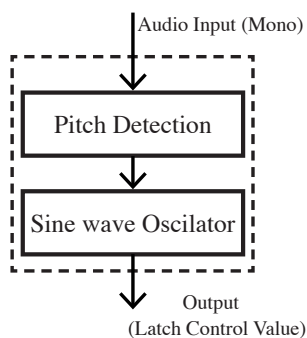
Autospatialisation (see Fig. 2) is achieved by panning the mono signal around a ring of speakers. This is achieved in SuperCollider by using the PanAz<sup>6</sup> function. Whilst more precise spatialisation could potentially be achieved by using VBAP or WFS, this project was primarily focusing on the interaction with the spatialisation. For this PanAz provided the perfect compromise between ease of use, only requiring one parameter, the panning azimuth, as well as providing effective spatialisation for the purpose of the performance.

Spectral analysis is performed on the incoming signal through the use of the SuperCollider FFT.<sup>7</sup> The centroid value of the input audio signal is calculated continuously. This value is used to determine the panning azimuth (angle) for the PanAz function, and thus the position the sound is panned to around the speaker ring. Once the sound has been panned the resulting audio channels are randomised in order to mitigate the inherent circling present in panning around a ring of speakers. This also reduces the multi-channel chorus like sound that can be produced when the signal is panned around the speaker ring too quickly. Whilst doing this means that exact spatial positions are unable to be specified, the overall result is a perceptually more spatial system.

<sup>5</sup> <http://supercollider.sourceforge.net/>



**Figure 2.** A structural overview of the autospatialisation part of the mono2eN system



**Figure 3.** A structural overview of the FX Latch part of the mono2eN system

### 2.2.2 FX Latch

The FX latch (see Fig. 3) generates a control signal that turns the magnitude freeze FX on and off. A pitch value ( $p$ ) is calculated using `Pitch`<sup>8</sup> with an amplitude threshold of 0.7 and median value of 7. When the input signal is above the amplitude threshold of the pitch detector. This value,  $p$ , is scaled and then used to set the frequency of a sine wave oscillator. The instantaneous amplitude value from the sine wave oscillator is then used as the trigger value for the magnitude freeze FX.

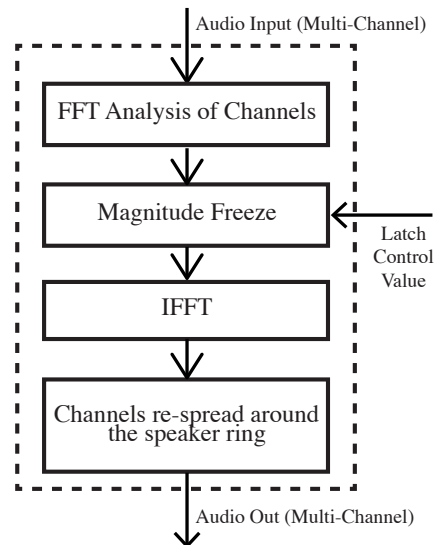
The sine wave oscillator also functions as a latch. When the input signal is below the pitch detector's amplitude threshold the sine wave oscillator's frequency is set to zero. The instantaneous amplitude of the oscillator remains constant until the frequency is set to a non-zero value, producing the latch behaviour.

Whilst the frequency of the oscillator is non-zero the instantaneous amplitude will vary between -1 and 1, the speed this occurs at is dependent on the frequency of sine wave

<sup>6</sup> <http://doc.sccode.org/Classes/PanAz.html>

<sup>7</sup> <http://doc.sccode.org/Classes/FFT.html>

<sup>8</sup> <http://doc.sccode.org/Classes/Pitch.html>



**Figure 4.** A structural overview of magnitude freeze FX part of the mono2eN system

oscillator (which is based on the input signal). This offers a degree of perceived instability to the latch, as well as offering the potential for skilled users of the system to trigger the magnitude freeze FX and develop rhythmic patterns.

### 2.2.3 Magnitude Freeze FX

The magnitude freeze FX (see Fig. 4) is applied to the spatialised audio signal. The output audio channels from the `PanAz` function (also corresponding to each output speaker) are individually spectrally analysed with an FFT. This analysis is done continuously. When the latch control value is above zero the magnitudes of the analysed values are frozen. This is achieved by using `PV_MagFreeze`.<sup>9</sup> An inverse FFT (IFFT) is performed to reconstruct the signal, and the channels are re-distributed around the speaker ring using the `SplayAz`<sup>10</sup> `SuperCollider` function. Finally, both the output of the spatialised signal and the frozen signal are added together and passed to the output.

## 2.3 Example Audio Files

Audio examples of the mono2eN system can be found at: <https://soundcloud.com/callumgoddard/sets/mono2ensamples>. An electric bass guitar and a Doepfer Dark Energy Synthesiser<sup>11</sup> have been used as the mono sound sources. An 8 channel output has been spread across a stereo field, both mono and processed audio examples are provided for comparison.

## 3. INVESTIGATION INTO THE SYSTEM

The evaluation of digital performance tools is becoming a much more important factor within the field of sound and computer music (SMC) and New Interfaces for Musical Expression (NIME). Whilst earlier methods within the

<sup>9</sup> [http://doc.sccode.org/Classes/PV\\_MagFreeze.html](http://doc.sccode.org/Classes/PV_MagFreeze.html)

<sup>10</sup> <http://doc.sccode.org/Classes/SplayAz.html>

<sup>11</sup> [http://www.doepfer.de/Dark\\_Energy\\_e.htm](http://www.doepfer.de/Dark_Energy_e.htm)



**Figure 5.** Picture of Cartes Flux Performance of wosawip

field have followed ideas from the field of Human Computer Interaction (HCI) [8], more recent approaches have questioned their suitability in assessing musical interfaces [9, 10]. This has led to the assessment of other evaluation methods, from quantitative to qualitative [9], to considering multiple perspectives [11]. Common to both [9, 11], is understanding what is wanted to be evaluated and why.

The investigation into the mono2eN system has been undertaken for two main reasons. The first, to gain insight into the immediate views and experiences of users of the system. Understanding and being aware of the users perspective, to inform and inspire further developments of the system. The second reason is to convey the experiential aspects of the system through presenting users views. These views, combined with audio files (Section 2.3, are hoped to provide sufficient indirect access to the mono2eN system to enable an insight into the experience the system provides.

The investigation draws on two cases. The first is a case study of an individual who adopted and used the mono2eN system into their performance practice. The second is a qualitative user study to gain insight into the initial impressions of musicians when using the system.

### 3.1 Performance Case Study

The mono2eN prototype system was given to, adapted and used by Till Bovermann within the performance wosawip, an improvised 4-channel duet.<sup>12</sup> The performance was performed as part of the Cartes Flux Festival<sup>13</sup> and CARPA 3.<sup>14</sup> Within the performance Till Bovermann played a monophonic synth called Benjolin<sup>15</sup> through a slightly altered version of the mono2eN patch. This was played alongside Chi-Hsia Lai who was performing with her own performance system WanderOnStage [12, 13].

Bovermann used the patch for a period of 6 months leading up to the first wosawip performance. During this period

<sup>12</sup> <http://tai-studio.org/index.php/projects/compositions/wosawip/>

<sup>13</sup> <http://cartes-art.fi/flux/en/ohjelma-programme/>

<sup>14</sup> <http://www.teak.fi/Tutkimus/carpa/>

<sup>15</sup> <http://casperelectronics.com/finished-pieces/benjolin/>

he made his own aesthetic adjustments to the patch via parameter values. He was interviewed after the Cartes Flux performance to gain insights into his experiences of using and performing with the mono2eN system.

Overall his experience was a positive one. It was noted that the system was easy to play at first and that it “takes care of the spatialisation aspects in a way I like”. More interestingly was that in using the mono2eN system with the Benjolin the original sound of the Benjolin was forgotten - with Bovermann stating: “I honestly forgot how the Benjolin sounds”. This resulted in the Benjolin + mono2eN system being perceived as a single instrument.

The sound of the magnitude freeze effect was also enjoyed once it activated. However, the transitions between it switching on an off were criticised due to their abrupt nature. So too was the control over the triggering, due to its perceived randomness in action. These factors meant that whilst the effect was enjoyed the control over it was mostly ignored, and the system was left to behave by itself.

Bovermann has continued to use the Benjolin through the mono2eN system in a second performance. Whilst more control over the magnitude freeze effect was desirable, his comments indicated that a lack of control did not render the system unusable or dramatically detract from the experience.

### 3.2 User Study

A qualitative user study was carried out to gain insight into the initial impressions musicians have when using the system. This was undertaken to inform the future developments of the mono2eN system.

#### 3.2.1 Experimental Methodology

In total there were 4 participants, all musicians, 3 male, 1 female. The sample size was small due to the need for participants to both be able to play an instrument and have familiarity with interactive music systems. Participants brought their own instruments to use with the system, these included: both an electric and an acoustic guitar, a tactile synthesiser and percussion bowls/blocks.

Each participant was invited, in individual sessions, to play their instrument through the system. The structure of each session was as follows:

1. Participants were asked to sign a consent form.
2. Participants were asked to describe their musical background.
3. Participants were invited to play their instrument through the mono2eN system.
4. Semi-structured interview was conducted asking participants about their experiences and impressions of the mono2eN system.

Within the interview priority was given to participants discussions of the system in their own terms. Due to the possibility for misconceptions or misunderstandings to arise in this scenario, the following was decided:

- All participants were allowed to ask questions when using the system, about how it works or on anything they were unsure of.
- If a participant wanted to know the details of the system it would be explained.
- Participants were allowed to play for as long as they wanted with no interruption to their playing.
- If they requested, they were allowed to have a second session after the interview.

The nature of the session was informal and planned to last 30 minutes. 10 minutes being allocated for participants to play with the system and 20 minutes allocated for the interview. In reality the playing times varied from around 6 minutes to 30 minutes, and with interviews lasting around 10 minutes. All performances were recorded. The mono input and multi-channel output of each performance were recorded through the MacBook Pro running the SuperCollider patch. A portable audio recorder with microphone also recorded the whole session, specifically to record the interview for transcription.

### 3.2.2 Analysis

The interviews were transcribed, then analysed based upon a grounded theory approach.<sup>16</sup> Here the data drives the theory formation. The interviews were compared for commonalities; these commonalities were then used to indicate the users' initial impressions and experience of the mono2eN system.

### 3.2.3 Results

The main areas of interest that arose from the interviews related to understanding, focus and enjoyment of the system. The overall comments indicated that the system was enjoyable to use. All participants when asked, were able to describe what the system was doing and were able to provide an explanation that approximated what the mono2eN system did. Participants did not find that the focus on their playing was disrupted by the system.

These results suggest that the system, as it stands, is easy to learn or at least intuitively understood when used. Playing times also indicate that the system encouraged playing, especially as 3 of the 4 participants wished to play a second time. The participant who did not wish to play again was satisfied with the playing session as well as with their understanding of the system deciding that no further playing was needed. They did however, express an interest in the code used for the system.

The comments from the case study relating to the instrument and system being perceived as one continued with the use of each instrument. The system also appeared to reveal parts of the instrument sound that participants were not aware of. This being indicated through a comment where a participant stated that they were: *"hearing things I hadn't heard before coming from my instrument when playing it*

*through the system"* and that it *"...brings out details you wouldn't have heard so obviously..."*.

As in the case study, concerns over the FX latch triggering were raised. Participants responses varied from having some understanding of control, to not being aware they had any control over the trigger for the magnitude freeze effect.

The last thing to arise from this user study was the inaccessibility of code to musicians. Those participating within the study were offered a copy of the patch and half declined due to their unfamiliarity with SuperCollider. This is a consideration needed when the system is further developed and distributed.

## 4. CONCLUSIONS

This paper presented the mono2eN autospatialisation performance system which algorithmically spatialises a mono audio signal around a speaker ring. The design challenges and implementation were described from a practice-led research approach and the system algorithms described. A case and user study were conducted to gain insights into musicians views of the system and to inform and inspire further development.

The mono2eN system used a relatively simple method for spatialisation, however, the result was an effective system for musical performance which does not require any specialised speaker setup (beyond position speakers within a ring). The effect of using a more sophisticated spatialisation method within the system is uncertain and maybe interesting to explore. However, the main focus of the system's development was to allow for automated control over sound spatialisation for a musical performance, which the system has achieved.

The interest of practitioners was positive as were the comments gained through the user tests and suggest the mono2eN system has the potential as a multi-channel performance tool. Comments indicated, that whilst the system is easy to use and understand in terms of the spatialisation algorithm, the method of control over the FX trigger caused concern. This concern however, did not prevent users from enjoying using the system.

The system's accessibility is also a concern and the way the final system is shared is an important consideration. Distributing the system as SuperCollider code allows for greater flexibility and user customisation of the algorithm, however, it also isolates the system from those who are not as technically inclined. Reducing the technological barrier of access, whilst encouraging adoption into practice, will need to be carefully considered as the system is further developed.

Practice-led development of the mono2eN system will continue. Finding solutions to these newly presented challenges will direct further development of the mono2eN system. In addressing these challenges it is hoped further spatial effects and interactions will emerge.

### Acknowledgments

The author would like to thank Julian Parker and Till Bovermann for their suggestions and advice.

<sup>16</sup><http://www.aral.com.au/resources/grounded.html>



## 5. REFERENCES

- [1] C. Lawson, "Practice-led research: Examples from artists working with technology," in *cumulshelsinki2012.org*, 2012, pp. 1–11.
- [2] B. Haseman, "A manifesto for performative research," *Media International Australia incorporating Culture and Policy, theme issue "Practice-led Research"*, no. 118, pp. 98–106, 2006.
- [3] F. Otondo, "Contemporary trends in the use of space in electroacoustic music," *Organised Sound*, vol. 13, no. 1, pp. 77–81, 2008.
- [4] V. Pulkki, "Virtual source positioning using vector base amplitude panning\*," *J. Audio Eng. Soc.*, vol. 45, no. 6, pp. 456–466, 1997.
- [5] G. Theile, "Wave field synthesis - a promising spatial audio rendering concept," in *Proc. of the 7th Int. Conference on Digital Audio Effects (DAFx'04)*, Naples, Italy, October 5-8 2004.
- [6] E. Corteel and T. Caulkins, "Sound scene creation and manipulation using wave field synthesis," IRCAM, Paris, France, Tech. Rep., 2004.
- [7] W. Fohl and M. Nogalski, "A gesture control interface for a wave field synthesis," in *Proceedings of the International Conference on New Interfaces for Musical Expression*, Daejeon, Korea, May 27-30 2013.
- [8] M. M. Wanderley and N. Orio, "Evaluation of input devices for musical expression: Borrowing tools from hci," *Computer Music Journal*, vol. 23, no. 3, pp. 62–76, Fall 2002.
- [9] D. Stowell, A. Robertson, N. Bryan-Kinns, and M. Plumbley, "Evaluation of live human-computer music-making: Quantitative and qualitative approaches," *International Journal of Human-Computer Studies*, vol. 67, pp. 960–975, June 23 2009.
- [10] A. Johnston, "Beyond evaluation : Linking practice and theory in new musical interface design," in *Proceedings of the International Conference on New Interfaces for Musical Expression*, Oslo, Norway, 2011.
- [11] S. O'Modhrain, "A framework for the evaluation of digital musical instruments," *Computer Music Journal*, vol. 35, no. 1, pp. 28–42, Spring 2011.
- [12] C.-H. Lai, "Wanderonstage: the convergence of percussion performance and media technology," in *Proceedings of the 7th Audio Mostly Conference: A Conference on Interaction with Sound*, Corfu, Greece, September 24-26 2012.
- [13] C.-H. Lai and T. Bovermann, "Audience experience in sound performance," in *Proceedings of the International Conference on New Interfaces for Musical Expression*, Daejeon, Korea, May 27-30 2013.