Expression and Spatial Motion: Playable Ambisonics

Joanne Cannon
Bent Leather Band
Christmas Hills
VIC, Australia
+613 9730 1026
joanne_cannon@bigpond.com

Stuart Favilla
Bent Leather Band
Christmas Hills
VIC, Australia
+613 9730 1026
sfavilla@bigpond.com

ABSTRACT

This paper presents research undertaken by the Bent Leather Band investigating the application of live Ambisonics to large digital-instrument ensemble improvisation. Their *playable* approach to live ambisonic projection is inspired by the work of Trevor Wishart and presents a systematic investigation of the potential for live spatial motion improvisation.

Keywords

Playable instruments, augmented instruments, expressive spatial motion, ambisonics

1. BACKGROUND

Bent Leather Band began experimenting with spatial sound during the early 1990s. It seemed a logical step as electronic musicians, to do something with sound using a loudspeaker field. The potential to move sounds in space, affect multi-channel echoes and delays and generally do things beyond the realms of conventional acoustic instruments, was exciting to say the least. The spatial projection works of Varese, Xenakis and Stockhausen were of great inspiration to us in our student days. As instrumentalists and improvising musicians, we dreamt of spatial motion, diffusion and effects as intrinsic expressive parameters in our live ensemble music. Back then, computer technology for spatial projection was simply not available to musicians like us, we were left to construct our own rudimentary joystick audio mixers [see fig. 1].

These devices were designed to mix a mono input across four separate outputs and were set into large plastic jiffy boxes with a joystick on top and jack connectors on the sides. Those simple CMOS circuit boards although a mess of wires, crystal clocks and op-amps, enabled us to pan and move our sound with some success. Reverbs, delays and filtering were added in an attempt to simulate distance cues and to add dimension to our mix. We began by presenting spatial sound concerts and gigs.

After the initial novelty wore off, we stumbled into a morass of technical challenges. First of all, pans were best heard from the central area also known as the "sweet-spot". This area was rather small and could only encapsulate either the musicians or about 5-10 seats for the audience. Also sounds would always perceptually be located at the periphery of the field and although our joystick mixers could easily pan diagonally across, the perceived course of the sound clearly did not travel in this fashion. There were also technical challenges setting up a four channel PA system in conventional concert environments. Acoustic reverb was critical to the spatial ensemble definition often washing out the detail and presence of audio. Acoustically dead cinemas were the favourite venues.

Fig 1. Joystick Audio Mixers, 1990's style

There were significant musical issues too. We discovered through our manual control that spatial motion is complex to perform being both control and performance feedback intensive. Performing a beautiful series of spins and rapid trajectories required a large cognitive load leaving little thought to do much else musically. Conventional musical language and form has little or no correlation to spatial motion. We tried Ambient pieces but these held only limited fascination, usually resulting in the audience tilting their heads backwards and going to sleep. The best success we had involved playing a rainforest of abstract bird and insect languages and mixing it up live. Here the audience and musicians had a clear understanding and appreciation of the piece, i.e. an immersive experience where synthesized sound's dynamics were mixed spatially.

At that stage, our research interests shifted towards developing new expressive controllers, virtuosic techniques and ensemble music language. Spatial sound was abandoned because of its capacity to decentralize the live musician and constrict control

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intimacy. We went on to develop our notion of *playable* instruments [11], [12], [13] & [14] and have now built an ensemble of augmented bassoons, saxophones, guitars, trumpets, lightharps and other controllers.

Our dream of expressing ourselves using spatial motion remained. Recently this interest in spatial motion has been revived in the *Heretics Brew* extended instrument ensemble. Here we have applied spatial motion as a form of dynamic mixing during performance.

2. LIVE SPATIAL EXPRESSION

The use of spatial sound as an expressive parameter extends back throughout history. As a term, it can be attributed to Henry Brandt, the Canadian multi-orchestra composer. Background sources [5], [15] who together with Zvonar [28], illuminate many key figures including; Pierre Henry, Francois Bayle, Pierre Schaeffer, Edgar Varèse, Iannis Xenakis, Karlheinz Stockhausen, Christian Clozier, Françoise Barrière, *BEAST* (the Birmingham Electro-Acoustic Sound Theatre), EAT, Giuseppe Di Giugno, John Cage, Stan Shaff, Max Mathews, David Tudor, Roger Reynolds, Zack Settel and Miller Puckette.

From the literature a number of approaches to musical expression emerge. The Orchestra of loudpeakers or live improvised diffusion approach, typified by Christian Clozier and Françoise Barrière, developed the technique of “tuning” loudspeakers to project sound [6]. By surrounding an audience with many tuned speakers dramatic tumbling and spinning effects are created. Clozier and Barrière developed this system for a number of years, building their own sophisticated spatial mixing console/instruments the *GMEBaphone* and *Cybernéphone*, adding phase and reverberant effects. As composers, they developed a special affinity with space and music, improvising the projection of sounds; “where they needed to go” [5].

As computer projection systems have developed, tuned loudspeaker arrays were replaced by Surround, Amplitude Mixing, Wave Field Synthesis and Ambisonic systems. A large body of compositional audio work has exploited the computer system’s capacity to record and reproduce spatial sound expression. However, live performance work remains musically restricted by the control complexity required to perform spatial motion. This is demonstrated by projects that have designed systems around specialized controllers including; 3D gloves [24], Polhemus 6DOF (six degrees of freedom) [21], Liberty 8 [19], Haption Virtuose [22], and 3D ultrasound [20].

Other important contributions have examined the morphological relationships, perceptual and psychoacoustic factors governing spatial sound. Denis Smalley argues that there is an implicit connection between the sound object and its spatial presentation [1]. Spectrum-morphology dictating the form of spatial projection was a point of view also shared by Pierre Schaeffer [15]. In contrast Trevor Wishart defines spatial motion as an independent expressive parameter for music, [27]. Wishart’s proposed taxonomy classifies spatial-motions into; direct, cyclic (oscillatory), irregular, time-based, frame orientated and counterpoint groups. Although they are presented in a two-dimensional planar form, Wishart’s spatial-motions are also transferrable to three-dimensional sound fields.

3. FOCUS ON AMBISONICS

As Multi-channel speaker projection has steadily become more accessible to live performers, Ambisonics in particular, is establishing itself as an excellent and versatile approach. Ambisonics has become available in software emulations [17], or as suites of external objects for MaxMSP by Schacher [23]. These software emulations require only a standard multi-channel audio interface.

Studies by Martin [18], have evaluated Ambisonics against three separate spatial techniques including Pair-wise Amplitude Panning, First-order Gradient and Polarity Restricted Cosine models. Other studies including Bates et al, [2] & [3] & Kearney et al, [16] have conducted comprehensive blind-fold subjective evaluations of higher order ambisonics against Vector-based Amplitude Panning, IRCAM’s SPAT system and Delta-stereophony. Technical and subjective evaluations have been made between Ambisonics, Wave-field synthesis [25] and also with Stereo-dipole loudspeaker propagation [10]. Studies correlating sound field microphone data with loudspeaker projection in concert environments have also been undertaken [4] & [8].

According to Daniel et al, [8] & [9], third order Ambisonics is capable of projecting convincing phantom images between speakers and also within the sound field. The size of the sound field’s sweet spot is also greatly increased. In fact, listeners situated outside the Ambisonic sound fields can still clearly perceive the motion of sounds and positions of phantom images, [4] & [8]. The technique is also capable of projecting an audible impression of height, which can be dramatically improved by adding more speakers to the system. This is a great improvement over amplitude mixing techniques, yet little work has been undertaken to apply Ambisonics to augmented instrument ensembles or live improvisation.

4. PLAYABLE SPATIAL MOTION

Conventional instrument gestures bear little or no relationship to spatial motion. This poses significant challenges to the development of *playable* systems. Projecting a musician’s sound from a localised position away from that very same performing musician is also fundamentally disembodying. Although spatial motion has the potential to separate many voices from the mix, this disembodiment may require ancillary or enhanced systems for performance feedback. Timing issues including latency and delay will also impact on the quality of audible feedback in performance [26]. Skilled instrumentalists rely primarily on direct sound (less than 1msec) and sonic vibrations felt directly through their instruments (via tactile feedback). Any computational delays (in the order of 10-20msec) will significantly limit controller intimacy and therefore skill development.

The research project began with the aim to perform Wishart’s spatial motions in real-time. The boundaries of our investigation focused on ensemble playing within a two dimensional or planar sound field. The ensemble project:

- Devised and constructed appropriate sensor systems,
- Created an ambisonic software implementation in MaxMSP,
- Programmed control mappings for spatial localization
- Developed software algorithms for direct, cyclical, irregular and double motions

- Work-shopped and improvised music using spatial motions
- Evaluated our extended instrument system

An implementation for third order ambisonics was assembled in MaxMSP using the objects developed by Schacher & Kocher, [23]. These objects include *ambiencode~*, *ambidecode~*, *ambimonitor~* and *ambicontrol~*.

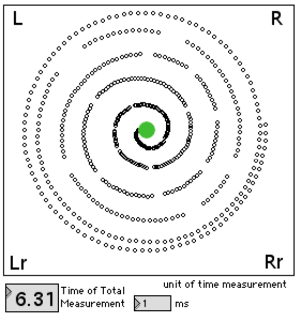
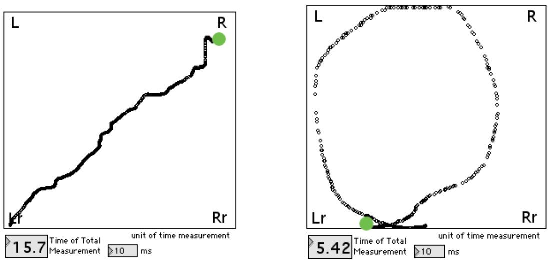


Fig 2. Plot of Outward Spiraling Motion, Viewing the Sound-field from Above

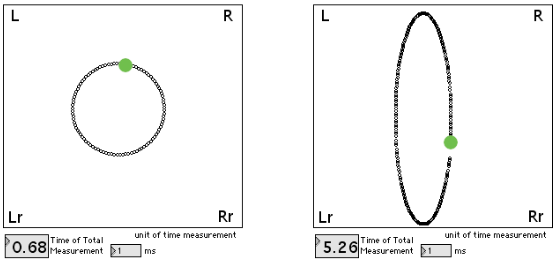
Workshop sessions were undertaken to test software and develop the necessary algorithms for spatial motion. Spatial motions were auditioned first using white noise and then performed on the instruments developing the sensor control mappings and techniques. Spatial motion trajectories were transcribed in two-dimensional plots (see fig. 2) where the front left and right speakers (marked *L & R*) and rear-left and rear-right speakers (marked *Lr & Rr*) are shown respectively. A small green circle marks the starting position of the recording, which is then traced out in small circular points. The time of the measurement is provided in seconds and the unit time of measurement (milliseconds) is also shown. The timing unit (or timing between the small circles) could be adjusted depending on the resolution required to capture the spatial gesture. A dynamic range extends across the sound field. Sounds projected from the centre of the field are loudest, reducing in volume as their position moves away towards the field edge. The size and dimensions of the sound field can be configured via the software objects in MaxMSP.

The project investigated a large range of spatial motions, including examples played by sensors mapped directly to *x y* coordinates and indirectly using software algorithms. Cyclic motions including circular, elliptical spins, spiraling motions, oscillating and zigzagging motions were also auditioned. These were controlled indirectly by mapping sensors to control the radius, speed and centre of spins. Irregular, scattered and random motions were also investigated together with data slewing and interpolation. Many distinct and identifiable spatial motions could be created with these techniques (see figs. 3.1-8).



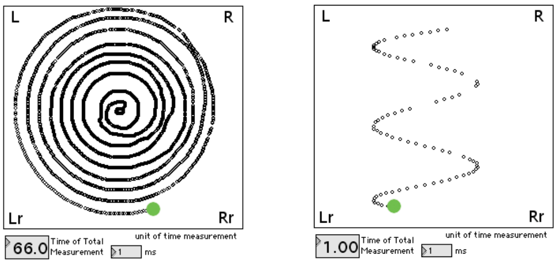
3.1 Direct joystick pan

3.2 Direct controlled spin



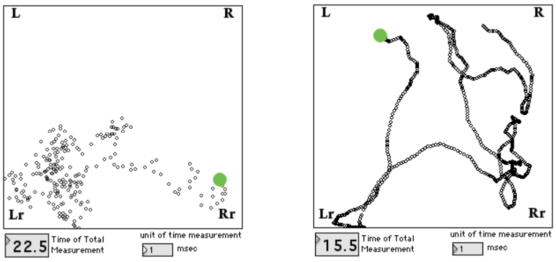
3.3 Fastest Discernable Spin

3.4 Ellipse



3.5 Long Spiral Inwards

3.6 Sine-wave Motion y axis



3.7 Random Scatter

3.8 Random Scatter with 500msec Slew

Figs 3.1-8 Examples of Spatial Motions using Direct and Indirect Control

Wishart's "double motions" include complex movements summed from two (or possibly more) cyclic or irregular motions. Double-motions have enormous potential for *playability* and spatial expression. In fact the possibilities are almost limitless. Our investigation focused on double-motions derived from summing two circle-tracing algorithms (fig. 4).

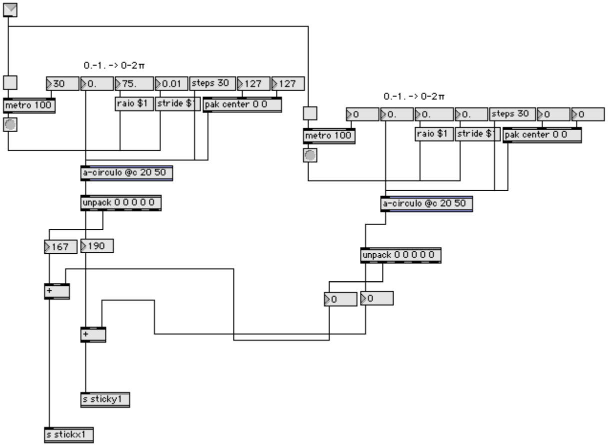
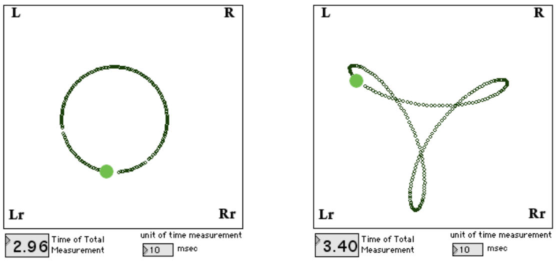


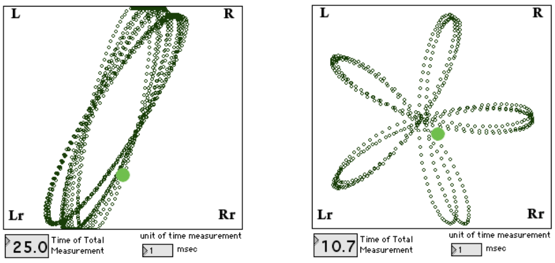
Fig 4. Double Motion (Circle) Generator

Controllable parameters that were investigated included; spin frequency, phase, radius, plot-stride (which can also be used to adjust speed and direction), output-data step-size and circle centre position. The speed of circle drawing, the radii and phase of each circle could also be "tuned" or proportioned harmonically. These parameters were mapped to instrument dials and rollers to discover how sets of parameters would work together in a playable fashion. Hybrid bassoons, meta-saxophones and Lightharp controllers were put to use.

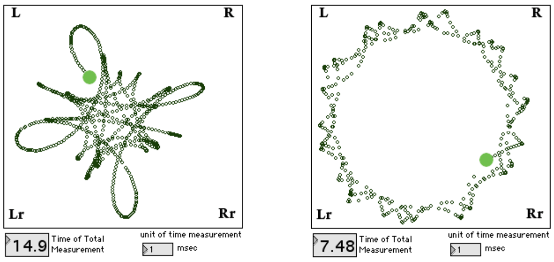
It was discovered that as few as three parameters could combine to produce a vast range of musical outcomes. (Figs. 5.1-6) demonstrate how a centred spin can be transformed by just a few variable parameters to develop a sequence of motivic spatial transformations. Those pictured were performed at the controls of the *Serpentine-bassoon*.



5.1. Spin motif 5.2. Loops



5.3. Phased Rotating Ellipses 5.4. Star Loops



5.5. Spriralling to Arcs 5.6. Expanded to Field Edge

Figs 5.1-5 Sequence of Developing Double Motions

5. EVALUATION

The Ambisonic software proved to be an excellent system for spatial projection. Sound could be localised effectively and convincing phantom images could be heard throughout the planar field. Height information was less convincing but we focused on planar motions and their accuracy for the study. Most spatial motions were audibly recognizable. Loops, arcs and sharp angled trajectories were clearly discernable from each other. Distance filtering proved a useful feature and assisted to accentuate definition towards the edge of the sound field.

The computational resolution of the ICST software was estimated in the vicinity of 6msec per processing step. This impacted on the system's capacity to project fast motions. Centrally positioned circular spins suffered the most from this resolution limit and began to break up past a rotational frequency of 1.5Hz. Ellipses, due to the slower passing at the ends of their curvature could spin faster 2.5Hz and still remain coherent and recognizable.

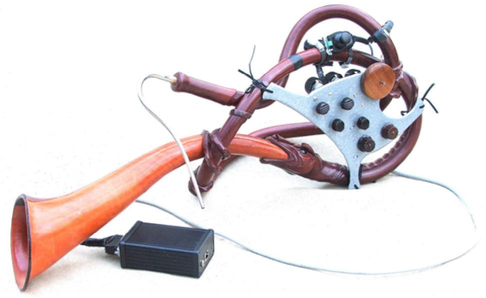


Fig 10. Serpentine-bassoon, 2010

Dimensions 33 x 78 x 26cm

Improvising music with the system revealed spatial motion to be a form of dynamic shaping. Because of this the dynamics of fast traveling motions would often predispose the structure of their spatial trajectory. Slewing of positional data was necessary to join breaks and avoid audio glitches. Experiments with random and stepwise motion also revealed that smoothing could be used as an expressive playable parameter in spatial motion.

Direct joystick control was discovered to be quite limited in its application. Lateral field error significantly inhibits the performer's capacity to play spatial motions with audible feedback alone. Visual feedback (playing with a computer screen or display) in performance significantly increased the accurate localisation of sounds within a planar field. Effective systems for performer feedback need to be developed for the acquisition of performance skill in this area.

Indirect control of spatial motion algorithms, were demonstrated to be highly expressive and playable in performance. The circular double-motion algorithm was by far the most versatile. It was capable of creating a huge range of interesting and distinct spatial motions from only a few playable parameters. This proved a fruitful area for sensor mapping experimentation allowing musicians to tweak (or finely adjust) two or three parameters in order to achieve a vast range of spatial transformations.

6. CONCLUSION

Spatial motion has a capacity to organize musical dynamics in a new way. This is its greatest potential for improvised music, especially if it is applied to mixing and organising large forces of electroacoustic musicians and extended instrumentalists alike. There is a potential here to solve the mixing problems facing large ensembles. Separating parts and instruments by spatial motion is an interesting alternative to conventional stereo mixing and equalization. The ambisonic projection method, with its extended sweet spot, can be organised with the musicians set up centrally, with the audience seated in the round.

There are a number of recommendations we can make for future work. First of all, the ambisonic system needs more temporal processing resolution to affect faster motions and trajectories. Some experimentation with the computational values of the *ambiencode~* object together with MaxMSP's digital audio settings, may yield some fruitful results here. A faster computer processor with an optimized packet size for audio processing may also greatly improve this timing resolution.

According to Daniel et al [9], adding a further four loudspeakers to the system should greatly improve the projection of height information and phantom images throughout the field. Speakers that project their sound at a 60degree angle should improve this also. There is a need to develop more sensor devices capable of performing 3D gestures. Visual displays also need to be designed for the performing musician together with tactile and haptic surfaces for them to use in performance.

There is no doubt that the development of spatial sound research and software has advanced a long way in just a decade. It is now time for us improvisers to embrace spatial motion and explore it as an intrinsic form of musical expression.

7. REFERENCES

[1] Austin, L. “Sound Diffusion in Composition and Performance: An Interview with Denis Smalley.” In Computer Music Journal, Vol. 24, No. 2 (Summer, 2000), pp. 10-21.

[2] Bates, E, G Kearney, D Furlong, and F Boland. "Localization accuracy of advanced spatialisation techniques in small concert halls." *Journal of the Acoustical Society of America*, Jan 2007.

[3] Bates, E, G Kearney, F Boland, and D Furlong. "Monophonic Source Localization for a Distributed Audience in a Small Concert Hall." *10th Int. Conference on Digital Audio Effects*, Jan 2007.

[4] Bertet, S, J Daniel, L Gros, and E Parizet. "Investigation of the Perceived Spatial Resolution of Higher Order Ambisonics Sound Fields: …." *30th AES Int. Conference*, Jan 2007.

[5] Chadabe, J, *Electric Sound, The Past and Promise of Electronic Music* 1997 Prentice Hall, New Jersey

[6] Clozier, C. "The gmebaphone concept and the cybernéphone instrument." *Computer Music Journal*, Jan 2001.

[7] Daniel, A, and D Jacques. "A digital emulator of the photosonic instrument." *Proceedings of the 2002 conference on New interfaces for musical expression*, 2002: 1-4.

[8] Daniel, J. "Spatial sound encoding including near field effect: Introducing distance coding filters and a …." ... *of the 23rd International Conference of the Audio …*, Jan 2003.

[9] Daniel, J, and S Moreau. "Further study of sound field coding with higher order ambisonics." *Proceedings of the 116th Audio Engineering Society …*, Jan 2004.

[10] Farina, A, and E Ugolotti. "Subjective comparison between Stereo Dipole and 3D Ambisonics surround systems for …." *16th AES Conference*, Jan 1999.

[11] Favilla, S. & Cannon, J, et al “GluiSax: Bent Leather Band’s Augmented Saxophone Project, *In the Proceedings of the New Instruments for Musical Expression NIME08,* Casa Paganini Genoa Italy, June 2008.

[12] Favilla, S. & Cannon, J. “Children of Grainger: Leather instruments for free music” *In the Proceedings of the New Instruments for Musical Expression NIME06,* IrCAm Pompidou Paris, July 2006.

[13] Favilla, S. & Cannon, J. “Fetish: Bent Leather’s Palpable, Visceral Instruments and Grainger” *Contemporary Music Review* Vol 25 parts 1 & 2, pp. 107-117.

[14] Favilla, S. & Cannon, J. & Greenwood G. “Evolution and Embodiment: Playable Instruments fro Free Music” *In the Proceedings of the International Computer Music Conference Free Sound*, ICMA, August 2005.

[15] Hugill, A. *The Digital Musician* 2008 Routledge, Taylor and Francis, New York.

[16] Kearney, G, E Bates, D Furlong, and F Boland. "A comparative study of the performance of spatialisation techniques for a distributed audience in a …." *31st International Conference of the Audio Engineering …*, Jan 2007.

[17] Malham, D.G. "ambis2.htm." *Web Page File*, Jul 2004. http://www.york.ac.uk/inst/mustech/3d_audio/ambis2.htm

[18] Martin, G, W Woszczyk, J Corey, and R Quesnel. "Controlling phantom image focus in a multichannel reproduction system." *PREPRINTS-AUDIO ENGINEERING SOCIETY*, Jan 1999.

[19] Marshall, MT, N Peters, AR Jensenius, J Boissinot, MM Wanderley, and J Braasch. "On the development of a system for gesture control of spatialization." *Proceedings of the 2006 International Computer Music Conference*, 2006: 260–266.

[20] Mott, I, Sosnin, J. “A New method fro Interactive Sound Spatialisation.” *Proceedings of the 1996 International Computer Music Conference* (Hong Kong), 1996: 169-172.

[21] Naef, M, and D Collicott. "A vr interface for collaborative 3d audio performance." Proceedings of the 2006 International Conference on New Interfaces for Musical Expression (NIME06), Paris, France, 2006: 57–60.

[22] Rodet, X, et al. "Study of haptic and visual interaction for sound and music control in the Phase project." *Proceedings of the 2005 conference on New interfaces for musical expression*, 2005: 109-114.

[23] Schacher, J, and P Kocher. 2006 "Ambisonics spatialization tools for max/msp." www.icst.net

[24] Schacher, JC. "Gesture control of sounds in 3D space." *Proceedings of the 7th international conference on New interfaces for musical expression* (ACM New York, NY, USA), 2007: 358-362.

[25] Sontacchi, A, and R Höldrich. "Further investigations on 3D sound fields using distance coding." *Proceedings of the COST G-6 Conference on Digital …*, Jan 2001.

[26] Wessel, D, M Wright, and J Schott. "Intimate musical control of computers with a variety of controllers and gesture mapping metaphors." *Proceedings of the 2002 conference on New interfaces for musical expression*, 2002: 1-3.

[27] Wishart, T, and Emmerson, S. *On sonic art*. Jan 1996

[28] Zvonar, R. "A History of Spatial Music." http://cec.concordia.ca/econtact/Multichannel/spatial_music.html