Expression and Spatial Motion: Playable Ambisonics

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ABSTRACT
This paper presents research undertaken by the Bent Leather Band investigating the application of live Ambisonics to large digital-instrument ensemble improvisation. Their research aims to use spatial motion and Ambisonics as a solution to the problem of mixing large ensembles of digital instruments. 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 your 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 is exciting to say the least. The spatial projection works of Varese and Stockhausen were also a 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. We added reverb, delays and filtering in an attempt to simulate distance cues and to add dimension to our mix. We began by presenting spatial sound concerts and gigs.

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NIME2010, June, 2010, Sydney, Australia
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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 confine control intimacy. We went on to develop our notion of *playable* instruments [12], [13], [14] & [15] and have now built an ensemble of augmented bassoons, saxophones, guitars, trumpets, lightharps and other controllers.

However, our dream of expressing ourselves using spatial motion remained and recently we have revived our focus of spatial sound in the *Heretics Brew* extended instrument ensemble. Here we have applied spatial motion as a form of dynamic mixing to solve problems confronting large ensemble performances.

### 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-instrument composer. Background sources [5], [16] who together with Zvonar, illuminate many key figures including; Pierre Henry, Francois Bayle, Pierre Schaeffer, Edgar Varèse, Iannis Xenakis, Karlheinz Stockhausen, Christian Clozier, Françoise Barrière, KEVRIN (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 loudspeakers 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 have been 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 [29], Polhemus 6DOF (six degrees of freedom) [25], Libberty 8 [23], Haption Virtuo [27], and 3D ultrasound [24].

Other important contributions have examined the morphological relationships, perceptual and psychoacoustic factors governing spatial sound. Denis Smalley’s 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 [16]. In contrast Trevor Wishart’s defines spatial motion as an independent expressive parameter for music, [32]. 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 [21], or as suites of external objects for MaxMSP by Schacher [28] & Wakefield. These software emulations require only a standard multi-channel audio interface.


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 yet 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 [31]. 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.

We began our research project 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, [28]. These objects include ambience~code, 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 from the centre to the field edge. The size and dimensions of the sound field can be configured via the software objects in MaxMSP.

Fig 12. Joystick Direct Mapping Control Gestures

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 fig. 3).
It was discovered that as few as three parameters could combine to produce a vast range of musical outcomes. (Fig. 5) demonstrates 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.

Controllable parameters that were investigated included; spin frequency, phase, radius, plot-stride (which can be used also to adjust speed and direction), output-data step-size and circle 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.

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 limited the study of double-motion, to the summing of two circle-tracing algorithms (fig. 4).

Fig 3. Examples of Spatial Motions using Algorithms and Indirect Control

Fig 4. Double Motion (Circle) Generator
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.

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 a good alternative to 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 ambience= 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 [8], 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 also 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


