CYCLICAL FLOW: SPATIAL SYNTHESIS SOUND TOY AS MULTICHANNEL COMPOSITION TOOL

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ABSTRACT

This paper outlines and discusses an interactive system designed as a playful 'sound toy' for spatial composition. Proposed models of composition and design in this context are discussed. The design, functionality and application of the software system is then outlined and summarised. The paper concludes with observations from use, and discussion of future developments.

1. INTRODUCTION

Cyclical Flow is a multichannel spatial composition tool and sound toy. The system was originally realised to create spatial sound materials for composition. The project is a real-time spatial composition or spatial performance system, in which spatial, textural and spectral parameters are interlinked. The player (composer) creates and modifies varied forms of spatial and spectral patterns or trajectories in real-time. Spatial, spectral and granular processing techniques are implemented and codependent. The system is intended for use as an exploratory and playful tool for spatial composition and performance in multichannel concert or studio spaces.

2. CONTEXT

The project is part of a series of sound toy systems [1] designed and implemented that explore compositional system development and design incorporating audio-visual interfaces [2][3][4], with symbolic interactions determining sonic output. These works explore sound toys as open work, composition medium and compositional tool, and are a collection of interactive sonic centric audiovisual systems, designed and influenced by aesthetics, processes and techniques familiar to the field of electroacoustic music, and informed through the realization of fixed media and multichannel electroacoustic compositional works.

These sound toy systems are designed according to a proposed model for composition (Figure 1). Compositional input is considered to be multi-dimensional, and the importance or significance of each input form as an element of composition is somewhat open to interpretation. Compositional input may be attributed to three primary forces or agents, each dictating or influencing characteristics of the output.

Composer/Designer - Offline
User/Player (Composer) - Real-time
Simulated Physics - Real-time

The composer/designer is responsible for designing and creating the framework for composition, making compositional decisions during the construction of the system. Modes of interaction, sound materials, transformation processes, compositional options and constrictions, and modes of presentation and representation are all determined by the composer/designer. The user/player engages with the system in real-time, responding to both visual and aural feedback from the system. There is often a codependency between the human player and a simulated physics system. This acts as a third compositional agent, adding an algorithmic component to the system.

The algorithmic component is accompanied by symbolic representations of the algorithmic processes in the virtual visual space. These provide the user/player with some insight into this aspect of the control system, which is enhanced through play, exploration and learning. Symbolic representation of a simulated physics system allows real-time interaction between the user/player and the system in both visual and aural domains, also allowing anticipatory responses that enable the user/player to react to forthcoming events. These two compositional forces (simulated physics system & user/player) influence each other throughout play.

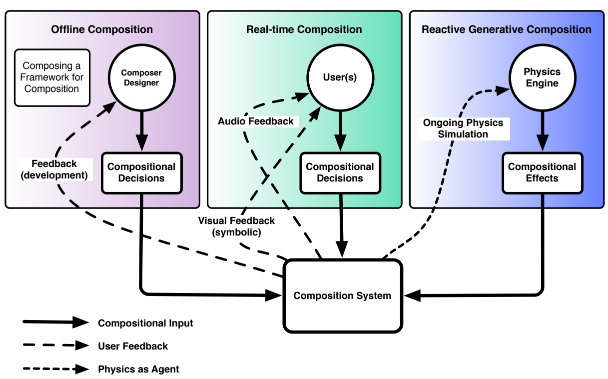

Figure 1. Designing for composition - three compositional forces

3. OVERVIEW

In *Cyclical Flow*, dynamic movement of sound through space is the central theme. Symbolic kinetic approaches in the visual domain represent and control spatial motion in the sound domain. The movement of symbolic objects within a virtual representation of a multichannel performance space directly control patterns of spatial motion and spectrum of sound. The visual component of the project attempts to provide a playful interface for spatial composition or "musicking" [5] [6]. The project is to some degree influenced by phase process music. The player may take a monophonic single line approach if they choose, but the system is designed to allow the creation of layered cyclical patterns of motion, where the relationships of each line/part shifts over time due to the use of different cyclical motion rates. This results in a form of spatial counterpoint [7] and spatial interactions between multiple spatialized sound materials.

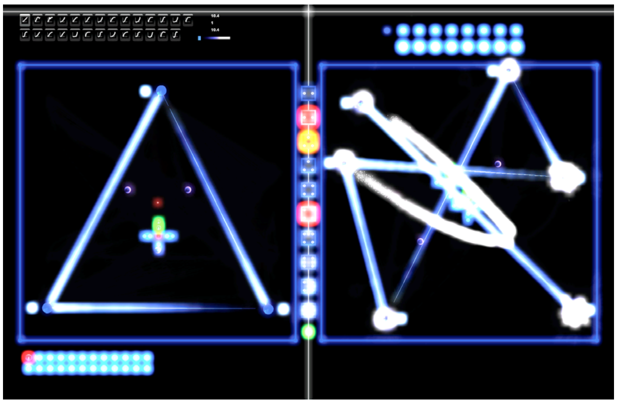

Figure 2. The graphical user interface (8 channel)

The system developed is the product of research and practical exploration of computer game engine technologies [1] used in conjunction with external software for sound and synthesis [8], in a range of compositional contexts. Two primary versions of the *Cyclical Flow* system have been developed. The first version is designed for a single ring of eight speakers. This project was then further developed, adding height, and three dimensional movement of sound in space. This version is configured specifically for use in the sonic laboratory at SARC, Queen's University, Belfast, and utilizes twenty-four discrete output channels (Figure 3). Speaker placement in the performance space uses a ring of eight loudspeakers below the listener, a ring of eight at listener level, and another ring of eight positioned above the listener. [1]

[1]The system may be easily configured for other speaker configurations in either two or three dimensions.

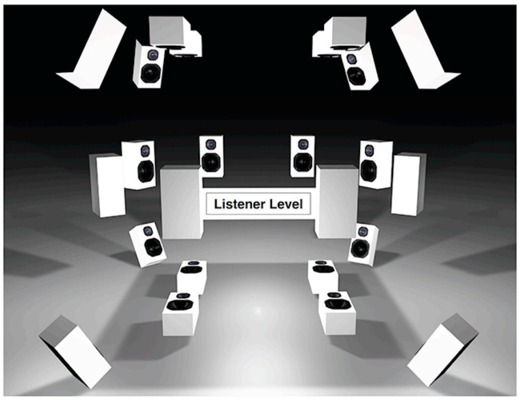

Figure 3. 24 channel speaker configuration used in the Sonic Lab at SARC, Queen's University, Belfast

4. SPATIAL MOTION

Ideas presented by Wishart (1996) on spatial motion are considered relevant to *Cyclical Flow*, and can be related to specific features of the system. These features are not necessarily direct realizations of his ideas. However, techniques he describes can be aligned with some of the spatial motion and spatial approaches adopted. Wishart's writing on spatial motion [7] includes a number of diagrammatic depictions of spatial trajectories, and a number of his representations of spatial contours and trajectories are achievable with the *Cyclical Flow* system. Theories presented by Wishart that are of particular significance include "time contours" [7]. Here he describes how "motion is characterized not only by its path in space but also by its behavior in time". He goes on to define "first order time properties (different speeds of motion) and second order properties (the way in which the speed changes through time, the acceleration or deceleration of the motion)". This is relevant to the twenty-seven easing types implemented, allowing the user to determine acceleration and deceleration of spatial trajectories.

In *Cyclical Flow*, symbolic systems for setting and adjusting trajectories and spatial pathway nodes (which the spatialized sound objects move through) are particularly relevant to Wishart's definitions of "frame", and "frame motions". The software system developed also facilitates a number of the frame transformations he describes. Simple quasi-generative systems implemented in *Cyclical Flow* for modulating trajectories and pathways are also relevant to Wishart's definition of "frame motions". See "frame rotate" for example, which represents one-dimensional frame motions. Frame rotations are implemented as an optional automated system, allowing the pathway of each sound object to be modulated at different speeds and in different directions, creating shifting spatial trajectories. Whilst there are distinct interrelationships between the features implemented in *Cyclical Flow* and the spatial motion techniques described by Wishart, it is important to note that the system is not a direct implementation of all the spatial motion behaviors and theories he presents.

However, a number of spatial techniques he describes can be related to specific features and intended spatial applications of the *Cyclical Flow* system.

5. SPATIAL & SOUND ENGINE STRUCTURE

The sound engine uses three primary sound sources for each *Spatial Object*. These may be used independently, or combined (mixed) to create richer textures. All three primary sound sources for each *Spatial Object* follow identical spatial trajectories. The three sound sources are an interpolating phase vocoder, [9], granular engine and simple sample player.

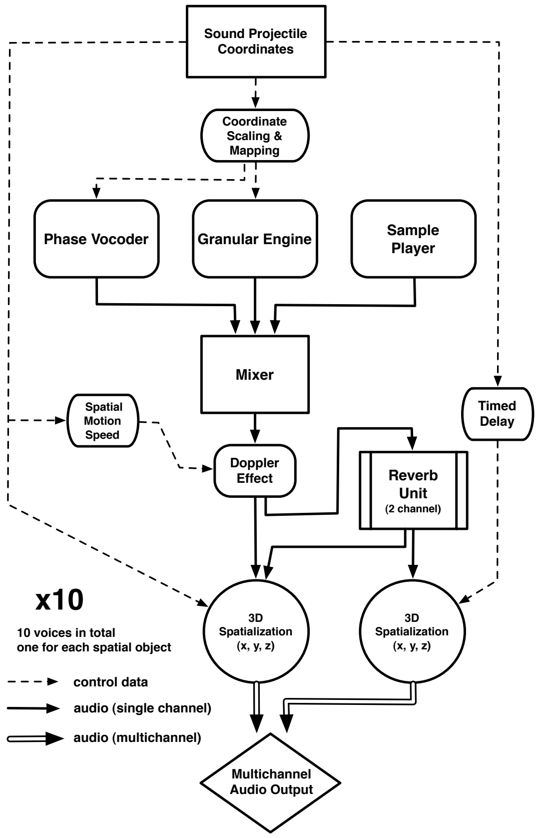

Figure 4. System structure

The developed game engine [10] application is a tool for creating real-time coordinate and control data, which is used to control an external spatial sound and synthesis engine constructed in *Max/MSP/Jitter* [8]. Coordinate data is mapped to a number of parameters. These include:

- Read position and interpolation of spectral data re-synthesized by phase vocoder.
- Read position of the granular engine, creating a granular time-stretch effect.
- Spatialisation of sound sources.
- Spatialisation of a reverb (two channel), using delayed coordinate data to create spatially moving reverberant trail effect.
- Speed of spatial motion determines pitch modulation, simulating Doppler effect.

Simultaneous mapping of coordinate data to both spatial and sound generation parameters creates a direct link between the sonic characteristics of the output, and its spatial behavior, as timbral development and spatial motion are interlinked when using the granular engine and phase vocoder sources. This technique, when combined with the simulated Doppler effect, provides a range of creative possibilities for spatial composition. ICST Ambisonic Tools [11] are at the foundation of the spatialisation system, using Neukom & Schacher's Ambisonic Equivalent Panning [12] techniques to reduce computational load. Mapping of Cartesian coordinates from the spatial composition play space to the spatial sound engine is made simple due to ICST's *ambimonitor* GUI object [11] accepting both Cartesian and spherical data input, so Cartesian coordinates output from the game engine only require smoothing and scaling before being mapped. It should be noted that the reverb trail system implemented is not intended to simulate real or imagined acoustic spaces, and is designed as a dynamic spatial trailing effect for moving sound objects.

6. 8 CHANNEL VERSION

The user is presented with a top down perspective of a 2D virtual space that represents the physical performance space. The player selects a sound type, a cyclical spatialisation sound object is then selected and introduced into the virtual space, this is known as a *Spatial Object*. The player adjusts the positions of *Path Maker Nodes* that determine the path, or trajectory of the sound generating object, which is termed the *Sound Projectile*. The coordinates of the *Sound Projectile* directly control spatial motion and two key parameters of sound generation. These are: spectral frame and grain read position (playhead) in the phase vocoder and granular synthesis engines. Coordinates of the *Sound Projectile* thereby control timbre, sound evolution and spatial motion. The x and y axis both control spatial parameters, whilst only the x axis is used to control spectral frame and grain read position. This mapping decision was considered appropriate for a series of pieces being developed, but may be quickly modified to use alternative axes, or decoupled completed if required. A simulated Doppler effect is also integrated to create more dramatic and quasi-realistic spatial motion effects. The Doppler effect becomes a more prominent feature when using faster spatial trajectory motion speeds. As a result, spatial motion can be perceptually exaggerated. High frequency absorption filtering is also implemented to simulate real-world spatial behaviors.

Each *Path Maker Node* has an associated *Projectile Rate Node* that is used to control the speed of the *Sound Projectile* as it travels towards the respective *Path Maker Node.* When *Path Maker Nodes* are positioned a greater distance apart, with a high *Sound Projectile* rate, fast moving spatial effects occur, with quicker transitions in timbre and more exaggerated pitch modulation effects. When the nodes are positioned closer to each other with a slower projectile rate, gradual timbral shifts occur within a more limited spatial area. As the y axis is not mapped to control spectral frame or grain read position, it is possible to create more gradual timbral shifts, with greater spatial motion by placing the Path Maker Nodes in roughly the same position along the x axis, but at very different positions along the y axis.

Figure 5 represents two *Spatial Objects* and their associated nodes. Each cluster of *Path Maker Nodes* corresponds with a player selected sound type, with motion of each *Sound Projectile* limited to the interconnected nodes within its cluster. Each of the *Path Maker Nodes* can be moved freely around the virtual space, changing the trajectory, or pathway of the *Sound Projectile* as it travels between the different nodes. The smaller sphere attached to each of the *Path Maker Nodes* is the *Projectile Rate Node*, this allows the player to control the speed of the projectile as it travels towards its corresponding *Path Maker Node*. The time contour of the *Sound Projectile* is determined by the user, through selection of the available easing curves, further shaping spatial modulations. As the *Sound Projectile* moves between the nodes, spatial and spectral parameters of sound develop.

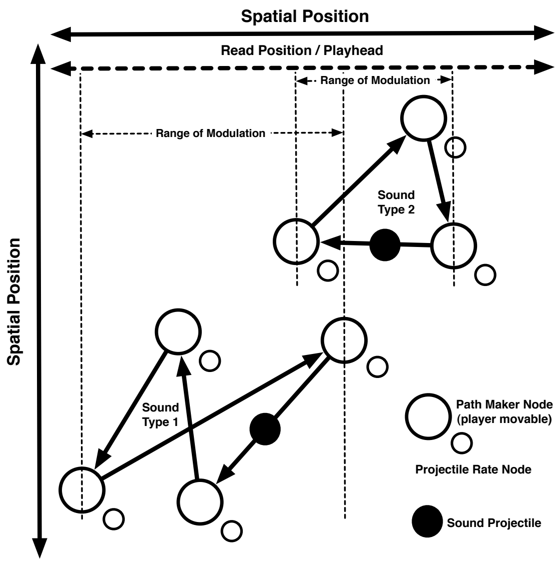

Figure 5. Spatial object clusters

These modulations are directly related to the position, range, and rate of motion of the projectile. The dotted lines in Figure 5 show the range of motion as dictated by the positions of the *Path Maker Nodes*. The player selects from the ten available *Spatial Objects*, each containing a different number of *Path Maker Nodes*. These consist of between two to eight nodes. Two nodes provide a simple two stage repeating cyclical motion. Eight nodes offer scope for more complex spatial and spectral modulations, but are a little more time consuming to work with. The number of nodes in each *Spatial Object* affects the degree of complexity of the modulations, and has an effect on the cyclical features of the sound output.

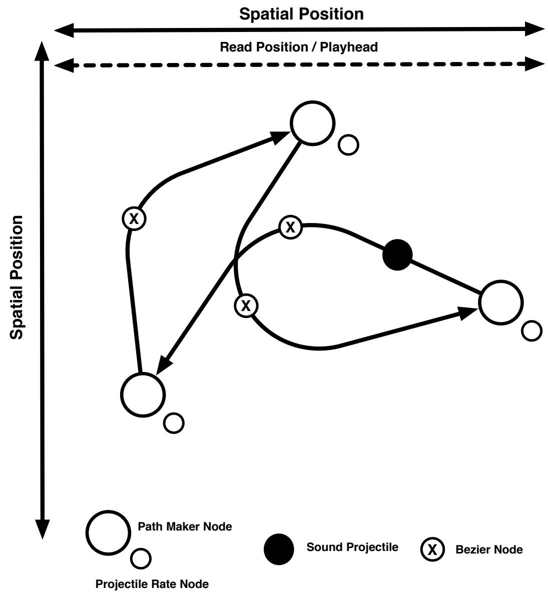

Figure 6. Bezier nodes

Figure 6 introduces the *Bezier Nodes*. These allow the player to vary the curve of the path of the *Sound Projectile* as it travels between each of the *Path Maker Nodes*. Placing the *Bezier Node* directly in line between its related *Path Maker Nodes* results in linear trajectories. The further the *Bezier Node* is moved out of alignment with its related *Path Maker Nodes*, then the more dramatic the curve.

7. AUTOMATIC TRAJECTORY MODULATIONS

A generative feature is implemented which enables the user to activate automated motion of all nodes within a *Spatial Object*, altering spatial targets and trajectories, resulting in dynamic shifting spatial, spectral, and timbral effects. Further user input is possible when the generative rotation modes are active, as the *Path Maker Nodes* and *Bezier Nodes* in a *Spatial Object* may still be freely moved and repositioned as normal.

A central rotation point is calculated for each *Spatial Object*. The rotation point is averaged from the positions of all *Path Maker Nodes* within the cluster. If activated by the player, these nodes rotate around the central rotation point in either a clockwise or anti-clockwise direction, according to the selection of the player. The *Bezier Nodes* may also be rotated, and these rotate independently to the *Path Maker Nodes*. If the *Path Maker Nodes* are kept static and the *Bezier Nodes* are rotated, then dynamic shifting trajectories occur which move between the same static points in space. The rate of rotation can also be adjusted for both node types. The rotation modes result in dynamically changing trajectories of the *Sound Projectile*, creating a form of generative effect that is dependent upon the position of each node relative to each other node. The player can continue to adjust node position relationships whilst the rotation mode is active.

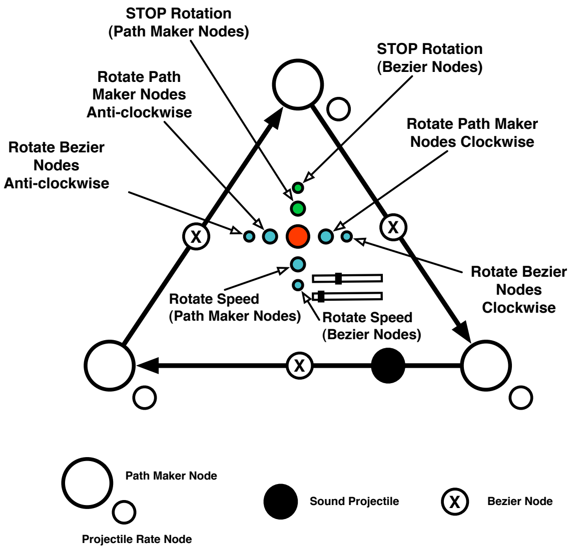

Figure 7. Automated rotation modes

There are a number of different ways *Cyclical Flow* can be explored, resulting in different spatial effects. Gradual textural shifts can be achieved using slow projectile rates and minimal relative node position range along the x axis. Rapid dynamic spatial trajectories are achieved using larger distances between *Path Maker Nodes* and faster projectile rates. Sounds may be attributed their own specific area within the performance space, or by using overlapped pathways, the user may create counter trajectories where different *Sound Projectiles* cross paths. Multilayered spatial interactions can be created using multiple *Spatial Objects*, with varied numbers of nodes and different motion rate settings creating shifting cyclical patterns.

8. USER INTERFACE LAYOUT

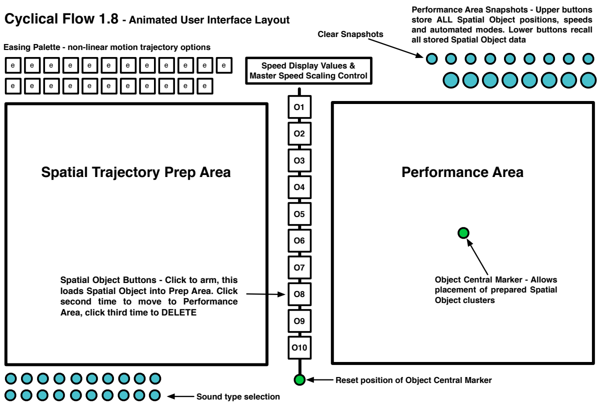

Figure 8. User interface layout (8 channel)

The user is presented with two work areas and several groups of button controls. *Spatial Objects* are instantiated using the icons in the center of the interface, (labeled O1, O2, O3 etc. in Figure 8). The inactive *Spatial Objects* appear in the *Spatial Trajectory Prep Area* where they can be freely positioned and speed settings adjusted. No sound is generated by the *Spatial Objects* when in the *Prep Area*. To move the *Spatial Objects* to the *Performance Area* where they become active and output sound, the corresponding *Spatial Object* icon is again selected. Once in the *Performance Area*, the *Spatial Object* is activated and animated, generating dynamic coordinate data for the spatial sound engine. When the *Spatial Object* is removed, or moved back to the *Prep Area*, sound output for the object ceases. When in the *Performance Area*, all nodes, modes and speed settings of the *Spatial Object* may still be modified by the user, allowing real-time modification of spatial and spectral trajectories during sound generation/spatialisation.

8.1. Easing Palette

The *Easing Palette* contains 27 different easing options, or interpolation curves that determine changes in speed, and sometimes direction of the *Sound Projectile* as it travels between each of the *Path Maker Nodes*. These expand the range of potential spatial and spectral effects, and allow time contours to be varied. Different time contours may also be combined.

8.2. Speed Display & Master Speed

The *Speed Display* section updates dynamically whenever a node speed parameter is changed, providing visual feedback of the speed settings for each node when adjusted by the user. The values represent the time it takes for the *Sound Projectile* to move from the previous node to the destination *Path Maker Node*. The overall speed of motion can be scaled for all *Spatial Objects* in the *Performance Area*, allowing all *Sound Projectile* object speeds to be increased or decreased, whilst still retaining relative rate relationships.

8.3. Snapshots & Recall

Once the user has created an active cyclical pattern, using any number or combinations of *Spatial Objects*, the position of every *Spatial Object* and its associated nodes can be stored as a *Performance Area* Snapshot. Speed settings and automated rotation mode states are also stored. These snapshots can then be later quickly recalled, allowing dramatic structural shifts in spectral and spatial features. The *Performance Area Snapshots* allow for thematic repetition, as previously created patterns can be reinstated. Cyclical patterns may also then be developed with further adjustments of the *Spatial Object* nodes from the stored snapshot positions. The snapshot feature enhances the performance potential of the project, as complex spatial patterns can be interchanged and developed quickly and efficiently.

9. 24 CHANNEL VERSION

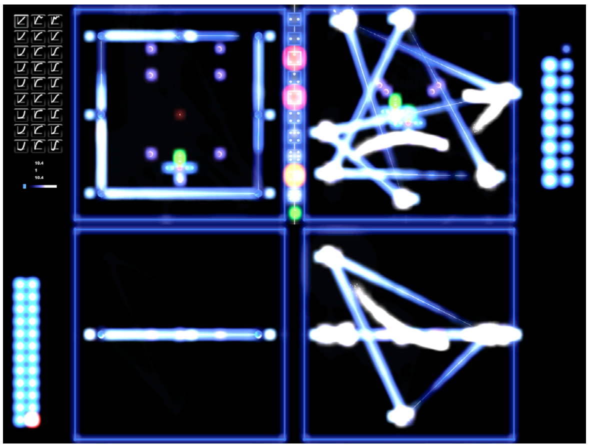

Figure 9. The graphical user interface (24 channel)

The primary functions of the eight channel version of *Cyclical Flow* are present in the twenty-four channel version, but in this version sound is spatialized in three dimensions. Additional player editable windows are included, facilitating the control of height. The new lower windows represent the same performance space, but provide a front facing perspective to accompany the top down view (upper windows). These allow the player to adjust the elevation of each *Path Maker Node* and *Bezier Node*, allowing spatial movement of sound throughout a three dimensional performance space. A 2D representation of a 3D space is implemented to assist in accuracy of object placement.

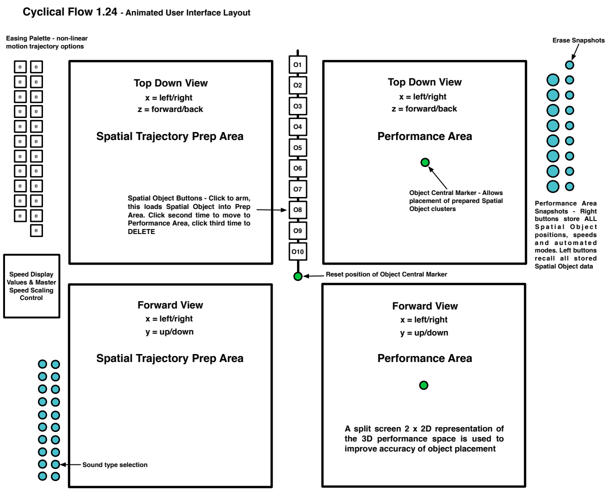

Figure 3. User interface layout (24 channel)

This version includes identical groups of button controls as are found in the eight channel version, except these are presented in a slightly different layout. The two additional lower windows represent height and width, the upper windows width and depth. Combined these windows represent all three dimensions (x, y, z) of the performance space. The upper and lower left windows represent the *Spatial Trajectory Prep Areas*, with the upper and lower right windows showing the active *Performance Areas*. All features of the eight channel system are available in the twenty-four channel system. *Spatial Object* behaviors, trajectory modulation modes, time contours, and snapshot storage and recall systems are fundamentally identical, except that in this version these systems function using coordinates in three dimensions.

10. OBSERVATIONS FROM USE

The system was explored during the realization of two twenty-four channel fixed media works. The opportunity to experiment, explore and improvise with interlinked sound generation, textural, spectral and spatial parameters provided an alternative perspective on working on and developing sound materials, with spatiality in three dimensions an inherent part of the sound creation and sound design process at an early stage of composition. It was found that shifting complex spatial counterpoint and intertwined trajectories can be quickly created and interchanged. The system was found to be best suited to real-time creation and performance of spatial materials, which may also be recorded, for use as multichannel materials for fixed media works, with technical barriers to quickly setting up complex spatial interactions in larger multichannel performance environments largely avoided. The system is less suited for use as a diffusion tool for existing fixed media works [13], and this was not an aim for the system. The flexibility of the system allows significant scope for a variety of sonic and spatial outputs, and different styles of interaction. Implementation of time contours is considered as being particularly successful, from both spatial and spectral perspectives due to the mapping strategies employed. The system is viewed as successful in that it allows spatial complexity to be easily achieved through the symbolic visual interface, this is particularly the case when working with larger scale multichannel systems. It therefore provides a personal solution for composition of multichannel works. Throughout the testing and development phase additional features were added to extend the performance potential of the system. Whilst these features have been used when capturing spatial performances for fixed media composition, the system has not been presented within a concert situation, so has currently only been tested and applied as a compositional tool. There is certainly scope for presenting the project as an audiovisual performance in a concert situation, in which the audience may view the performed and generative trajectories, and meaningful feedback on audience experience in this context is to be sought.

11. FINAL COMMENTS & FUTURE DIRECTIONS

The system was originally designed and conceived as a solution, tool and sound toy for real-time transformation and spatialisation of sound materials for personal compositions in larger scale multichannel environments. However, the system may be easily adapted for alternative specialist performance spaces with differing speaker configurations, and further opportunities for testing, development and creative exploration are to be sought, with the software made freely available for other composers to investigate and explore. There is potential for exploring and applying the tool in the composition and realization of multichannel pieces and performances on various scales. Initial testing has also been conducted using binaural / HRTF techniques, predominantly for documentation, demonstration and system development purposes, with the system being flexible enough for this approach to be easily and quickly implemented. The results of which were encouraging, although not deemed as successful as when working with a multichannel loudspeaker array. More thorough testing in this area is yet to be completed. The system could also translate effectively to current multi-touch technologies, with the visual interface application running on a multi-touch device, communicating coordinate and control data over a wireless network to the sound engine running on a host machine.

12. REFERENCES

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