The Development of Physical Spatial Controllers

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ABSTRACT
This paper introduces recent developments in the Chronus series, a family of custom built controllers that afford a performer gestural interaction with surround sound systems, and that can be easily integrated into their personal performance systems. The controllers are built with the goal of encouraging more electronic musicians to include the creation of dynamic pantophonic sound fields in performance. The paper focuses on technical advances of the Chronus_2.0 prototype that extend the interface to control both radial and angular positional data. There is also discussion of the controller's ease of integration into electronic performance configurations, both for diffusion and for performance from the wider electronic music community.

Keywords
Interface design, spatialisation

1. INTRODUCTION
Live electronic music is increasingly being performed through multichannel sound systems capable of spatialised sound. The paradigm of sound diffusion has until recently been largely based around the user interface of the mixing desk, making spatial performances often limited to specific diffusion concerts rather than allowing an easy integration into an electronic musician's performance configuration.

With an increasing number of performance venues catering to various forms of surround sound systems, there is an ongoing desire to utilize these systems in the more expressive ways. However, with commercial interfaces, many performers are left with a knob controlling a stereo spread as the only dynamic spatialisation option. In this situation, the rear speakers are often set merely to mirror the frontal stereo field, doing very little to make use of the potential pantophonic spatial trajectories afforded by surround systems. Many musical controllers are equipped with standard knobs that are often mapped to control stereo spread. Whilst continuously rotating knobs are available, the majority of controller's knobs are only able to rotate approximately 300 degrees in one direction, significantly hindering the potential for 1:1 mapping of spin-based spatial trajectories, limiting the performer to side to side motion.

This paper introduces some possible solutions for electronic musicians wanting to utilize the potential spatial aesthetics afforded by the emergence of surround systems in performance venues. The paper starts by introducing the field of interface design for spatialisation performance and looks at examples from the paradigm. There is a case study on the Chronus interface, with a focus on technical developments to Chronus 2.0 that have achieved heightened control of positioning within the spatial field. Section 4 discusses the modularity of the authors spatialisation system and how the Chronus series of controllers integrates into the system, as well as ways in which electronic performers can integrate the controller into their own systems. The paper concludes by suggesting future improvements planned for the Chronus series.

2. RELATED WORK
A large number of diffusion artists have expressed concerns with the limitations of the use of the mixing desk as a performance tool for live spatialisation [12], [10], [2]. The biggest concern is that the ergonomics of the interface significantly limit the spatial trajectories able to be performed in real time. The mixing desk can be configured in many different ways, the most common being to group the speakers in left/right pairs and have the front speakers controlled by faders on the left of the desk through to the back most speakers controlled with faders on the right. Many other configurations are available; however, with almost all configurations of a mixing desk, the performer is very limited in the real-time control of any spin-based trajectories, and control of the perceived distance from the listener.

In the past ten years, many institutes have explored the potential for increasing expressive range in spatial performance through the development of new interfaces specifically for diffusion performance. The ReSound [11] and BEAST [5] systems both offer variations on the mixing desk and include the ability to access preprogrammed trajectories. In a move away from the mixing desk, a wide range of new spatialisation systems have emerged, including the use of tools such as WiiMotes and GameTraks appropriated from the gaming industry [8], [3], gesture tracking devices both customized and utilizing the Microsoft Kinect [2], [4], [9], and multi-touch applications [1], [6]. A common trend amongst these new systems is a desire to increase potential spatial motion whilst encouraging gestural interaction with the space. The development of these interfaces has encouraged the creation of phantom source positions within dynamic spatial fields. This differs in aesthetics from traditional diffusion performances where individual or group speaker gains were controlled directly rather than as a function of discrete source positions.

The area within new interfaces for spatial performance that has been the least explored is that of developing new physical interfaces. As such, spatialisation systems have largely remained within the field of diffusion rather than being incorporated into the wider field of electronic performance. The controller presented in this paper aims to allow intuitive gestural control of spatialisation and increase expressive spatial range, while being accessible to diffusion artists as well as a wider range of electronic performers.

3. THE CHRONUS CONTROLLER

The authors have been developing a series of interfaces that aim to address many of the technical and performance based issues exhibited by other systems. The design goal is to produce a new physical interface that can be used for spatial performance and can be easily incorporated into any live electronic setup. The interface must be highly intuitive so performers can learn to use it on the fly and must not require constant physical contact so the performer is able to control the spatialisation as an addition to their performance, without hindering their established practice.

3.1 Technical Design

The first version of Chronus [7] shown in Figure 1, featured an intuitive design able to directly map the circular motion of a spinning disc to a sound object's position in space. The design features a rotary encoder that is controlled via a free spinning disc operated by the user. Multiple controllers can all be linked to a single Arduino mircocontroller, allowing performers to simultaneously control the position of a number of different sound sources.

This prototype proved the disc design was easy to use and very fast to learn for performers, however it only allowed control data to be sent in regards to an angular position in space. In order to increase expressivity and potential sonic trajectories a second prototype of the interface, Chronus_2.0 has been designed and built to afford the user control of both radial and angular position in space. The subsequent sections explain the upgrades needed to include the radial position in a cost effective manner, and without compromising the intuitive behavior of the controller.

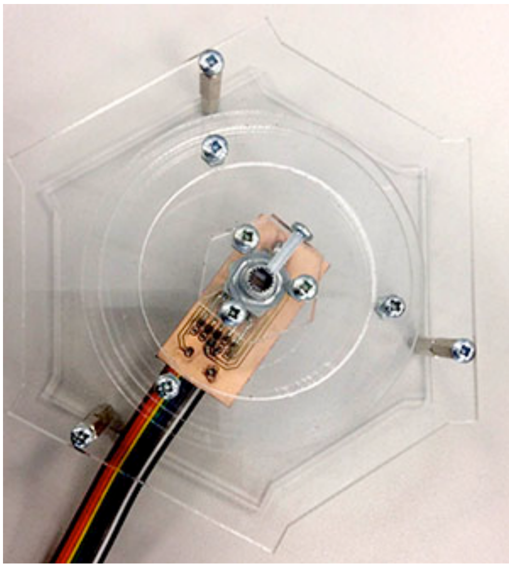

Figure 1. Chronus_1.0 Controller

The obvious addition to Chronus was to add a fader that could control spatial distance. In order to keep the spatial mapping direct to the physical gesture, the fader would need to spin with the disc and constantly point to the sound source. This would cause the wires associated with any standard fader configuration to tangle very quickly and render continuous circular trajectories impossible. Chronus_2.0 incorporates a slip ring in order to allow free movement of the fader and intuitive gestural interaction with space without wires limiting directions of rotation. The controller was designed with the aid of CAD program SolidWorks, where a 3D model was first built, allowing various parts of the assembly to then be exported and cut with a laser cutter.

3.1.1 Slip Ring

The slip ring, shown in Figure 2, is a device that allows electrical signals to be transmitted from a rotating structure (the spinning disc) to a stationary structure (the micro-controller). A rotating steel disc or brush within the slip ring structure makes contact with a stationary metal ring, allowing current to flow through the two points as the disc is rotated. Thus, continuous real-time transmission of data is possible without limiting any circular motion. The rotating section of the slip ring is attached to the spinning disc via a tube. The user rotates the disc, this causes the tube and in turn the slip ring to rotate as the angular position is changed. The wires from the contact points on the potentiometer are guided through the inside of the tube to the slip ring protecting them and ensuring there is no chance of them becoming tangled as the disc rotates.

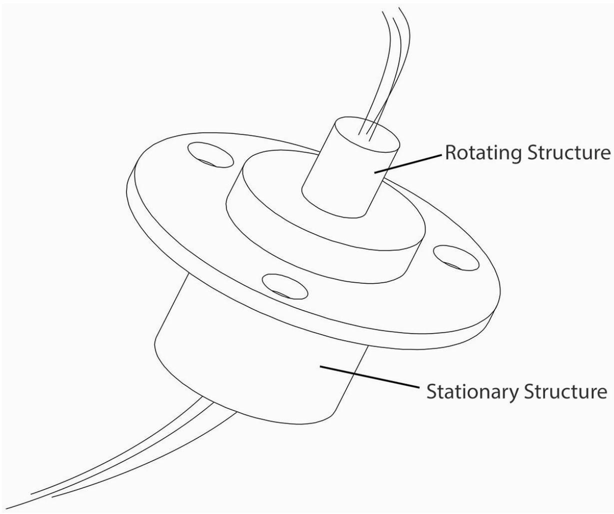

Figure 2. Slip Ring

3.1.2 Gear and Encoder System

The linear potentiometer and slip ring are a necessary inclusion into the design in order to increase expressivity, however they interfere with connection between the spinning disc and the rotary encoder that conducts the angular data in the Chronus_1.0 design. A range of commercial encoders exist that could attach to the outside the tube, however these were not an option for this project due to their relatively high cost. In order to save money and allow full functionality with a standard encoder available for under USD $5, Chronus_2.0 incorporates a gear system. Two involute meshing gears designed with the aid of CAD software, and laser cut from 6mm thick acrylic transfer the motion from the tube to the encoder. The first gear is attached to the tube that rotates with the spinning disc; this rotational motion is then transmitted with a 1:1 ratio to the second gear which is attached to, and transmits the motion to the encoder, allowing the movement to be read by the micro-controller. This assembly is outlined in Figure 3.

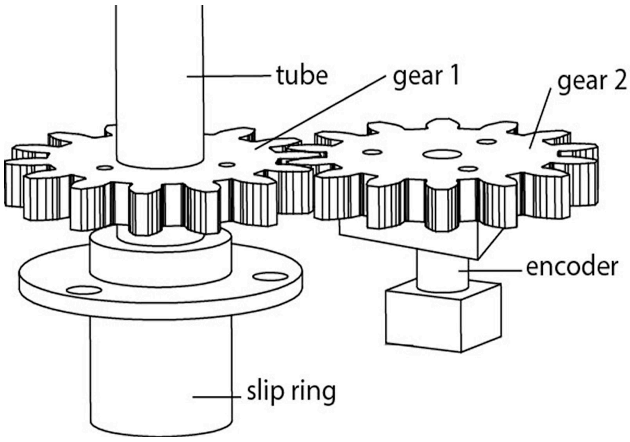

Figure 3. Encoder/Gear System

3.2 Structural Design

The full internal structure of Chronus_2.0, shown in Figure 4, is based around the slip ring, gears and rotary encoder all being able to be controlled from the one rotation of the spinning disc. This design ensures that the user is able to control all the movements with only one hand, and therefore able to use the controller simultaneously with other musical controllers within their performance.

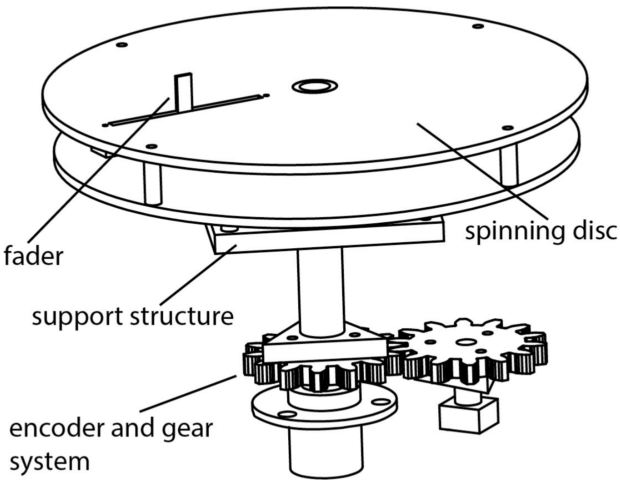

Figure 4. Chronus 2.0 Internal Design Structure

The internal structure sits within a custom enclosure that has been laser cut out of clear 6mm acrylic. The acrylic needs to be at least 6mm thick to support the weight of the internal structure, and to ensure durability making the controller easy to transport. All features of the structural design are placed within the enclosure with only the spinning disc sitting above, as shown in Figure 5. The encoder and slip ring are attached to a false bottom, separating the rotating parts from the stationary ones. This also allows the Arduino to sit underneath the false bottom and to be enclosed by the outer structure ensuring no wires are left exposed. The design was chosen for visual aesthetic reasons as well as to protect and support the weight of the disc and allow the tube to spin with ease. The clear acrylic is visually compelling and also allows the user to see all the internal parts to check that everything is functioning as desired.

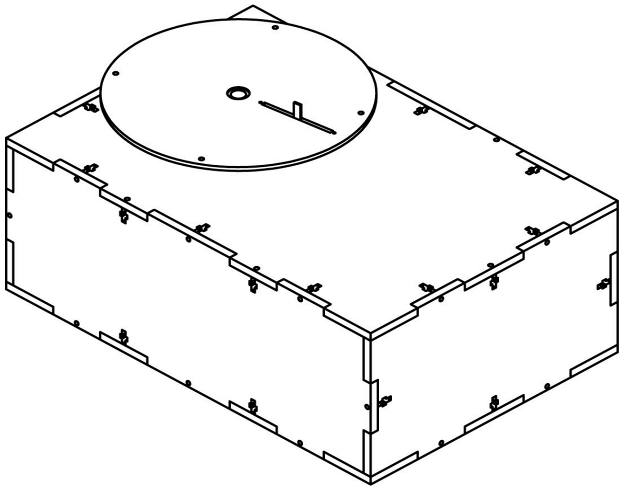

Figure 5. Chronus 2.0 Enclosure

4. PROTOCOL/INTEGRATION

In its current incarnation the positional data from the fader and encoder are read by an Arduino microcontroller. The Arduino sends serial data to be processed in Processing. The first step is to scale and convert the data to polar coordinates (a theta and radius). The angular data can be converted to either degrees or radians and the radial data is scaled based on a user input of a maximum distance (the radius of the desired spatial scene). The data is then sent via OSC messages as its polar coordinates, an example of which is shown in Figure 6. The data is calculated in this manner with the intention of having the interface easily integrated into any spatialisation system. The protocol is designed so as not to isolate the interface to work with specific spatialisation algorithms. Polar coordinates are the common input messages for the majority of advanced external spatialisation objects in audio environments including both VBAP and ambisonics in Max/MSP. It was also important that the device feature the same protocol as the author's other spatialisation tools [12] so that either user interface may be interchanged to suit the performers personal requirements. The goal is that the entire system be as modular as possible so that various user interfaces can be interchanged to all work within the authors wider spatialization system as well as with other systems.

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Protocol
/radius/i f
/angle/i i

Example Message
/angle/1/270
/radius/1/1.52
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Figure 6. OSC protocol example. The int depicted by i is the ID of the controller so that multiple controllers may be used concurrently and individually directed to separate sound objects

While the controller was designed specifically for intuitive spatial positioning of sounds, the intended modularity of the system means that the interface itself merely sends the control data to be processed elsewhere. Therefore, there is no reason that the controller could not be mapped to any other musical parameter or used with any other software.

In performances by the first author, the polar coordinates are then unpacked by a separate Processing sketch that processes the data and converts it to weighted gain factors via a custom implementation of a VBAP algorithm. This sketch was originally designed to convert spatialization data from the *tactile.motion* diffusion interface. Currently this process is deliberately separated from the conversion to polar coordinates because it relies on external knowledge such as preferred spatialisation algorithm, the number of speakers and their configuration. This separation keeps the full spatialisation system functioning in the most modular way possible.

Any audio software capable of receiving OSC could potentially unpack the messages and map them to gain factors. The author has developed a custom Max/MSP patch that drives all the audio for the spatialisation. The patch unpacks the gain factors and directs them to control the audio signal they correspond to. The patch accepts up to 8 channels of audio in any combination of live input or audio file and can output anything up to 24 speaker channels.

As discussed, the entire system, as outlined in Figure 7 is designed to be as modular as possible with each section able to be interchanged at any point.

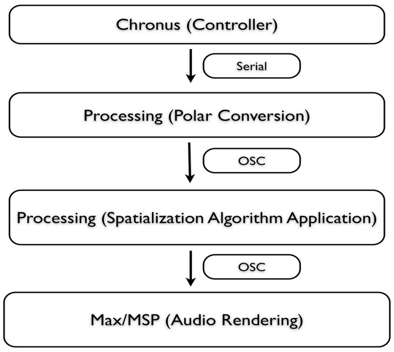

Figure 7. Modular Spatialization System Overview

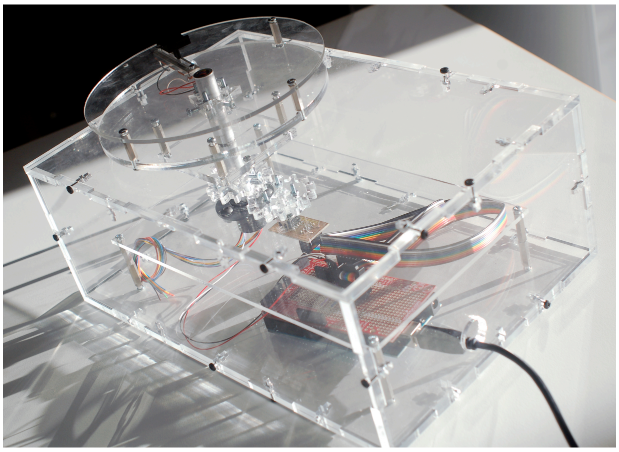

Figure 8. Chronus 2.0

5. CONCLUSIONS

The Chronus controller affords the performer accurate control of spatial positioning within a pantophonic sound field. The inclusion of the slip ring and gear system gives the performer a second axis of control while maintaining an intuitive gestural relationship to sonic trajectories, at an affordable cost. A full modular spatialisation system has been designed to utilize this and other performance interfaces to encourage heightened control and greater expressivity in spatial performances. Whilst designed to be incorporated into this system the controller can be used with any spatialisation algorithm and could easily to set up to send MIDI messages in order to communicate directly with Ableton Live or other DAW's in both studio and live applications (as is intended for the next version of the series).

With many of the new diffusion interfaces requiring constant physical contact, the Chronus 2.0 controller aims to allow easy integration with other controllers to complement a performer's configuration without hindering their current set up. It is hoped that this ease of integration will encourage more performers to utilize the surround sound systems available in performance venues, and add an extra dimension of musically expressive range to their performances.

6. ACKNOWLEDGMENTS

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