MULTI-TOUCH INTERFACES FOR PHANTOM SOURCE POSITIONING IN LIVE SOUND DIFFUSION

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ABSTRACT
This paper presents a new technique for interface-driven diffusion performance. Details outlining the development of a new tabletop surface-based performance interface, named *tactile.space*, are discussed. User interface and amplitude panning processes employed in the creation of *tactile.space* are focused upon, and are followed by a user study-based evaluation of the interface. It is hoped that the techniques described in this paper afford performers and composers an enhanced level of creative expression in the diffusion performance practice.

Keywords
Multi touch, diffusion, VBAP, tabletop surface

1. INTRODUCTION
The field of live sound diffusion has recently seen a new generation of performance techniques catalyzed by major developments in the field of new interfaces for musical expression. Since the 1950s, the performance interface for diffusion has remained largely stagnant: performances use standard mixing desks or customized groups of fader banks. However, the past five years have shown an increasing desire to develop new gestural interfaces and adapt existing technologies such as those from the gaming industry for use as diffusion performance tools. This paper introduces and evaluates *tactile.space*, a multi-touch performance interface for diffusion built on the BrickTable [7]. It describes how *tactile.space* implements Vector Base Amplitude Panning to achieve real-time source positioning. The final section of this paper presents the findings of a user study that was conducted by those who performed with the interface, evaluating the interface as a performance tool with a focus on the increased creative expression the interface affords, and directly comparing it to the traditional diffusion user interface.

2. THE DEVELOPMENT OF CURRENT DIFFUSION PERFORMANCE PRACTICE
The performance practice of sound diffusion began in the early 1950s with the release of the *potentiometer d'space* by Schaeffer and Henry [1]. As the first user interface for real time sound spatialization, *potentiometer d'space* consisted of a quadraphonic speaker array and a vertical fader bank with each fader controlling the direct gain of a particular speaker. Thus arose the paradigm of sound diffusion with many similar systems being developed across Europe and the United Kingdom in the 1970s and continuing to evolve to this day. Whilst these systems, such as BEASTs [6], The Gmebaphone [3] and the Acousomium [4], continue to use the vertical fader bank as their user interface, the software driving these systems began to allow discrete source positioning of sounding objects through spatialisation algorithms such as Vector Base Amplitude Panning (VBAP) [14] and ambisonics and wave field synthesis**.** In addition to these more traditional systems, some research groups have attempted to address the disembodiment caused by the fader bank as user interface in diffusion performance by developing software allowing greater control of source positioning on the fly and a wider range of possible sonic trajectories that are able to be performed live. Some examples of such systems are GSMAX [15] and M2 [12]. These systems, while still focusing on fader banks and traditional user interaction paradigms (mouse and keyboards), were built in recognition of a need for research and development into the performance interface used for diffusion. Their goal was to give the performer a more intuitive and sophisticated command of the spatial field with an increase in the potential sonic trajectories.

Around the turn of the century, a new field of electronic performance arose developing existing user interfaces originally built for gaming or other forms of interactive computing as musical performance tools. In 2012 Vigliensoni and Wanderley conducted a study on some such devices, naming them position trackers [16]. For the purposes of this study we shall include such technologies as iPhones and WiiMotes in this particular category. These developments have seen user interfaces such as the WiiMote, the iPhone and the GameTrak all become tools for the control of panning in electronic performance. With the common accessibility of VBAP and other spatialisation audio plugins, as well as Max/MSP objects, users were able to directly map the position of their chosen device to the angle and radius parameters of a VBAP algorithm. Performances of this nature have catalyzed an opening in the diffusion paradigm for user interfaces with the intuitive spatial nature that many of the positioning trackers exhibit to be developed specifically for the performance of sound diffusion with a focus on the ability to create phantom source positions in real time. It was within this new field of interface-driven diffusion performance that *tactile.space* was developed.

3. SYSTEM OVERVIEW
3.1 *tactile.space* Hardware and Software
tactile.space was designed to run on a large-scale tangible user interface, the BrickTable. Table-top surfaces have proved their place in electronic music through applications like the

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AudioPad [13] and the reacTable [9]. Their gestural capabilities and intuitive nature make them a suitable platform for development of gestural performance interactions.

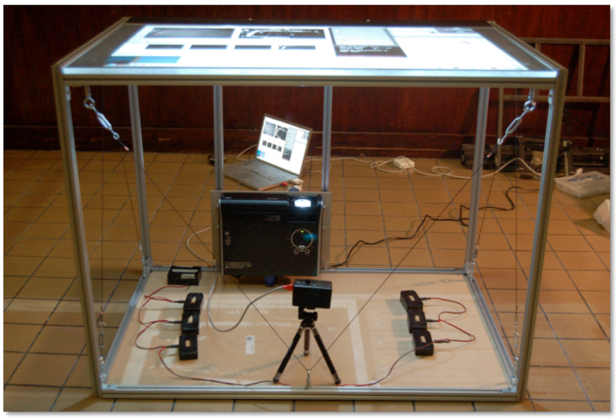

Figure 1. The BrickTable

The BrickTable makes use of the reacTIVision [10] tracking framework. The toolchain begins with the open-source software Community Core Vision (CCV)[1]. CCV is the tracking software that recognizes the touch data from the view of the camera and sends it via the Tangible User Interface Objects (TUIO) [11] protocol, which is received in Processing using the TUIO client library. Figure 2 gives an outline of the *tactile.space* tool chain.

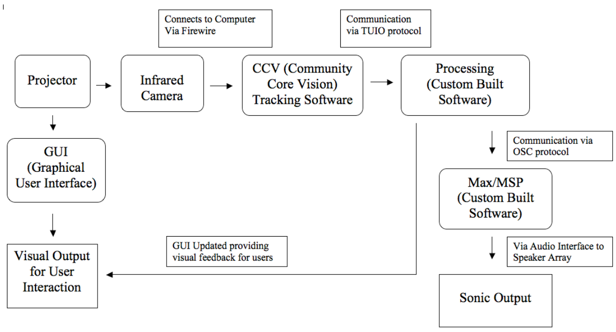

Figure 2. *tactile.space* data flow

3.2 *tactile.space* Implementation

The system architecture of *tactile.space* is such that the interface is highly configurable for individual performers' wants and needs. It allows the interface to quickly and easily cater to the specific technical and aesthetic needs of each composition, making a smooth transition possible between pieces in a concert setting without placing restrictions on possible configurations for the individual performer.

In its simplest form the user drags a visual representation of an audio track and positions it amongst a representation of an array of loudspeakers. Calculations are made to position that audio in the desired location.

3.3 Configurability and Modes

tactile.space can be run in three varying modes, each utilizing a different set of spatialisation techniques; the modes are quadraphonic panning, stereo pairing, and VBAP. The user may also specify the number of speakers and their configuration, as well as the number of audio input channels and the type of channel (live input or audio file). The user may also make aesthetic decisions about the size of the control area, the presence of numbers helping to identify audio objects and the distance from the sweet spot the speakers are. For full explanation of the technical capabilities of *tactile.space* please refer to [8] for more UI-related information.

Figure 3. User Controls Spatial Positions On *tactile.space*

4. DIRECT SOURCE POSITIONING IN DIFFUSION

tactile.space was designed with the goal of increasing the intuitive and gestural interaction with space for the diffusion artist. In standard diffusion practice, the performer is controlling a left/right panning spread in performance. VBAP is a common spatialisation rendering algorithm but has not been widely implemented within a live setting. In VBAP mode on *tactile.space,* the audio object's position within the representation of the speaker array (as placed by the performer) directly correlates to the perceived position of that audio track within the spatial field. VBAP mode was conceived of as a way to increase the possibilities of dynamic source positioning and the variety of sonic trajectories available to the diffusion artist within a pantophonic speaker array.

To implement direct source positioning, the speaker array is divided into pairs of speakers in a manner by which each speaker is a member of two pairs, known as pair wise panning (see Figure 4). When an audio object is moved with in the speaker array, its position is evaluated to decipher which two adjacent speakers it falls between; these will be the two speakers used to create the phantom source position. The audio object's angle and radius within the pair of speakers it is closest too is calculated and used to provide gain factors for each speaker (see Figure 4).

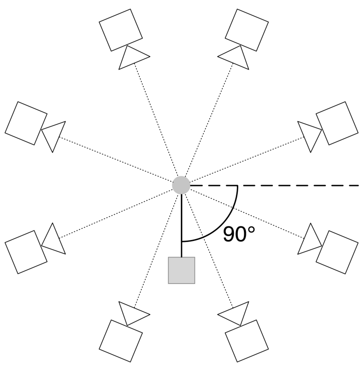

Figure 4. Speaker Pair Fields with Radius and Angle Calculations

[1] http://ccv.nuigroup.com/

The gain factor for each speaker is created with a version of the trigonometric panpot law [5]. This panpot law was first built as a result of an understanding of human psychoacoustics in a frontal stereo field. It can, however, be equally as effective in a pantophonic array. While there are many variations of panpot laws, the sine cosine law was chosen for *tactile.space* as it is the most accurate in most circumstances: it is less affected by listeners' head angle and the frequency of the sound source. The equation was adjusted within *tactile.space* to accommodate the data flow of the interface.

$$L = \cos\theta * i$$
$$R = \sin\theta * i$$

For the above equations, L and R are the two speakers in use, θ is the angle of the desired source position and i is the audio input. When this equation is in operation within the *tactile.space* system, there is no way of knowing the value of *i.* Therefore, a concession was made to always assume 0.8 as the input gain. Within the system, this equation solves for gain factors rather than direct gain values and therefore works as long as the 0.8 gain remains constant.

5. USER EVALUATION

In order to evaluate the success of *tactile.space* as a performance tool for sound diffusion and the affects of direct source positioning, a user study was conducted. A group of 18 students participated in the user study, evaluating their experience using the performance interface and comparing it to a traditional diffusion user interface (such as a mixing console). All of the participants were studying, or had previously studied, electro-acoustic composition and had varying levels of experience with traditional diffusion techniques.

The participants used common speaker configurations (as shown in Figure 4) to eliminate variation in results that may have been caused by differences within the interface itself. Participants were asked to rank the interface on a scale of 0-10 (0 being the lowest possible score and 10 being the highest possible score). They were also given the oppurtunity to comment on any part of the interface.

Particpants were asked questions from three categories about their experience in performing with tactile.space as a diffusion performance interface. The first area looked at the success of *tactile.space* as a new performance interface and evaluated its goal as an inutive form of gestural diffusion. The second area addressed the success of direct source positioning as a diffusion technique. The third category asked particpants to evaluate *tactile.space* in its ability to afford creative musical expression. Overall, the study found *tactile.space* to be a successful new tool for sound diffusion, and all particpants expressed an interest in performing on *tactile.space* again. The following subsections detail the user study's results.

5.1 Success As New Interface

In order to address disarray with traditional diffusion practice techniques, one goal of the *tactile.space* project was to create an intuitive gestural interface for the performance of sound in space. Participants were asked about the ease of learning to use *tactile.space*. The interface scored highly in with the average score for intuitiveness being 8.8. The gestural intuitiveness of *tactile.space* was successful in providing a transparent relationship between gesture and sonic output for both the audience and the performer.

Closely linked to the intuitiveness of the interface was its ease of learning for a diffusion artist new to the interface. This was important as the nature of the BrickTable or other touch table interface means that rehearsal time can be minimal and performers need to minimize the time needed to familiarize themselves with the interface and maximize the time spent focusing on developing their performance aesthetics in order to make the most of this new interface. The average score for learnability was 9 suggesting this element was successfully achieved. Figure 5 shows the results of questions asked in this category.

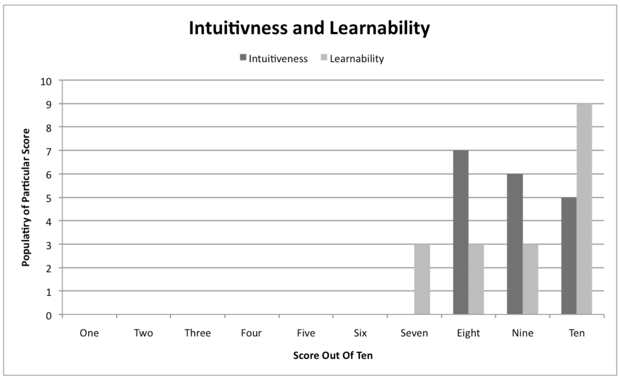

Figure 5. Intuitiveness and Learnability Results

5.2 Success of Direct Source Positioning

This category assessed the VBAP mode of *tactile.space*. As a tool for diffusion performance, the ability of *tactile.space* to provide an accurate and dynamic depiction of a sound field needed to be assessed. Participants were asked how much control of the spatial field they had through diffusion on *tactile.space*. As participants in the study were both performers in a concert and audience members, they were able to comment on the control they felt they had as a performer and the relationship between performative gesture and sonic output that was exhibited as an audience member. The average score for control of phantom source location and real time movement of an already defined source position were both 8.8 and 8.3 respectively.

The results for this section were relatively high considering human sound localization is quite dependant on the listener's position within the space and the individual's head related transfer function [2], perceptive localization of a dynamic sound field must always be considered quite subjective. Considering this, the results were favorable; the average score for perception of spatial position and movement were both 8.0. Results of this category are shown in Figure 6.

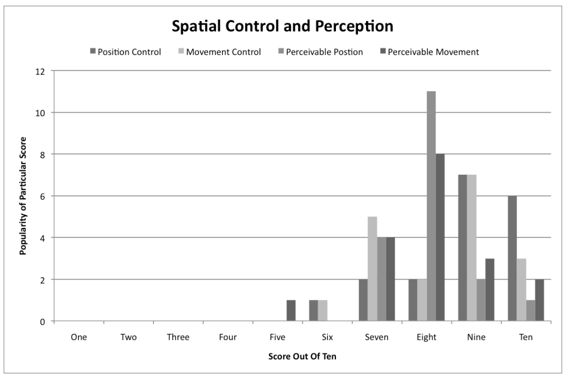

Figure 6. Results for Control and Perceivability of Spatial Field

5.3 Success as Interface For Creative Musical Expression

The final section of questions assessed the interface as a tool providing the performer with an open range of creative expression. As these questions were often concerned with the aesthetics of a performance again, the results should be viewed as quite subjective. These questions exhibited the most variation in their results.

When asked to rank the expressivity of *tactile.space*, over 50% of performers gave the interface a score of 9 or above, however this question also received a score of 4 from one participant; this was the lowest score recorded across the entire study.

Participants also ranked the performativity of the interface. They were asked to what extent they felt their interaction with the performance interface gave them the feeling they were actively performing the music. The average score for performativity was 8.6 with one participant stating: "[*tactile.space*] allowed for actual bodily integration as opposed to a mixing desk which without the visual aid of the touch table is not as intuitive and performative".

The final question in the creative expression sentence asked participants if they had the feeling their performance was adding an extra element to the piece in the concert setting. This question averaged 8.6 suggesting that performers got a great deal of satisfaction from diffusing their works with *tactile.space*.

In direct comparison to the traditional diffusion user interface of the mixing desk, all participants stated they preferred the *tactile.space* interface. The full results for creative expression are shown in Figure 7.

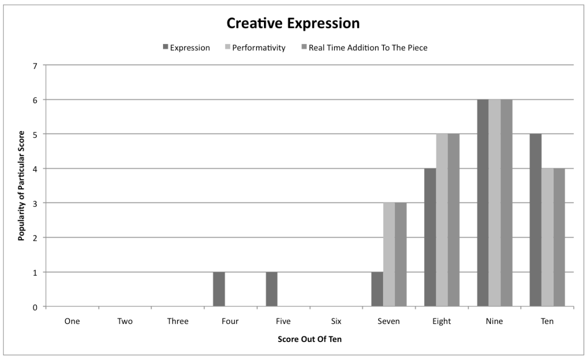

Figure 7. Results for Creative Expression

6. CONCLUSION AND FUTURE WORK

tactile.space has proven itself as a dynamic and expressive alternative performance interface for sound diffusion. The gestural intuitive aspects of a multi touch based interface exhibit a strong potential for the development of new spatialisation techniques and the furthering of existing rendering techniques into the sound diffusion performance paradigm.

tactile.space is the first in a series new interfaces developed for spatial expression. Future developments of *tactile.space* include targeting the software to mobile computing platforms, as well as the addition of multi-touch gestures to trigger specific sonic trajectories, and exploring its potential as a studio tool for spatialisation.

7. ACKNOWLEDGMENTS

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