Non-tactile Gestural Control in Musical Performance

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ABSTRACT
This paper outlines the development and application of *Gestate*, a prototype non-tactile gestural system intended for the augmentation of vocal and piano performance. Influenced by embodied and experiential mapping approaches, the design builds on a performer's existing movement language and patterns by mapping ancillary movements to digital signal processing and virtual instrument parameters. The mapping strategies employed in the *Gestate* system address the absence of haptic feedback inherent in non-tactile interfaces by providing additional cues for the performer in the form of visual feedback. Reflections on the prototyping process and subsequent performances provide insights into the experience of integrating gestural technologies in contemporary performance practice.

Categories and Subject Descriptors
J.5. Performing Arts: Arts and Humanities.

General Terms
Design, Performance.

Keywords
Gestural control; interactive performance; improvisation; non-tactile controllers; augmented instruments; vocal enhancement.

1. INTRODUCTION
The availability of cost-effective sensors has prompted a rise in the development of new musical interfaces, yet the need for more nuanced gestural control and proprioception is still lacking in the musical sphere. Controllers that rely on remote sensing technologies leave performers with a greater dependence on proprioceptive, visual and aural feedback to compensate for the missing tangible feedback loop that is present in acoustic instruments [23]. This research examines design strategies aimed at improving user experience of gestural control, focusing on enhancing the precision and nuanced control of non-tactile interfaces in a performance context. Central to this investigation is the design of *Gestate*, an interactive system exploring relationships between gesture parameters and sound properties, also referred to as gesture-to-sound mapping.

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Situated within augmented instrument praxis, the *Gestate* system employs a Microsoft Kinect depth camera to capture commonly identified ancillary gestures of vocalists [8, 15] and pianists [9, 10] in order to control real-time digital audio signal processing. To uncover the creative possibilities of digital signal processing in augmented piano and vocal applications, *Gestate* follows in the direction of similar systems, including Nicholas Gillian's gesturally controlled improvisation system for the piano [14], Donna Hewitt's extended microphone stand, the eMic [15], the Multimodal Music Stand [4] and Lähdeoja, Wanderley and Malloch's guitar enhancement system that provides subtle control of digital audio effects through head and weight shifting movements [19].

Throughout the prototyping process, growing bodily awareness and kinaesthetic skills have evolved in conjunction with the conception and refinement of the system design. Physical engagement with the system during rehearsals and performances has influenced the evolution of initial mappings, revealing the parallel importance of bodily awareness and technical mastery for the performer. Informed by related approaches in the dance and somatic fields, the design is equally influenced by movement experience and computational representations of movement [26].

2. MOTIVATION & SYTEM OVERVIEW
The current system was designed in response to the need for an integrated and embodied live instrument that provides the performer with digital effects processing and virtual instrument control without inhibiting movement. Remote access to software effects, synthesisers and instruments, promised by spatial control, enables a vocalist to move around the stage freely and maintain direct communication with the audience. Remote sensing also offers an unobtrusive way of extending piano performance by minimally influencing the movement range of the pianist.

The system captures continuous joint position data from a range of ancillary motions. Within Max/MSP [22], an overall 'energy score' is calculated, based on cumulative limb positions and velocity. This general effort measurement is used to control levels of processing intensity and related audio control parameters of Max for Live instruments within Ableton Live [1]. Acceleration is seen as a prime expressive indicator. Not only does it indicate magnitude and speed of movement, but also conveys information about how a body occupies surrounding space, holding clues about intensity of physical engagement, and also how and where effort is directed.

Different forms of visual feedback were explored as a means to providing more nuanced control and immersion in gestural performance. The visualisation assists the performer to calibrate their motions, particularly when controlling multiple parameters simultaneously. Audio signal information and movement position data is mapped to video effects parameters and evolving particle systems in Isadora Core [17], highlighting evolving relationships between gesture and sound for the audience and promoting more precise control for the performer. The visual feedback provides explicit cues to encourage intuitive understanding and mastery of the interface. To provide simultaneous feedback to the performer and audience, a transparent scrim is used as the projection surface. The projected imagery amplifies and draws out key characteristics of captured movement data, including trajectories of motion. It is also designed to magnify the subtleties of movement that are sometimes lost in performance.

The abstract visualisation has evolved from an Open GL visualization coded in C++, called *Smokescreen*, to individual patches in Isadora Core that take the performer through a set of audiovisual modes according to the requirements of each piece in a live set. Designed to represent the dissipation of musical phrases when heard for the first time, *Smokescreen* detects position and audio level messages that disturb a 2D fluid simulation.

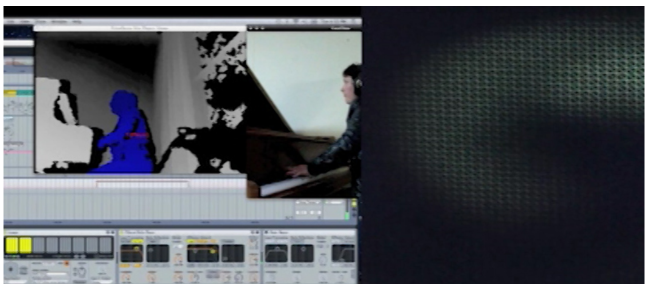

Figure 1. Screenshot of Gestate looping application, and the *Smokescreen* visualisation controlled by ancillary piano movements.

3. PERFORMANCES

3.1 Concentric Motion

A series of performances conducted over a two-year period became the basis for testing initial mappings and developing physical confidence with gestural control. Rehearsals offered an opportunity to conceive and refine mappings based on movement improvisations that are found in embodied approaches to interaction design [2, 3, 11, 16, 18]. Echoing the body-centric mapping approach demonstrated by Bencina, Wilde and Langley [5], this performance-oriented research investigates direct physical methods for exploring mapping strategies. This experiential mapping approach is an iterative process where the performer designer undergoes a personal process of transformation, expanding kinaesthetic awareness and developing a deeper physical understanding of the body's capacity through the experience of gestural control in rehearsal and performance.

The first major work presented was *Concentric Motion: Concerto for Piano, Voice and Gestural Controller*, which premiered at the International Space Time Concerto Competition in Newcastle, Australia. Cumulative acceleration derived from ancillary gestures controlled the level of several effects buses, reflecting the performer's fluctuating energy levels that increased in intensity as they became more engaged in a work.

The soloist alternately processed the input of the acoustic piano, voice and orchestra, gradually expanding their range of movement, becoming more overt in the vocal sections of the piece, when free air gestures can be used. A particle system, representing audio input levels and joint position was projected on either side of the performer.

The performance yielded many valuable lessons about the importance of balancing the cognitive demands of gestural control with instrumental and vocal performance. This experience highlighted the need to continue rehearsing in order to develop finer control and physical mastery over the interface. After subsequent performances of the same piece, the performer was able to develop more refined control in vocal performance by experimenting with different ways of moving, focusing on changing individual elements such as pace, direction and posture.

To ensure that effects processing did not overwhelm the acoustic signal, ancillary motions were adapted slightly to ensure that certain movements were carried out at the tail end of a phrase so as to select the right audio segment for processing. As much as it is desirable to design a system that does not affect the spontaneous movements of the instrumentalist or vocalist, the performance revealed that movement was influenced by the interaction. When ancillary gestures are used as control data, their usual meaning is disrupted [27]. In performance, extramusical gestures may acquire a theatrical character, becoming exaggerated or drawn out, as the performer reacts to the digitally altered sound and responds accordingly.

3.2 Alignment

Presented at the 2013 ACM Creativity and Cognition Conference, this semi-structured improvisation utilised the system's looping function, simultaneously triggering effects to create dense textural layers of dry and processed sound. Discrete gestures, in the form of flicking wrist motions, were used to activate the record and playback functions of the looper. Challenges in finding the right balance between ancillary and deliberate gestures revealed the need for further refinement in this aspect of the mapping design. The option of integrating gesture recognition in future performances is currently being considered as a means to achieving more seamless integration between continuous and discrete control, using the Gesture Follower [13].

3.3 Gestural Studies

At the 2013 Electrofringe Festival a collection of 6 *Gestural Studies* representing different forms of gestural control, were presented, each with a distinct visual signature. The pitch of MIDI note-events or pre-composed MIDI parts was controlled by the right hand and effects' levels were regulated by the left hand.

Figure 2. Cube visualisation at Electrofringe performance in 2013.

The first piece featured a cube that is punched by the right hand to trigger chord changes in an arpeggiated physical mallet model, visualised as a rotating 3-dimensional cube. The motivation was to illustrate a clear and direct illustration of the gesture to sound mapping for the audience while also providing useful feedback to the performer. The use of a virtual physical model based on percussive instrument features that originate from natural, physical sources, tested the potential of physical modeling to offer a more natural connection between input parameters and resulting sounds. As all of the sonic parameters controlled have a real world origin, chosen mappings potentially contribute to a more natural control environment [12].

The next piece uses a virtual mixer, controlling volume and panning of 6 pre-composed MIDI parts. Volume increases as either arm increases its distance away from the torso. The application requires a great deal of measured control by the performer to produce smooth transitions in sound level. Even after much practice, the performer felt the room to develop more accurate control over the mixing function. Similarly, when controlling the pitch of a virtual arpeggiator, the inability to move in discrete steps caused some unintended glissando effects. Further rehearsal and the ability to detect smaller scale and more detailed gestures afforded by sensors such as the Leap Motion could assist in addressing this situation.

More customisation is needed to change individual effects parameters and select sound bank changes quickly and easily during performance. Currently the settings are locked to individual scenes in visual mapping software, Isadora Core.

Performing with gesturally controlled virtual instruments and vocals again presented multitasking challenges, which led to some physical stiffness and self-consciousness, as the performer was preoccupied with managing a range of processes. The performance experience also showed the importance of expanding movement range in a dance-like or theatrical way, to extract more nuance and variation from the system.

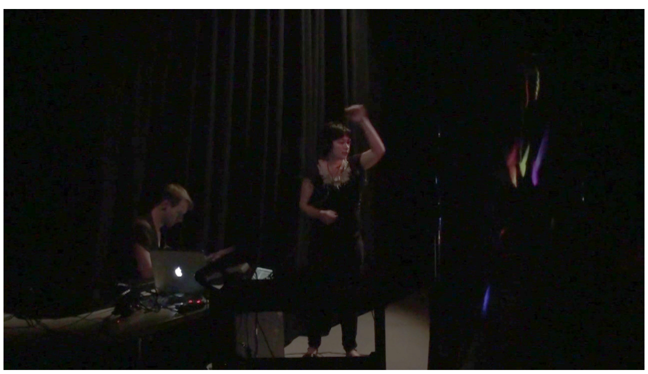

Figure 3. 2013 performance of *Concentric Motion* with arpeggiator instrument.

4. FUTURE DIRECTIONS

Early findings from a system evaluation involving expert users have indicated the need to refine the visual feedback component to provide more explicit and detailed visual information for performers with improved reinforcement of gesture to sound mappings. To date, the visualisation was mainly created to reinforce gesture-to-sound mappings for the audience. To observe mode and loop changes, it is still necessary to glance over to the laptop screen, sometimes interrupting the movement flow for the performer. By integrating explicit cues in the overall visual feedback, the performer does not need to divert their attention away from the audience or visuals at any time.

5. REFLECTION

For musicians hoping to incorporate gestural control seamlessly into their performance practice a balance of technical mastery and kinaesthetic awareness is needed to adapt existing approaches to their own purposes. This research explores how the partnering of technical refinement and increased physical awareness can promote the usability of non-tactile gestural systems. Successful implementation of current gestural technologies in performance can be aided by experiential design approaches based on a deeper understanding of the body's unique movement patterns.

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