OROBORO: A Collaborative Controller with Interpersonal Haptic Feedback

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ABSTRACT
OROBORO is a novel collaborative controller which focuses on musical performance as social experience by exploring synchronized actions of two musicians operating a single instrument. Each performer uses two paddle mechanisms – one for hand orientation sensing and one for servo-motor actuated feedback. We introduce a *haptic mirror* in which the movement of one performer's *sensed* hand is used to induce movement of the partner's *actuated* hand and vice versa. We describe theoretical motivation, and hardware/software implementation.

Keywords
Musical Controller, Collaborative Control, Haptic Interfaces

1. INTRODUCTION
Outside the sphere of computer music, in the physical world, the constraints of human anatomy limit the complexity of expression of any single musical instrument. A natural way to add richness to musical performance is for musicians to assemble in groups, bands, combos, ensembles or orchestras. In these communal performances, the interpersonal dynamics between musicians are responsible for much of the fascinating richness and subtlety of the music. Alas, all too often recent software tools have ignored this important interpersonal component of musicianship by concentrating solely on the single-performer, single-computer paradigm. Reconnecting to communal practices, we focus on *collaborative controllers* for computer music which require contributions from multiple musicians. By exploring musical space together, the performance itself can serve as a potent medium for interpersonal communication. Toward this end we have built OROBORO[1] – a music controller that connects two players sonically and haptically.

[1]In reference to *Oroborus*, the serpent that bites its own tail.

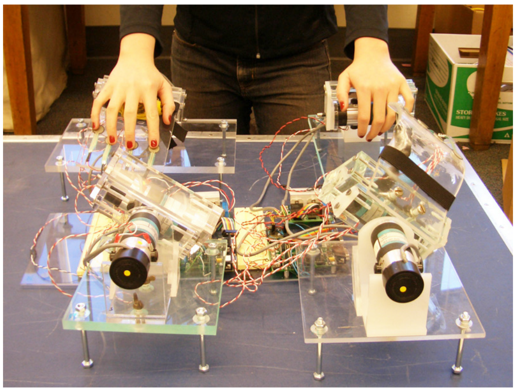

Figure 1: Physical controller setup

2. SYSTEM
OROBORO was explicitly designed to be played communally – design choices for our system were made to strongly emphasize the connectedness of the two performers.

2.1 Overview
Using a mirror metaphor, two musicians face each other across a table. On each side of the table two paddle mechanisms are placed that support the performers' hands (see Fig. 1). The paddles are used to record/induce movement in the following way: For each performer, the right hand is *sensed*. Movement and finger pressure are recorded and sent to a PureData (Pd) patch for sound synthesis and sample playback control. From the point of view of the musician, this is her *active* hand. The left hand is *actuated*, or *passive* from the performer's perspective. Its cradle mechanism is equipped with positioning motors that relay the orientation of the other performer's active hand (see Fig. 2). Through this *haptic mirror*, performers are more deeply aware of what their partner is doing – they can see, hear and feel the collaborative effort. We consciously separated sensing and actuation into separate hands to avoid a haptic tug of war between the performers. We rely on each performer to integrate incoming and outgoing signals mentally. Sensor data from both performers' active hands is combined to provide control for sound synthesis control. For left handed musicians, the arrangement of controllers can be swapped.

2.2 Hardware and Electronics
Each of the four hand controllers is based on a paddle mounted on top of a 2D Gimbal mechanism which allows

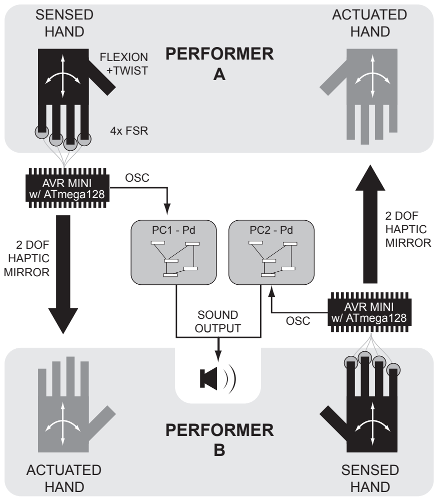

Figure 2: Flow of haptic and control data

for wrist flexion/extension and twisting of approximately 60^o past the neutral position in each direction. After building multiple foamcore prototypes, we arrived at the current controller design for which parts were laser cut from 1/4" and 1/2" acrylic. *Sensing* hand mechanisms are equipped with Electro-Craft E364 motors with rotary encoders. We do not connect the motors themselves for the sensing hand but only use the encoders to obtain orientation data for the two Gimbal axes. In addition, four force sensitive resistors (FSRs) are placed underneath the performers' fingertips. *Actuated* hand controllers are also built around two E364 motors which are powered and used as servos. The two motors are controlled with MotorDriver boards from Procyon Engineering. Each pair of linked sensing/actuating controllers is connected through a Procyon AVRmini board equipped with an Atmel Mega128 microprocessor. Each AVRmini board is in turn connected via a serial connection to a host PC.

2.3 Software

Interpretation, transformation, and relay of encoder data from the active hand to the passive hand is handled directly by each Atmel microprocessor running a simple C program. We targeted a haptic update rate of at least 1kHz but have not made precise measurements of the servo loop performance. Sensor and encoder data is also sent through the AVRmini using Open Sound Control (OSC) to a Linux Machine running Pd at a rate of approximately 50Hz. A Pd patch collects the sensor data from all hands and then maps this collaboratively-created data bundle to sound synthesis and playback parameters. We have thus far written two different parameter mapping schemes for the controller which are described below. We continue to explore the space of parameter mappings to find satisfying musical interpretations of the haptic mirror paradigm.

2.3.1 The Distributed Violin

Our first patch makes use of only two controllers to play a simulated bowed string instrument (the *bowed˜* Pd object from the Percolate library). One performer moves the virtual bow by twisting her wrist back and forth. The other performer controls which strings are bowed by pressing FSRs and also where on the fingerboard strings are held by flexing the wrist. The bowing motion is relayed as haptic feedback from the bower to the string selector. We discovered though that this patch is more rewarding to play as an individual performer instead of in collaboration.

2.3.2 The Field Recording Player

Our second patch is a sample player for field recordings. Each performer can trigger four different samples with the FSRs on their *sensed* hand. Each performer accesses a different set of samples. Wrist twist is mapped to playback speed and wrist flexion to playback volume. Resistance of the *actuated* hand to the relayed partner's movements controls the delay time and feedback amount of a variable delay line, distorting the overall sound as the orientations of the linked hands diverge.

3. RELATED WORK

Dourish [4] provides a theoretical foundation for our work that links tangible interaction and social computing through embodiment. Blaine and Fels [1] outline a model of the design criteria applicable to the creation of collaborative interfaces and provide a survey of existing collaborative musical controllers. We highlight Blaine and Perkis' Jam-O-Drum [2] for its similar spatial arrangement of participants facing each other. Brave et al. [3] have explored interpersonal haptic communication devices but have not used them for musical control.

4. FUTURE WORK

While the performative aspect of traditional instruments affords a rich audience experience, watching computer musicians is often like watching office workers. We would thus like to make the visual impression of an OROBORO performance more engaging by projecting video onto a semi-transparent screen between the performers to make the their actions more visible to the audience. It would also be interesting to test a networked performance where players are in different geographic locations.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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