Hyper-shaku (Border-crossing): Towards the Multi-modal Gesture-controlled Hyper-Instrument

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ABSTRACT

Hyper-shaku (Border-Crossing) is an interactive sensor environment that uses motion sensors to trigger immediate responses and generative processes augmenting the Japanese bamboo *shakuhachi* in both the auditory and visual domain. The latter differentiates this process from many hyper-instruments by building a performance of visual design as well as electronic music on top of the acoustic performance. It utilizes a combination of computer vision and wireless sensing technologies conflated from preceding works. This paper outlines the use of gesture in these preparatory sound and audio-visual performative, installation and sonification works, leading to a description of the *Hyper-shaku* environment integrating sonification and generative elements.

Keywords

Gesture-controllers, sonification, hyper-instrument

1. INTRODUCTION

Background developments contributing to the *Hyper-shaku* project are intelligent sensor environments (sensate spaces) and gesture-controller interactive audio-visual works. This paper describes the gesture-controlled audio-visual hyper-instrument and previous interactive gestural works that have led to it. Human movement, social and gesture data used as the foundation for sonification and visualization are shown, an alternative to the common sonification process of analyzing and representing abstract, non-contextual data. In contrast, gesture-data and room-data are user-centric, contextual, situated and experiential. In this way, ambient display and installation art influences conflate in informative data-driven aesthetic displays (bimodal audio and visual). The responsive/intelligent room using pressure and motion sensing demonstrate environmental data used as the basis for sonification. The sensor technologies are essentially like embedded, passive gesture captors that track mobility in the environment, not worn and portable sensors. Ambient display in architectural spaces provides interesting information about the inhabitants and activities of a location in the socially reflective experience. Several of the works discussed implement generative structures integrated with information representation for interactive installation. Generative algorithmic structures provide a representation with a consistent mapping scheme and transforming, evolving display that is intended to enhance sustainable participation and motivation over longer periods of time. The example works from performance to installation in the first part of this paper have shaped the technology integration for the hyper-instrument: wireless gesture-controllers, computer vision motion triggering and real-time generative displays in Max/MSP + Jitter.

The second part of this paper is concerned with development of a gesture-controlled hyper-instrument (system). A key feature, distinguishing this from other hyper-instruments, is transforming the acoustic instrument into a hyper-instrument capable of both augmented audio and visual display. The system aims to control not only gesture-response events but also to trigger generative design processes affected by movement. Hence, the proposed system is a performance "environment" for multiple related compositions. It can be used to augment purpose-composed notated music for *Hyper-shaku* or in an improvisatory audio-visual performance context.

2. FORMATIVE WORKS

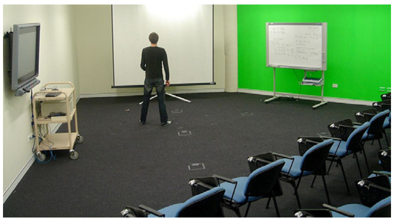
Gestural interaction, sonification and generative display in the following works influence the design of *Hyper-shaku*. Responsive/reactive spaces are discussed, followed by works that respond to gestural interpretation of space in performative works. This section considers mapping correlations between spatial activity and auditory display, in order that gestures can be understood by the interface-user and the audience.

2.1 Audio-visual Responsive Environments: Reactive Space

Other audio-visual responsive spaces, such as the Golan Levin's work, *Eyesweb,* and other systems for movement capture using computer vision establish the concept of pervasive and responsive display is socio-spatial contexts. Tod Machover's Hyperinstruments group at MIT Media Lab also addresses visual feedback in instrument design while Andy Hunt's MIDAS programming environment and other work examines auditory and visual mapping of gestures that has contributed to the formation of this approach.

Emergent Energy developed in the University of Sydney, Key Centre of Design Computing and Cognition's sensate lab (Figures 1, 2 & 3) demonstrates the way in which socio-spatial behaviours are mapped onto a computational process of sonification and visualization. Beilharz, Vande Moere and Scott's *Emergent Energy* (Figure 1) is an iterative, reflexive bi-modal (audio-visual) system of interaction in which motion, speed, number of users and position in a space (triggering pressure-sensitive floor mats) determine the growth of a visual design drawn with a Lindenmayer System (L-sys) generative algorithm [3; 7; 17; 22; 23; 24]. The design artefact is an embedded history of the movements, interactions and number of people who produced it. Sound is a spatial experience, inseparable from context [21] so it is logical to utilize 3D spatial interaction to measure activity and manipulate sound.

Figure 1. Beilharz, Vande Moere & Scott's L-system generator patch in Max/MSP + Jitter software [15] used to create branched visualizations on screen. In the corresponding sonification, the number of people relates to dynamic intensity, position to *timbre* (tone colour) and speed to frequency (pitch) [3].



Figures 2. & 3. The Sensate Lab (2 views) showing the "invisible" pressure sensitive floor mats, triggering the visual and auditory sound system and (bottom) before carpeting, networked to the Teleo (analog to digital in/out) modules for conversion to a USB interface [20].

Sonic Kung Fu by Jakovich and Beilharz (at *Sydney Esquisse* exhibition, March 2005) is a sonic art installation using colour-sensing gestural interaction with sound, in which participants wear coloured gloves to perform gestures that produce a real time responsive audio soundscape (Figure 4). A web cam receives the visual gesture information. The Max/MSP patch responds to the motion of the centre-point of a specific colour (calibrated to match the glove being worn), responding with auditory variation across a range of *x* and *y*- axis values. The immediacy and mapping of this work was intentionally as simple and intuitive as possible for recognition to invoke interaction by passers-by in a gallery setting. The result was that users spent considerable time with the "instrument" learning to understand and control its performance.

Figure 4. Gestural interaction with auditory display created in response to colour tracking of the spatial glove motion.

2.2 Gesture Mapping for Auditory (and Visual) Display: Interpreting Space

Correlating/mapping gesture to responsive representation involves the design decisions most crucial to comprehensibility and intuitive interaction [1; 2; 25]. Depending on the context, the degree to which gestures and reflected consequences have to be learned varies. In the public sphere, like in Jakovich and Beilharz's *Sonic Tai Chi* Sydney Powerhouse (Design and Technology Museum) installation, the audience is transient, covering a range of ages from children to adults and the immediacy of engagement determines the length of time a user will participate in the display. Regardless of the simplicity of mapping correlations, users seemed to naturally pay primary attention to the visual display and, when questioned, it took longer for users to understand and explain their interpretation of the relation between their movement and auditory display than both the literal and generative visual display elements.

Sonic Tai Chi uses a computer vision system (identical to the method in *Hyper-shaku)* to capture movement data to produce a visualization comprised of the interpolated real image of the user combined with random Cellular Automata and the music is a sonification of the motion left to right and up and down with pitch, spatial panning, timbre and intensity affected by user interaction. A second sonification engine produces audio particles from the position, multiplicity and intensity of the Cellular Automata that can be triggered into rapid proliferation (using the breeding metaphor of aLife) by moving the body in one horizontal direction across the room and towards stasis by moving in the opposite direction (Figure 5). This piece is designed for spatial interaction by the general public. It has its own approximately 25m-square room, rear projection, stereo speakers hidden in the walls and camera concealed below the screen.

Max/MSP + Jitter uses the Horn-Schunk method to estimate optical flow of movement captured by the web cam [16]. There are numerous possibilities of rules to govern the propagation of Cellular Automata [9; 26] but this scenario uses the original, quite simple rules for pattern formation based on John Conway's *Game of Life*.

Figure 5. *Sonic Tai Chi* (BetaSpace, Sydney Powerhouse Museum, installation) uses computer vision to capture movement data that produces the vizualisation and sonification.

The *Sensor-Cow* project uses the La Kitchen Kroonde Gamma receiver and wireless UDP[1] transmitter and gesture captors. The sensors used were acceleration, gyroscopic and bi-directional motion captors. Figure 6 shows the way in which these sensors and transmitter are attached to the calf for capturing the data. The outcome was a sonification of the calf's motion.

The highly sensitive mercury motion sensors operate between extremes of direction, registering a "bang" (signal to the sonification program) when changes in direction occur. Thus these were attached to the front legs to indicate steps as the calf walked. The acceleration sensor values were scaled to 128 distinct output values. These sensors were attached to the calf's ear and forehead, respectively, because these regions isolate significant independent gestures. The calf naturally raises and lowers its head to eat, when flicking away flies, in response to people and other animals - it is expressive and the range of motion is diverse. While naturally following whole head movements, the ear is also flicked and rotated independently producing an audibly recognizable gesture.

A distinctive *timbre* was attributed to each sensor in order to make it possible to distinguish the sounds arising from each sensor region. The rhythm, pace/acceleration and velocity of action are heard in real time. Hence the correspondence between rapid gestures and rapid sonification is literal. For both the acceleration and gyroscopic sensor, extremes of motion away from the median, drives the pitch in directional extremes away from a central pitch region. The direction of pitch, ascending and descending away from the mean, corresponds to the *x*-axis direction of motion so that changes in direction are audible and circular motions of the ear and head produce sweeping auditory gestures that reinforce the audio-visual connection between activity and sonification. The sonification was programmed in Max/MSP +Jitter using La Kitchen's Kroonde Gamma recognition [14] and CNMAT Berkeley's Open Sound Control [10].

The Music Without is concerned with exposing the motion of music. Real time computer music responds to sensors placed on the violinist's left-hand finger and forearm and the bowing arm. The gyroscopic, binary-motion and acceleration sensors convey the intensity, physicality and movement (outside forces) that performing involves. Typically, we think of the music within, of the source of musical creation being the mind (composer) and the heart (interpretation). Most reactive, responsive computational real time music systems analyze and respond to pitch, harmony and rhythm. Thus, most systems for improvisation and collaboration are responding to the musician's inner music by "listening" to the auditory outcome.

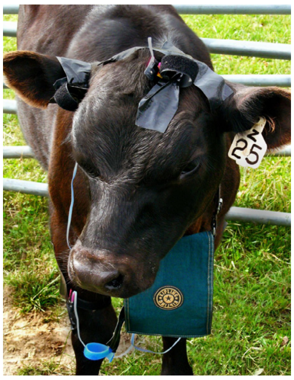


Figure 6. Bi-directional (mercury) motion sensors are attached to the calf's front legs, a gyroscopic sensor on the forehead and accelerometer on his right ear. The pouch hanging around his neck contains the radio frequency transmitter that sends the real time data to the (La Kitchen) Kroonde Gamma wireless UDP receiver [18]. It is connected by Ethernet to the computer running the data sonification with Max/MSP object-oriented programming environment.

In contrast, this system creates a response to the physical forces producing sound; hence 'the music without' is more like choreography. The "other musician" here is a sonification of the external energies creating music. The system is generating a musical response to gestures perceived by the sensor devices. It is not so much listening as feeling, or experiencing, the process of performing. This work emphasizes a different and often overlooked part of the music-creating process.

3. HYPER-SHAKU (BORDER CROSSING): AUGMENTING SPACE

Hyper-shaku is a new hyper-instrument performance environment that uses motion to trigger response events and growth of generative process in both auditory (electronic) and visual displays. Its purpose and configuration follow.

3.1 Description and Objective

Hyper-shaku (Border-Crossing) is both a digital audio-visual creative environment and a performance/composition outcome.

[1] UDP is a protocol for high speed, high precision data-acquisition.

The motivation behind this application is two-fold:

1) To develop a system of computer vision and sensors producing an augmented sound-scope and derivative visual projection (that will be applied to a prototype and continuing works); and
2) To demonstrate the prototype with an initial concert installation (by performance with a composed, notated *shakuhachi* part).

This project develops an ongoing framework of computer vision for capturing movement of a performer, together with wireless sensor information to trigger a generative computer system. The generative part of the process produces a motion-activated fabric of computer music and graphic visualization. First stages of using computer vision with web-cam sensing and Max/Jitter software patches integrating Pelletier's cv.jit 'Computer Vision for Jitter' programming objects[2] were implemented in Jakovich and Beilharz's *Sonic Kung Fu* (Sydney Esquisse Exhibition) and *Sonic Tai Chi* (Cité Internationale des Arts, Paris in September 2005 & Sydney Powerhouse BetaSpace Exhibition in November-January 2005-2006). Radio-frequency gesture controllers (similar to the proposed WiFi sensors in this project) were used in *Sensor-Cow* and *Music from Without.* Musically, the intention of this project is to utilize this technological approach in a more developed electro-acoustic musical and visual context. Rather than producing literal sonification and visualizations as in previous works, this project will use the motion data to trigger synthesis processes in real time and to control a computational generative process for sound and visual design. Former work demonstrates the use of a Lindenmayer generative system (in *Emergent Energies)* and Cellular Automata *(Sonic Tai Chi)* for evolving graphical responses to user interaction. The generative part of the process produces a motion-activated fabric of computer music and graphic visualization. *Hyper-shaku* combines an aleatoric generative process using Cellular Automata with a homeostatic process using Neural Network Oscillators. The breeding behaviour of the Cellular Automata is moderated by the large upper body movements of the player, tracked by the web cam. Within the Neural Network Oscillators, triggers in individual "neurons" (Max/MSP software model, Figure 7) instigate moments of excitement that infect other neurons [11]. Over time, the effect of one neuron in the network influencing another develops stabilizing homogeneity, as gradually the neurons resemble and emulate one another. The combination of the chaotic and vigorous process of the Cellular Automata and the stabalizing, homeostatic nature of the Neural Network Oscillators [12] provides a suitable excitement-stasis balancing structure for the production of long background transitions, behind a foreground of dynamic activity responding to the live performance. Algorithmically, the output of each neuron in the network is determined by the weighted outputs of every other neuron. The critical threshold of perturbation, beyond which reorganization is triggered, is an adjustable parameter in the Max/MSP model. This is akin to the musical effect of stable harmony so the metaphor provides a suitable excitement-stasis balancing structure for long background transitions, behind the foreground of live performance activity and relatively immediate, agile C.A. responses to the wireless captors. The fundamental units of an artificial neural network (units/nodes/neurodes) are modeled after individual neurons: its dendritic tree collects excitatory and inhibitory inputs from other neurons (the 'receives' in the Max/MSP model), and passes these messages, as voltages, on to the cell body (soma) (see Figure 7). These voltages are added to the current voltage if excitatory and subtracted if inhibitory. When the threshold is exceeded, a signal is transmitted [the 'sends' in the Max/MSP model] down an axon to synapses that connect the tree to dendrites of other neurons [13].

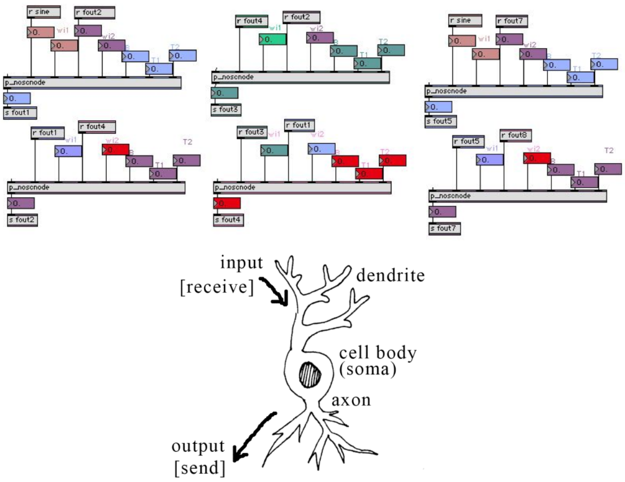
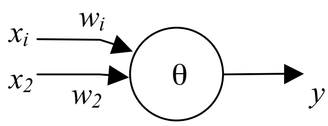


Figure 7. The Max/MSP Neural Oscillator Network patch, here showing the first 6 nodes, each sending and receiving information between nodes [12] that will be used as a stabilizing influence affected by large camera-tracked gestures. The Max/MSP patch is modeled on individual neurons: dendrites receive impulses and when the critical threshold is reached in the cell body (soma), output is sent to other nodes in the neural network.

Neurons (also called a linear threshold device or a threshold logic unit) can be modeled formally (mathematically) (Figure 8):



x_i -- the inputs
w_i -- the weights (synaptic strengths)
θ -- the threshold
y -- the output

$$y\,(t+1) = \begin{cases} 1 & \text{if} \quad \sum_i w_i x_i\,(t) \geq \theta \\ 0 & \text{otherwise} \end{cases}$$

Figure 8. A symbolic simplification of a neuron with a formal model of threshold.

The new media technologies (the software patch and methodology) from this project will be applied and adapted to a series of future works, each unique because it is a responsive interactive system, a synergy of notated, performed music and sound and visual material generated from the performer's gestures. The author's chamber concerto for *shakuhachi* and

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[2] Jean-Marc Pelletier (IAMAS)
http://www.iamas.ac.jp/~jovan02/cv/

ensemble, *The White Face of the Geisha,* performed by Yoshikazu Iwamoto with Ensemble Recherche, Freiburg (2000) and Jeffrey Lependorf's article, 'Contemporary Notation for the *Shakuhachi:* A Primer for Composers', in *Perspectives of New Music* [19] provide some background in idiomatic techniques, notation and articulations.

The physical nature of playing the *shakuhachi* makes it especially suitable for motion triggering since pitch inflection is achieved by angling the chin relative to the instrument and dramatic *atari* (articulation) attacks and head vibrato are part of the ornamentation approach to pitch production, in addition to fingering and upper body movement typical performing an instrument. Traditional live music-processing approaches analyze and synthesize real time musical response from the musical (audio) content of a performer. The approach of this project, in contrast, focuses on the **gestural/spatial** and theatrical nature of *shakuhachi* performance. The whole system is an "environment" - a hyper-*shakuhachi,* augmenting the sound scope from traditional sounds of the bamboo end-blown Japanese flute to include computer-generated music and visual images for a single-performer holistic presentation.

The reason for this project is multi-fold: to stimulate the interest in a traditional instrument; to augment its capability into the multidisciplinary, trans-medial realm of electronic music as well as physical, acoustic sound; to re-invigorate interest in traditional instruments amongst Japanese and other audiences with listening tendencies moving towards Western or technologically-enhanced listening. There is more interest in the traditional Japanese instrument in the U.S.A. and Australia (with its great cultural inheritance of *shakuhachi* players like Riley Lee, James Franklin, Andrew McGregor) than in Japan [8]. Hybridization with technologies and a new approach bringing its attention to a new and possibly younger audience potentially contributes to a new role for the instrument. In addition, traditional repertoire is extremely ancient and there is not very much contemporary repertory or performance context for this instrument, hence a multimedia environment positions it in a contemporary performance context.

This project will develop the method and a prototype piece. The method is transferable to other instruments (though specialized here for the *shakuhachi)* as well as further improvisation and composed performance pieces. The prototype will be developed with a notated *shakuhachi* part to demonstrate the development for the first performance exposure but the infrastructure will also contribute to subsequent creative work in the field of gesture-controlled hyper-instruments by the composer.

3.2 Technical Configuration

Method & configuration are illustrated in figure 9. A continuation of the web cam computer vision system based on earlier works and Pelletier's Computer Vision Jitter objects are used to capture visual data about the *shakuhachi* performer (using luminosity tracking). Wi-Fi (wirelessly transmitting) sensors[3] capture and convey motion data from the performance in real time. Both data inputs will be processed in Max/MSP + Jitter (visual programming environment) to produce both real time auditory augmentation and visualization of the performance energies with some additional generative design (building and transforming over time). Cellular Automata (for random material), L-system (for tree-like growth) generative algorithms will be applied to visual display in Jitter, along with the musically stabilizing Neural Oscillator (NOSC) Network for sound only. The electronic augmentation is two-fold: comprising event-response immediate reaction events activated by the different motion captors and isolated captors trigger successive events in the aleatoric (C.A.) and generative (L-system) hyper environment. Signals emanating from distinct captors are mapped to individual *timbres* in order to distinguish subtle effects of isolated gestures. A second sonification engine, similar to the approach demonstrated in *Sonic Tai Chi,* will display an auditory representation corresponding to the C.A. visual generative design. The sonic material for the sound synthesis will be real-time samples captured from the live *shakuhachi* performance, in which the granularity and synthesis parameters are determined/affected by degree of motion (calibrated according to individual captor types). Sound is played back alongside the performer with adequate stereo separation to optimize spatial panning in response to horizontal motion detected by the Computer Vision and the visual display is projected onto an on-stage screen. The notated *shakuhachi* part for a prototype performance is fully composed.

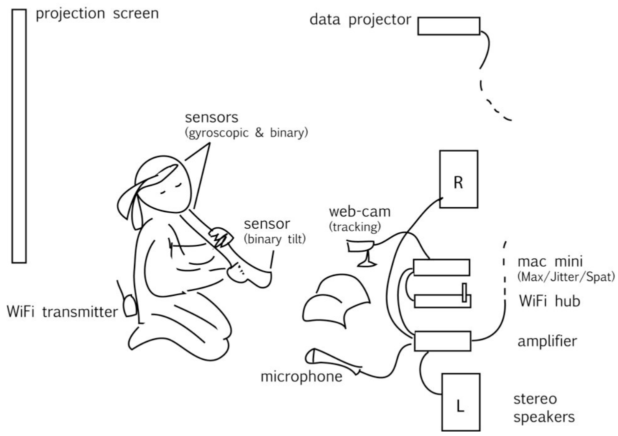

Figure 9. Configuration for performance. Visual and motion data is captured by wireless sensors and web cam producing augmented real time audio and feeding a generative audio-visual design system in Max/MSP + Jitter.

4. CONCLUSION

Hyper-shaku is a confluence of technologies, sonification and generative methods in a growing body of interactive work. This paper briefly outlines the transition of gestural technologies into the hyper-instrument environment that augments the acoustic instrument in both auditory and visual domains.

5. ACKNOWLEDGEMENTS

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[3] WiFi protocol wireless sensor transmission, e.g. Emmanuel Flety's WiSe Box

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