A Component Model of Gestural Primitive Throughput

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ABSTRACT
This paper suggests that there is a need for formalizing a component model of *gestural primitive throughput* in music instrument design. The purpose of this model is to construct a coherent and meaningful interaction between performer and instrument. Such a model has been implicit in previous research for interactive performance systems. The model presented here distinguishes gestural primitives from units of measure of gestures. The throughput model identifies symmetry between performance gestures and musical gestures, and indicates a role for gestural primitives when a performer navigates regions of stable oscillations in a musical instrument. The use of a high-dimensional interface tool is proposed for instrument design, for fine-tuning the mapping between movement sensor data and sound synthesis control data.

Keywords
Performance gestures, musical gestures, instrument design, mapping, tuning, affordances, stability.

1. INTRODUCTION
This paper is theoretical and propositional to the extent that the explication of the proposed model is founded upon the theoretical basis of a perception-action oriented performance paradigm with respect to the long-standing tradition of musical performance practice. The proposition of *gestural primitive throughput* is much in line with the research concerns expressed by other researchers in so far as to multiparameter mapping strategies and feature extraction. The instrumental gestures defined in Cadoz [1] are more comprehensive and the research challenge is broader than mapping or feature extraction. A formalized approach for a component model can be considered in which the results from the two research areas can be brought together into the structure of a signal pathway. The purpose of such consideration is first to disambiguate the relationship between performance gesture and musical gesture. Second, once disambiguated the throughput model provides loci to host a designed configuration of the structure of the signal processing between them.

From the evaluation of our previous research we determined that the throughput model was implicit in the implementations of interactive signal pathways, but its role was not fully articulated. The throughput model is intended to provide a basis for robust tuning of gesture-based performance systems, calibrating gesture-sensitive devices and interactive displays to optimize the affordances for performers' movements. This calibration is analogous to the tuning of a musical instrument which enables a performer to sustain intonation during a performance, especially when the performer is required to manually override the instrument's native tuning limitations.

This paper first presents a model of symmetry in musical instrument throughput, then introduces gestural primitives, then discusses their relevance for mapping strategies in the design of music instruments and interactive presentation systems. System tuning using a model for gestural primitive throughput is intended to be extensible from musical instruments to multi-modal systems, for example the calibration of graphical displays as described by Goto [2].

2. SYMMETRY AND ASYMMETRY IN MUSICAL INSTRUMENT THROUGHPUT
Consider as a generalizable abstraction that musical instruments may be represented using a throughput model comprised of two gestural subsystems: a movement-sensing system and a sound-generating system. The movement-sensing system provides transducers that respond to *performance gestures*. The sound-generating system provides excitatory and resonating bodies to produce *musical gestures*. In traditional musical instruments these two systems are in immediate proximity to one another, with energy transfer from one to the other by direct contact of physical materials or by materials that may be one and the same. Figure 1 illustrates the symmetry between the two gestural subsystems; dotted lines indicate material regions and boundaries in various instruments. For example in a clarinet the keys and the reed are sensors; the reed is also an excitatory body; the clarinet body and resonator are the same tube. The functional components in Figure 1 are common to all musical instruments and are found in various arrangements according to differences in design.

One of the technological achievements of musical instruments is the coupling of two gestural subsystems into a single physical device. Disambiguating the relationship of two coupled subsystems can assist in the clarification of unresolved issues in the study of musical performance gestures. Two such issues may be referred to informally as the "handwriting recognition problem" and the "causality problem." Briefly, the handwriting problem undertakes a search for elements and features of gestures, their boundaries and generalizability. A question remains whether to measure such units and features at the performer, the instrument, or the sound. The causality problem attempts to identify gestural units on the basis of musical structures that are notated in a score or produced in performance, leaving the question of which comes first, the movement or the sound. The present lack of clear definition of "what is a gesture" in musical performance can be related to confounding aspects of these two problems. Cadoz and Wanderly provide a framework for disambiguating gestural relationships in [3].

Study of the transfer of movement in a signal pathway provides a re-orientation for these questions. Gestural primitives are an impetus; they can be detected in the transfer of movements; they are not proposed as units or segments of gestures. Movement transfer occurs at locations of transducers. The throughput model proposed in Figure 1 shows two sites of transducers, first from the performer to the physical instrument, second from the physical instrument to sound.

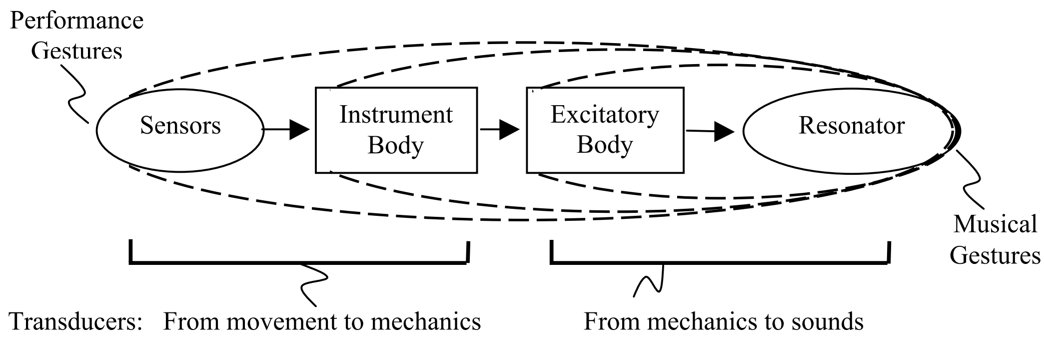

Figure 1: Music Instrument Symmetry Model

2.1 Local symmetry and global asymmetry in gesture throughput

The symmetry of the coupling between movement-sensing and sound-generating systems can be described as the association of performed movements to performed sounds. This association has been discussed as a mapping, i.e. the correspondence of sounds to movements as discussed for example by Hunt and Kirk [4] and Soto [2]. In further distinction, the symmetrical throughput model proposes a second-order correspondence, from one gesture transducer to another, a mapping of (a) movement gestures transduced as mechanical forces, with (b) mechanical forces transduced as sounds. Musical instruments are constructed to enable a limited range in a movement-sensing system to control a much larger range in a sound-generating system. This means the two gesture subsystems are radically asymmetrical; performers learn to master the asymmetry in order to stabilize the instrument into limited regions that are reliably symmetrical. Here "reliable" means a range of actions generates a predictable range of sounds. Instrument design and musical performance require mastery to create *local symmetry* within a range of gestures. This locally-symmetrical but globally-asymmetrical property in musical instruments creates performance conditions where a working definition of *gestural primitive throughput* can be applied. The definition will account for the role of gestural primitives in the actions of a performer to stabilize an instrument in a symmetrical region or to transition from one symmetrical region to another.

2.2 Symmetries as manifolds in musical instrument performance

Local symmetries between movement-sensing and sound-generation can be described as *manifolds*: a movement subspace and a sound control subspace that are continuously covariant. Learning to perform a musical instrument is a process of acquiring an ability to navigate these manifolds, a process in which the mode of navigation is defined by device-specific interaction. Performers execute transitions from one manifold to another with controlled degrees of discontinuity. The history of performance practice for a family of musical instruments includes a repertoire of gestures that reflect the characteristics of the manifolds native to that instrument family. Musical idioms common to an instrumental family reflect these characteristics. Performers learn idiomatic gestures as a repertoire of manifold stabilization and navigation techniques. These techniques are related to the musical idioms of an instrument's vocabulary. Gestural primitives provide a view of these idioms not as musical units rather as a performer's stance and movement orientation toward an instrument, undertaken to generate correspondences in sound.

3. A COMPONENT MODEL OF GESTURE THROUGHPUT FOR INSTRUMENT DESIGN

For the design of new musical instruments involving digital signal processing and movement sensors, a component model of gesture throughput includes an input control device, a manifold interface, a generative mechanism and a sound synthesis engine. Figure 2 illustrates these in a schematic model with a manifold mapping as an axis of symmetry. The manifold map is situated between two gesture transducing subsystems. In a traditional music instrument this mapping is a property of energy transmission through the instrument's body. In digital instrument design the manifold interface provides a dedicated mapping component to bring the first transducer into a symmetrical relationship with the second.

3.1 Gestural Primitives

Researchers have identified basic movement orientation as a structure contributing to gestures, for example the models of effort, after Laban, discussed in Camurri and Trocca [5]. Gestural primitives are fundamental human movements that relate the human subject to dynamic responses in an environment. With respect to musical instrument performance, a gestural primitive represents a chosen physical disposition to a movement sensor with intent to modify a dynamical process generating sound. The classification is based on the most fundamental human factors that are (1) the sense of movement, (2) the sense of weight distribution, and (3) the sense of organizing recurrent tasks. Concomitant gestural primitives are trajectory-based, force-based, and pattern-based primitives [6]. This classification is determined by the relationship between the performer's orientation and the mechanical or computational signal path where the gesture is transduced. The present task is to trace the relevance of gestural primitives along the signal path.

3.2 Gesture Transducers

In Figure 2 an input control device transduces movement as a function of two conditions. First the physical configuration of one or more sensors provides affordances for a performer's contact and movement. Second the movement at the sensor is encoded and quantized in range, resolution and in timing, then relayed along a signal path. In a computational system this encoding may involve pattern recognition or other data classification. Together the sensor configuration and the

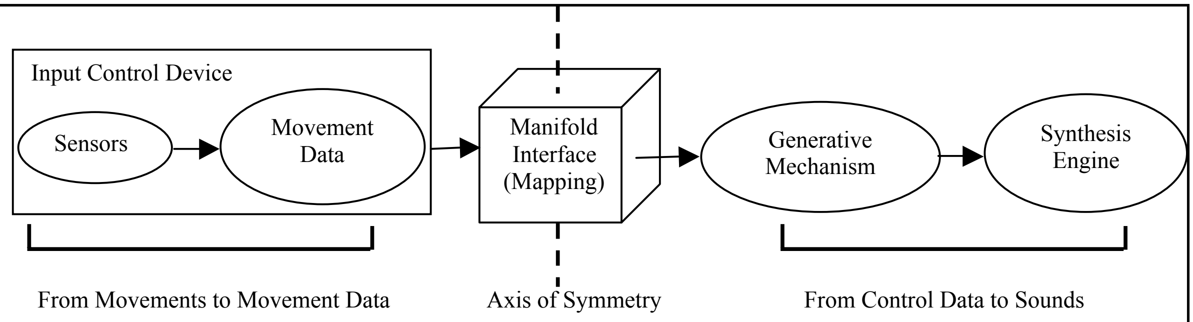

Figure 2: Gestural Primitive Throughput component model

encoding performed by the input control device determine the system affordances for gestural primitives.

In Figure 2 a generative mechanism is situated to receive data signals from an input control device and generate control signals for synthesis engines. The term "generative mechanism" implies that the control signals transmitted to the sound synthesis engine will be generated to exhibit coherence properties of some kind [6]. Coherence in control signals produces signatures in the sound in the form of covariance of multiple audible properties. For example, a generative mechanism might ensure that brightness in the sound co-varies with loudness, register and speed of onset (so-called "attack transients"). Coherence may be obtained through look-up tables, physically-based models or other methods for imparting structure.

Gestural primitives can affect the characteristics of control data transmitted to a generative mechanism, in turn affecting the coherence of a sound. These affects may be thought of as auditory signatures of the gestural primitive. A music instrument's capacity to transmit movement characteristics into auditory signatures is supported by the mapping that defines the symmetry in the instrument model.

3.3 Manifold interface properties

There are many methods for establishing the *m:n* mapping required to convert movement data into sound control data. In the method presented here, a manifold interface was previously developed for real-time control of a chaotic circuit as a musical tone generator [7]. Chaotic circuit oscillations present similarities to stability and instability of oscillation in traditional music instruments [8]. The manifold paradigm proved useful in identifying stable regions and generating control signals that required covariance of a large number of parameters (13 in the initial case). The algorithm supporting this interface provides an efficient way to establish *m*:*n* mappings that are continuous and differentiable within bounded parameter subregions of the total control space [9]. The interface supports the dual-transducer model in Figure 2 by establishing a "Window Space" – an abstract spatial model of the movement data from the input control device (in *m* dimensions). The interface is able to map continuously the Window Space into a "Phase Space" – an abstract spatial model of the sound synthesis control parameters (in *n* dimensions).

Using this interface a manifold subregion may be varied continuously within the global *m:n* asymmetry. This permits smooth transformation of the relationship between movement data (transducer 1) and multiparamter sound control (transducer 2). This smooth transformation capacity is important for real-time fine-tuning during a performance, and important also for tuning the sound-generating system when changing from one form of input control device to another, each supporting different gestural primitives

4. INSTRUMENT MODEL TUNING WITH GESTURAL PRIMITIVES

The capacity of an instrument model to produce musical gestures and with them musical idioms can be traced from the sound generator back through the physical controller to the performer's stance and disposition. Gestural primitives are generated with respect to this stance and contribute to the auditory signatures that are possible within the system. A system can be tuned for optimal symmetry, resulting in auditory signatures that reflect adequately both the properties of the sound generator and the details of a performer's movements. In practical application this means that a performer will be able to observe a variety of sound transformations corresponding to his or her disposition to the instrument, including but not limited to the individual actions imparted to the instrument. Sequences and relative changes in forces and nuances of actions are determined by the gestural primitives involved.

The task of musical performance includes real-time complex path planning in a control space, where the states of oscillation and the navigation strategies are informed and assisted by auditory feedback. Because music instruments present an entrainment scenario to a performer, the auditory feedback can be understood as an index of the performer's movement orientation with respect to a manifold space. Symmetry is important for instrument optimization because the gestural primitives provide a performer's primary sense for regulating upcoming actions and navigating the stability of the oscillatory system. A well-tuned manifold improves the transfer of the dynamics of gestural primitives into auditory signatures. For the performer these signatures become the idiomatic expression of the stability or transience of an instrument's oscillations with respect to performance actions.

The purpose is to develop a tuning process for new instrument designs. A tuning process can provide an overview of possible system states and a structure for selecting mappings. The intent is to improve upon the practice of generating *ad hoc* control movements and tweaking various parameter settings until "it sounds better." The representation of control space as a manifold lends a useful structure for identifying the subset of oscillatory states that are contiguous under a performer's sequence of actions. This representation can be used both to fine-tune the settings of an instrument and to assist performers in developing an understanding of the idioms of the instrument.

4.1 Proposed work

New research focuses on developing a system to determine the measurability of gestural primitives through auditory signatures. As stated above gestural primitives are an impetus; they are detectable in the transfer of movements in a signal path; they are not units or segments of gestures. In [10] Marin introduces a signal analysis approach to study covariance of movement and sound in the case of a conductor's movements. Further development of a measurement approach to evaluating movements with respect to sounds is needed, and is an appropriate topic for a PhD thesis in the field.

A real-time implementation of the component throughput model is underway in an interactive performance system and will be available to study the signatures of gestural primitives. The system combines previous work in manifold representations and mappings and in gesture-based performance. A computational implementation can be used to investigate the design of alternative high-dimensional maps situated between movement sensors and musical signal generators. Planned research includes developing a specification for a design interface at the axis of symmetry in instrument models. This interface would enable the optimization of stable manifolds using the signatures of various gestural primitives as a tuning method.

5. REFERENCES

[1] Cadoz, C. "Instrumental Gesture and Musical Composition." In *Proceedings of the 1988 International Computer Music Conference.* San Francisco, ICMA, pp. 1-12.

[2] Goto, S. "Virtual Musical Instruments: Technological Aspects and Interactive Performance Issues." In *Trends in Gestural Control of Music.* Battier and Wanderley, eds., IRCAM, Centre George Pompidou, Paris. 2000.

[3] Cadoz, C. and Wanderley, M. "Gesture – Music." In Battier and Wanderly, Op. Cit.

[4] Hunt, A. and Kirk, R. "Mapping Strategies for Musical Performance." In Battier and Wanderley, Op. Cit.

[5] Camurri, A., and Trocca, R. "Movement and Gesture in Intelligent Interactive Music Systems." In Battier and Wanderley, Op. Cit.

[6] Choi, I. "Gestural Primitives and the context for computational processing in an interactive performance system." Battier and Wanderley Op.Cit.

[7] Choi, I. "Interactive exploration of a chaotic oscillator for generating musical signals in real-time concert performance." *Journal of the Franklin Institute*, vol. 331B, no. 6, pp. 785-818

[8] Rodet, X. "Stability/instability of periodic solutions and chaos in physical models of musical instruments". *Proc. ICMC*, Aarhus, Denmark, pp. 386-393, 1994.

[9] Choi, I. "A Manifold Interface for Kinesthetic Notation in High-Dimensional Systems." In Battier and Wanderly, Op. Cit

[10] Marrin, T. "Searching for Meaning in Gestural Data." In Battier and Wanderley, Op. Cit.