Haptic Control of Multistate Generative Music Systems

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ABSTRACT

Force-feedback controllers have been considered as a solution to the lack of sonically coupled physical feedback in digital-music interfaces, with researchers focusing on instrument-like models of interaction. However, there has been little research applied to the use of force-feedback interfaces to the control of real-time generative-music systems. This paper proposes that haptic interfaces could enable performers to have a more fully embodied engagement with such systems, increasing expressive control and enabling new compositional and performance potentials. A proof-of-concept project is described, which entailed development of a core software toolkit and implementation of a series of test cases.

1. INTRODUCTION

Most digital-music interfaces do not provide 'ergotic' coupling [1], an important means for informing effective and affective shaping of music for the performer. Researchers have investigated force-feedback interfaces as a means for providing such coupling, focusing on emulation of instrumental interaction models such as piano actions, violin bowing or string plucking, often applied to physical modelling synthesis, such as in [2-5]. Other indicative approaches consider how force-feedback could improve accuracy of control of synthetic sound, such as improving pitch-selection accuracy on a continuous-pitch controller [6].

Yet digital-music performers often are not triggering individual events like a traditional instrumentalist. Instead, they are controlling patterns and behaviours generated by computer algorithms (which in this paper will be referred to as *generative systems*). These algorithms could range from simple arpeggiation procedures to artificial-intelligence driven response. Compared with the standard digital musical instrument model, there are additional layers of technical mediation and abstraction between the actions of the musician and the sounds generated.

2. HYPOTHESES

The authors hypothesize that it is possible for a haptic interface to productively raise the performer's level of embodied, non-conceptual engagement with generative-music systems. 'Productively' will here be defined as either increasing the speed, accuracy or expressiveness of music control and/or opening up new musical potentials.

At the simplest level, it seems reasonable to extrapolate from existing research [7] and predict that force feedback, employed to control parameters of a generative system, will likely enable the musicians to increase their speed of learning and accuracy of control for those parameters to at least some degree.

However, the authors propose that particular gains can arise when there is a coherent perceptual parallel between haptic qualities of the interface and resultant subjective sonic qualities. Performers could simultaneously feel and shape the subjective-expressive tension of a musical texture, or aspects of that texture, for example. Further, performers could push or pull the system to other states, enabling musically useful linkage of physical tension and release to musical macrostructure. More speculatively, a generative music system and its haptic interface could be seen to embody a set of musical potentials and constraints through its system of virtual physics.

The last two hypotheses have been inspired in part by Lerdahl's concept of tonal pitch space [8] and Steve Larson's proposal that "we not only *speak* about music as if it were shaped by musical analogs of physical gravity, magnetism, and inertia, but we also actually *experience* it in terms of 'musical forces'" [9]. One could imagine a performer engaging with a force-feedback system with gravity fields modelled on (for example) hierarchical models of tension in harmonic progressions – potentially pushing the system through a plane of resistance into a new key, whereupon the system reorders the haptic topology. Gesture studies of Indian *khyal* classical vocalists musicians also provide a provocative model, revealing that some performers conceive of the performance of a *raag* as a type of path through a "flexible but stable topology that singers explore through both melodic and gestural action" [10] – suggesting a strong conceptual link with the potentials of force-feedback interfaces.

The primary aim of the research described here was to establish proof-of-concept of the general claim through a series of graduated test cases and lay the groundwork for further research.

3. RELATED WORK

The authors have been able to find few direct investigations of haptic control of generative systems in the literature. Inspired by DJ technique, Anderson *et al* created a motorized-slider interface through which a performer could both feel and alter the amplitude envelopes of sound loops [11]. Rydberg and Sandsjö's BeatCatch uses a haptic mouse as a metronome which can provide force-feedback control of rhythm patterns [12]. Gabriel *et al*'s BounceSlider uses one-dimensional force-feedback sliders as a tangible interface to set initial state for a bouncing-ball model for generating MIDI data, with intent to "provide a tool for exploring perceived physical characteristics of *sound as an object*" [13].

More distantly, Berdahl, Cadoz and Castagne's work with force-feedback control of a neural oscillator model could be considered an interesting example of control of a semi-autonomous generative system, though aimed primarily at solving human-robot control issues [14]. If one considers granular synthesis to lie conceptually between a standard instrument model and a generative system, then O'Modhrain and Essl's tangible devices to control audio-driven granular synthesis controllers could be seen as an intriguing approach to ensure a correspondence between haptic experience of an interface and generative-system sonic output [15].

4. TECHNICAL APPROACH

The technical approach needed to facilitate rapid development of proof-of-concept. The authors also wanted to be on the path to creating a toolkit that would be relatively easy and inexpensive for artists to use. For this reason, Max/MSP[1] was chosen for coding the music algorithms and sound generation. The ideal target force-feedback interfaces were the GeoMagic Touch[2] (formerly Sensable Phantom Omni) and the Novint Falcon[3]. The former provides a robust and proven platform. The latter provides a low-cost, practical entry point for artists. The preferred target platform was Macintosh, since much of the authors' composing and research work is based on this platform.

There are crucial distinctions between the technical demands of force-feedback devices and the standard design of realtime computer music systems. To ensure acceptable levels of interaction stability, a typical specification for a force-feedback system entails maintenance of a 1000Hz. closed loop or better, with maximum latency of 1ms. and very little jitter, typically implemented with a high-priority thread on the computer. Computer-music systems are typically running at much higher speeds for audio signals (such as 44.1kHz), but computed in multi-sample blocks for efficiency — thus introducing latency. With PD[4] and Max/MSP, the control rate is conveniently 1000Hz, but it is has been claimed that the timing is not accurate enough for force-feedback applications [16].

Thus Ed Berdahl's Open Source Haptics for Artists (OSHA), which is focused on controlling physical-modeled instruments and implements force-feedback calculations via audio functions in Max/MSP, requires Max's audio processing to be set at a vector size of 1 sample [17]. OSHA demonstrates one attractive approach to making haptics more accessible to artists: allowing haptic interactions to be specified via directly via modules within a music-oriented graphical programming language. OSHA also comes ready to work with the Novint Falcon (though not the Phantom Omni). However, the computational cost of running with a vector size of 1 is very high, and it could prove problematic if creating a full-scale performance work.

In contrast, Steven Sinclair used a client-server approach with his DIMPLE system [18]. The server is implemented in C++ using the open source libraries Chai3D and ODE, thus integrating the needed low-latency force-feedback loop with a physical modeling system. Chai3D is multi-platform (Linux, Windows, and Max OS) and supports multiple haptics devices. Any Open Sound Control enabled music client, like Max/MSP, can communicate with DIMPLE via OSC messages to specify particular haptic setups, send data to those setups and to receive interface data to control sound algorithms. The authors were advised that DIMPLE was in need of updating during the period of the authors' project and was not available.

Therefore, the authors developed a similar client/server approach on the Windows platform, using only the Phantom Omni. The core software toolkit integrated Bencina's Oscpack Open Sound Control library with Geomagic Open-Haptics Toolkit 3.0 (OH). OH provided a proven, robust solution and wide-ranging library for working with the Phantom Omni. In order to ensure sufficiently fast processing of OSC messages, the Oscpack listener was implemented in an OH Server_Run() callback function, with a priority level of ' default'. Hard-coded specific servers and Max/MSP clients were established for each of the test cases.

5. TEST CASES

A series of test cases was executed, moving from simple, non-generative system tests through more conventional instrument-like paradigms and ultimately to multi-state generative systems. A subset of these cases is described below. Video documentation of this subset and technical details of

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[1] http://cycling74.com

[2] http://geomagic.com/en/products/phantom-omni/overview

[3] http://www.novint.com/

[4] http://puredata.info

the implementation are available on a web site[5]. The intent was to establish proof-of-concept and to clarify potentials rather than to provide rigorous refinement and formal evaluation of each test case.

5.1 Wall Contact

A simple virtual wall on the Z-axis was the first test case, where touching the wall triggers a sawtooth tone. By applying sufficient force, the user can push or pull the interface pointer through the wall. A simple indication of whether the wall was being touched was sent to Max/MSP via OSC.

A small alteration immediately created a greater sense of expressive control: the force values for the haptic arm were returned to Max/MSP and mapped to signal amplitude and the cutoff of a low-pass filter, such that the sound became louder and brighter the harder one pushed against the wall. This provided a simple but effective correspondence between haptic tension and sonic experience.

5.2 Amplitude Envelope Sensing

Granular and/or looping sound playback could be seen as a type of generative system, and one to which haptic control could be applied. Towards this end, first the ability to feel amplitude envelopes of sound was tested. The code used an OH model of a movable frictionless plane to apply forces to the haptic device on the Y (up-down) axis.

This function was extended to two additional test cases. In the first case, the user could freely scrub the time pointer of a sound granulator from left to right across the time domain of an audio sample, feeling the amplitude of the resulting sound in the Y-axis. The results suggest that this can be a simple but powerful way to provide fine control over the granulation time-pointer, particularly when approaching a strong attack transient in the source sound.

In the second case, the granulation example was extended such that the granulation was not heard. Instead, the performer heard looping sample-playback, where the loop-end point was determined by the arm position. Though it was possible to choose some precise loop points by feel, such as kick-drum events in a drum loop, long delays between that choice and the loop-playback reaching that point seemed to reduce the sense of satisfactory control.

5.3 Simple Arpeggiator

A 3D virtual spring was established, where distance from the spring center was mapped to the upper limit of a fixed-interval MIDI arpeggiator. The resulting spring tension formed a convincing perceptual parallel with the extent and pitch-range of the arpeggiator.

5.4 Multistate Complex Arpeggiator

Building on the same 3D virtual spring, this test case also enabled a true multistate function. When the spring stretch exceeds a certain distance in the virtual space, the spring influence breaks and a new spring is launched at the given position — and the base note of the arpeggiator rises one step in a chosen scale mode. If a button on the haptic arm is pressed when the spring snaps, the resultant semitone shift is downward, instead. As the spring is stretched, the interval between notes of the arpeggio increases, tempo slows, and amplitude decreases — creating a greater sense of suspense, uncertainty and tentativeness. The launch of a new spring is often accompanied by an immediate contrast: a rapid cluster of new, high-velocity, close-interval notes. The authors found the overall feel and behavior of the system provided an immediate, intuitive and compelling sense of expressivity and haptic correspondence to sonic results.

Further, the multistate aspect of the design enabled distinctive behaviors that are immediately amenable to creating musical macrostructure. The approach to and execution of the launch of a new spring provided a highly malleable and expressive gesture-type that, together with the resulting rise or fall of the base pitch, can accumulate in time to provide a flexible basis for establishing higher-level dramatic form.

It is interesting to note that, while the system could be implemented as a one-dimensional spring, the 3D spring served for some performers as an invitation to work across the full position range of the device, perhaps bodily enacting in this whole 3D space aspects of the arising conception of the macrostructure of the improvisation.

6. DISCUSSION

While acknowledging that the multistate complex arpeggiator has not been formally user-assessed, the authors consider the system sufficient proof-of-concept to justify further development and pursuit of formal user assessment. The research has also raised a number of technical and conceptual questions.

First, the authors have been surprised to find only limited analysis of the minimal technical requirements required to enable acceptable-quality force-feedback implementations of the types of systems explored here. Though the broader haptics literature provides rigorous treatment of engineering of force-feedback systems, to-date the authors have not been able to find the type of focused, formal analysis that would answer basic questions relevant for musical haptics applications. Clear answers to such questions and rigorously tested guidelines for tuning systems for common scenarios could help expedite development of tools and broader and more successful uptake of force-feedback interfaces among musicians.

The authors have proposed that there is particular value in establishing coherence between the haptic sense of the inter-

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[5] http://BatHatMedia.com/research/hapticspilot.html

face and the subjective response to the generative system's sonic output. This coherence could be addressed through a variety of means, providing rich potential for future exploration. Clearly this coherence can be established by heuristically guided design, such as with the multistate complex arpeggiator. However, powerful potentials may arise through applying automated analysis to the music-symbolic or signal output of generative systems and mapping results back to the haptic interface.

7. CONCLUSIONS

These initial test cases strongly suggest that force-feedback interfacing can productively raise the level of embodied, non-conceptual engagement with generative-music systems, while multistate approaches could also enable novel approaches to generating musical macrostructure linked to physical gesture.

Though the primary focus here has been on the performer experience, it would not be surprising if such linking of effortful interfaces with subjective musical results could also result in an greater sense of *kineasthetic empathy* [19] with digital-music performances on the part of a viewing audience.

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