PERFORMING ARTICULATION AND EXPRESSION THROUGH A HAPTIC INTERFACE

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ABSTRACT

While digital technologies offer a host of new sonic possibilities, we are no longer dealing with the physical vibrations of strings, tubes and solid bodies as the sound source, but rather with the *impalpable* numerical streams of digital signal processing (DSP). As a result, when we perform with digital musical instruments (DMIs), we can no longer make use of haptic feedback provided through the body of the instrument itself. Furthermore, many DMIs are derived from interfaces designed for effortlessly smooth human-computer interaction. Here, however, the struggle afforded by the resistance and physical forces of acoustic instruments, which I will argue is integral to musical performance, is all but lost.

This paper discusses the musical outcomes of an exploration into the use of a haptic interface as an instrument for the performance of digital music. I will argue that it is the reintroduction of these tangible forces that is crucial for the articulation and effectuation of sonic ideas. In particular, the instrument will be discussed in relation to the work *Running Backwards, Uphill (2011)* for piano trio and live electronics, where a potentially high level of sophistication of expression was required that would allow the laptop performer to embody the musical intentions of the piece.

1. INTRODUCTION

> *A violin, played at professional standard, can be likened more to a localised instrument of torture (with its complimentary disciplinary rewards), than a harmonious continuation with human agency. Why is there no impetus to develop a violin that blends ergonomically with the player?* [10]

When playing acoustic instruments, the haptic perception involving both tactile sensors in our skin (especially in the fingertips, hands or lips), as well as our kinesthetic perception of the position and movement of our muscles and joints, is pivotal within the complex relationships between performer, instrument, and the resultant sounds produced. It is precisely these ongoing negotiations and reassessments through multimodal feedback loops that lead to the diversity of achievable musical expression. However, the audio-tactile link has been largely missing in systems of digital music. Instruments can no longer be said to describe only those resonating bodies of physical constructs; indeed the sound sources of DMIs cannot usually be linked to real-world vibrating objects. Emmerson writes that, as performers, we "sense this loss of 'tactile location'"[4]. MIDI controllers are often modelled on the studio paradigm, consisting of knobs and faders, and tend not to offer the types of interaction that make use of physical forces such as pressure, friction, collision, resistance, and so on. Even instrument-based MIDI controllers not only fail to communicate the whole picture in terms of the performer's gestural information, but do not go far enough in allowing the vitally *unharmonious* types of engagement to manifest between performer and instrument, as hinted at by Rebelo and Coyne's quotation.

As research into tangible computing develops, the importance of how we engage with the digital world through our physical interactions is being increasingly highlighted. The incorporation of haptic feedback into mobile phones, and more recently tablet computers, is one such example. Developments in the field of haptic technology directly related to music are steadily increasing. These include ways of using our tacit knowledge of how we interact with physical objects as a means of mapping input gesture to digital audio parameters [8]. Other work specifically uses the already acquired motor-skills of a musician as the basis for haptic instrument design [2]. In related research, I have attempted to reintroduce the tactile sensation of sound to the performer by incorporating vibrotactile feedback within the performer-instrument coupling [6].

In what follows I will attempt to argue the case for employing tangible forces as a means to enhance the potential for sophisticated expression and articulation of performed digital music. I will propose that:

1. Diverse musical expression is achieved through constant multimodal negotiation between performer and instrument.

2. Exploring the resistance of an instrument, either physically or virtually, can help to craft a performance.

3. Haptic technology can help to create shared participation between performer, instrument and performance space.

2. SOUND SCULPTING WITH A HAPTIC CONTROLLER

During his keynote address at the *International Computer Music Conference, 2011*, University of Huddersfield, Simon Emmerson suggested that the idea of sculpting sound was now "a metaphor that could be made 'real' through suitable haptic interfaces and three dimensional representation." [4]. What follows will offer a modest step towards a realisation of this idea, where digital audio can indeed be moulded and articulated through three-dimensional (3D) tactile interactions. In this way, not only do we rely on auditory feedback to navigate between sounds, but we are also guided by ongoing *tangible* exchanges with the instrument.

2.1. Repurposing a Commercial Game Controller

The *Novint Falcon* is an affordable[1] commercial 3D game controller, providing up to 9 newtons of resistant force-feedback to the user [1]. While this is of a much lower bandwidth than, for example, Claude Cadoz's *Modular Feedback Keyboard* [3], one of the first haptic musical instruments, or "*gestural force-feedback transducers*", it is nonetheless receiving attention as a low-cost solution to designing haptic DMIs. The *Haptics Lab*[2], at CCRMA, Stanford University, is an audio-interaction workshop specifically based around the Falcon.

Open source software is available from Nonpolynomial Labs[3], enabling the Falcon to operate within musical programming environments such as Max/MSP and Pure Data[4]. Edgar Berdahl, at CCRMA, developed *HSP*, "a simple platform for implementing haptic musical instruments" [1], aimed at making the incorporation of haptic technology into DMIs both inexpensive and easy to programme. The toolkit offers a series of basic force-feedback profiles for the Falcon, including virtual walls and springs. Used and adapted in combination with various DSP techniques, new *instrument* prototypes start to emerge.

The Falcon ball grip can be moved within a 3D space, approximating a cube of side around 11 centimetres. However, depending on design choices, a virtual space of *infinite* size could be traversed. The haptic technology can provide the experience of palpable (but virtual) objects, surfaces, and indeed textures. Thus possibilities for designing interactions based on a host of different gestures arise, where we can imagine not only *bumping* into virtual surfaces, but also being able to move through different *atmospheres*, at various speeds, depending on the viscosity employed[5]. Furthermore, interactions that defy real-world physical relationships can be created through the HSP's interface. For example, a simple wall model could *disintegrate* after being hit with a particular velocity, and *reform* once the user has passed through to the other side. Of course, meaningful relationships between such interactions and their effect on the musical outcomes must be considered.

2.2. Performance Potential

On trying out the device for the first time, it feels, peculiarly, both new, yet familiar. After initial experimentation within this environment, the possibilities for prototyping new haptic-based musical instruments become obviously clear. The three degrees of freedom gives potential not only for micro-movements of the hand, but for further engagement from more of the body. Thus larger gestural movements can be *transduced* into parametric information, while still allowing for finely focussed articulations. Rebelo refers to performance as a "multimodal participatory space", somewhere where the performer employs "negotiation of subtlety and the recognition of threshold conditions" [9]. I would argue that by introducing haptic devices, we also increase the potential for this type of engagement.

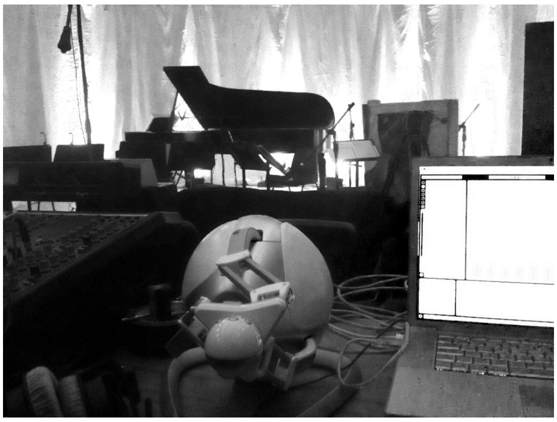

Figure 1. Performance of *Running Backwards, Uphill*, Reid Hall, Edinburgh, 2011.

Emmerson's idea of sound sculpting suggests that 3D manipulations would enable us to mould multiple aspects of the sound simultaneously. The very nature of the Falcon affords this type of interaction, given that any movement will produce a minimum of three data streams[6]. Thus, the potential for multi-mapping is inherent. The expressive potential of acoustic instruments can, in part, be attributed to the multiple and ongoing negotiations between performer and instrument. For example, playing fast *staccato* scales on a piano requires continuous assessment by the performer about kinaesthetic and haptic information, such as the bounce of the fingers against the keys, and the speed or acceleration of the hand. Thus, simply by nature

[1] Costing around $250 at time of writing, January 2012.

[2] `https://ccrma.stanford.edu/wiki/250a_Haptics_Lab`

[3] `http://sourceforge.net/projects/libnifalcon/`

[4] As well as providing cross-platform functionality to include OS X, which is, at time of writing, unsupported by Novint.

[5] Viscous damping is implemented in the HSP toolkit through a series of biquad filters.

[6] On the most basic level, x, y and z position can be extracted, before even considering force and resistance.

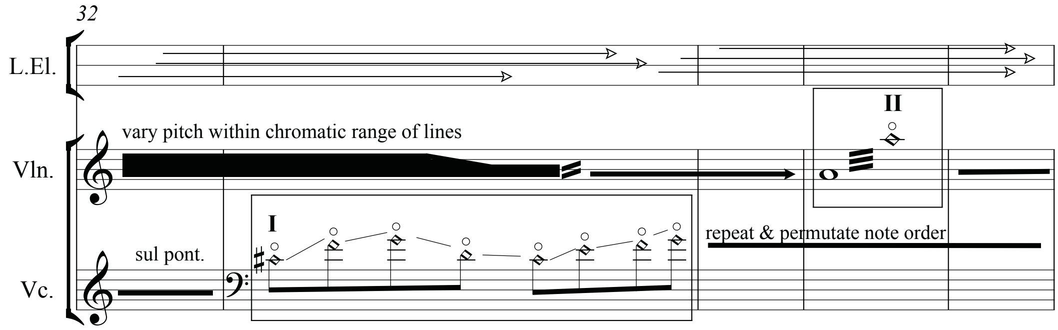

Figure 2. Score with thick black lines illustrating gradual transitioning of sound. Electronic part indicates to play samples with varying speed of playback and dynamic.

of its design, the Falcon already goes some way in offering the qualities necessary to make a convincing instrument.

2.3. Development of an Instrument

After testing the various physical models given within the HSP examples, the virtual wall was used most extensively as a starting point, as the action of striking a surface with different objects and forces could be considered to be one of the most primitive sound-producing gestures.

I implemented a visual rendering of a ball bouncing on the wall using *JavaScript* within Max/MSP, which was initially useful for providing additional visual feedback while developing the system. However, since much of my practice within computer music aims to remove the need to look at a laptop screen while performing (through engagement either with haptic interfaces, or augmented instruments) [7] [6], this quickly became redundant.

One of the most interesting aspects of the instrument was that depending on the different force profiles used, it could rapidly change between allowing wild gestures, to a very resistant, even *secure*, environment where moving through detailed nuances of a sound could be explored. The four buttons on the small ball grip of the Falcon allow rapid switching between different forces profiles and parameter mappings, within a single performance.

3. *RUNNING BACKWARDS, UPHILL*

This section describes the implementation of the Falcon as a performance instrument within a compositional framework.

Running Backwards, Uphill (2011)[7] for violin, cello, piano and live electronics, attempts to explore the relationships between touch, gesture and timbre by examining the sonic qualities of the acoustic instruments, and furthering these through the use of electronics. The performers are directed to lurch and fall off the keys; or, to create the most delicate airy bowed sound. Extended techniques are combined with sound analysis methods, resulting in an informed integration between the two sonic worlds.

3.1. Articulation and Expression

One of the challenges with this composition was to develop a method for articulating the electronic part that could evoke the same expressive qualities within the music as would be expected of the professional ensemble. The musical language of the piece itself is very gestural (see Figures 2 and 3), and thus it was important that the electronic part should also be performed in such a way as to reflect this.

The boundaries of any instrument can be where the most expressive moments emerge, from an unstable clarinet multiphonic, to the point at which a digitally generated pulse turns into pitch. But for instruments within the class of *resonating bodies*, these boundaries are intrinsically coupled with *physical* resistance. As Aden Evens explains:

> *For his part, the musician resists the resistance, which is to say, he employs technique... technique is designed to place the instrument's resistance in contact with the musician, to allow him to feel the many dynamics it offers of force and sound.*[5]

Thus, by working with the haptic device, I could successfully couple physical resistance with these virtual boundary areas, which in turn allowed for a greater range of potential expression in which the performer could employ technique.

In the first part of the score (see Figure 2), the Falcon is used to play short segments of samples of a prepared piano. With the added resistance of the controller, I was able to make micro-movements along the domains of both start and end points of the sample, as well as the speed of playback of the samples themselves. Without the force to play off, the result would have sounded jerky and ill crafted, whereas pushing through the resistance allowed

[7] A live recording of the work can be heard here: `http://soundcloud.com/elleesaich/running-backwards-uphill`

smooth transitions through the various parameters, producing a *legato* effect.

In this section, the string instruments play long tremolo lines in which both the speed of the tremolo, and pitch transition continuously. The dynamics also ebb and flow gradually until the entrance of the piano. I wanted the electronic part to reflect these characteristics by transitioning gradually both in timbre, dynamic and pitch. The haptic device gave the performer a sensation, or *feeling* of moving through the sound, increasing the amount of information available for negotiating the performance.

Figure 3. Score illustrating frenetic, gestural section.

In the middle section of the piece (see Figure 3), the Falcon was used to transduce fast gestural sweeping movements to process various effects (including bit-crushing, feedback and filtering), which were applied to a second set of samples. Here, the piano part leaps through descending cluster chords, in a syncopated manner. The pianist is instructed to play "clumsily, with hands almost falling off keys". The laptop performer uses a different, non-uniform force profile in this section, which facilitates the "jerky" expression marking notated in the score, but which also provides more resistance at the boundaries of the DSP. In this way, the performer is less likely to, for example, hit the more piercing parts of the audible feedback, as the added resistance would prevent them from reaching that part of the instrument's range easily.

4. RESULTS AND DEVELOPMENT

The purpose of this paper was not to detail the technical capabilities of the Novint Falcon, as these are thoroughly described elsewhere [1], but rather to describe how employing a haptic device can manifest imagined musical ideas and *expressive* nuances. Not only through practice, but also by considering the crucial negotiations and feedback loops that take place between performer and instrument, it becomes evident how employing haptic technology can solve some of the problems associated with the performance of live electronic music.

Implementations of different force profiles, combined with viscous damping, allow the performer to *feel* their way through different aspects of digital audio, and sculpt the sound accordingly. In the work described, using resistant forces designed with very simple physical manifestations allowed vastly different types of engagement to be employed within the piece. Through the use of haptics, as a performer, I could more easily position myself within the shared participatory performance space. I will conclude by suggesting that this is a place that we, as composers of digital music, need to more deeply explore.

5. REFERENCES

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