Vibrotactile Feedback-Assisted Performance

Lauren Hayes
Department of Music
University of Edinburgh
Alison House
12 Nicolson Square
Edinburgh
EH8 9DF
laurensarahhayes@gmail.com

ABSTRACT

When performing digital music it is important to be able to acquire a comparable level of sensitivity and control to what can be achieved with acoustic instruments. By examining the links between sound and touch, new compositional and performance strategies start to emerge for performers using digital instruments[1]. These involve technological implementations utilizing the haptic[2] information channels, offering insight into how our tacit knowledge of the physical world can be introduced to the digital domain, enforcing the view that sound is a 'species of touch' [14].

This document illustrates reasons why vibrotactile interfaces, which offer physical feedback to the performer, may be viewed as an important approach in addressing the limitations of current physical dynamic systems used to mediate the digital performer's control of various sorts of musical information. It will examine one such method used for performing in two different settings: with piano and live electronics, and laptop alone, where in both cases, feedback is artificially introduced to the performer's hands offering different information about what is occurring musically. The successes of this heuristic research will be assessed, along with a discussion of future directions of experimentation.

Keywords

Vibrotactile feedback, human-computer interfaces, digital composition, real-time performance, augmented instruments.

1. INTRODUCTION

Being arguably the most highly developed of the senses [5], the importance of touch is often, it will here be suggested, erroneously overlooked in human-computer musical systems. This paper examines some possible advantages in exploring the audio-tactile link for practitioners of digital music, and will propose introducing vibrotactile feedback as a new strategy for improving performance in the field. An assessment will be presented of what has been lost, in terms of interaction, in the move from traditional acoustic instruments to commercial interfaces for digital music. This will be followed by a discourse on using vibrotactile signals, directly applied to the performer's hands, as a means of communicating information about the music and score during a performance. The theoretical ideas are put forth in relation to the creative practice of the author; the output of this work being original compositions and improvisations. Links to audio[3]. and video[4] examples of these works have been provided for reference.

2. SOUND AND TOUCH

2.1 Haptics

When hungarian psychologist Revesz first introduced the word haptic, from the Greek *haptesta* (to touch), in 1931 [3], it was used to describe the process of actively exploring a shape or spatial dimension with the hands, discussed in the context of his research on blindness and its profound effects on the other senses. He contrasted this process with the event of indirectly sensing something on the skin (*ibid.*), such as experiencing differences in temperature or feeling something brush against the body. However, when discussed in terms of human-computer interfaces, the word haptics is often used as an umbrella term encompassing both the active information gathering that Revesz described, as well as the tactile sensations that he classed separately, and additionally, kinaesthetic information about the body in relation to space [12].

Haptic devices are carefully designed interfaces that usually involve some type of actuator or mechanical device, such as small vibrating motors. Their purpose is to improve the translation of gesture between the physical world and the digital realm by considering both the body's kinaesthetic system, which detects position and motor control of muscles and joints, as well as the tactile sensors in the skin, which are extremely sensitive and capable of detecting highly complex patterns of information [6].

2.2 Instruments

2.2.1 Acoustic Instruments

The skin's sensing nerves are most densely collected in the lips and hands [9], [12]; since most acoustic instruments are constructed to be played with the mouth or fingertips, this distribution of sensors in the skin allows for the maximum amount of information exchange. During engagement with the instrument, the performer receives feedback in the form of various resistant forces and vibrations (for example, the

[1]Instrument is used here to encompass the entire system which may include: human-computer interface(s), computer, bespoke software, loudspeakers and so on.
[2]Related to the modality of touch.

[3]Audio recording of improvisation for laptop using vibro-tactile feedback device: http://soundcloud.com/elleesaich/multifingeredbodyparts
[4]Video of *kontroll* for prepared piano, self-playing snare and live electronics: http://www.vimeo.com/13493035

vibration of guitar strings, along with the force of the fingers on the strings).

This haptic information supports the auditory feedback received through the ears as sound is made. Hence a closed feedback loop is created: the performer makes a sound, which is heard and also perceived physically, judged, and considered before the next sound is made. This process occurs in a very short space of time and is constantly ongoing throughout musical play: the auditory and haptic feedback is immediate, with the latter signals received perhaps almost subconsciously. Certainly while the amount of force used to strike keys while playing the piano is a conscious consideration, vibrations received through the feet may not be consciously perceived, but are no doubt significant in creating the collective feedback information being received. As Cadoz claims, this bidirectional information exchange 'provides us with manipulation possibilities and even signals the nature of the sound phenomenon itself.' [1] Furthermore, this entire process is uniquely private to the performer, compared to noticeable *visual* exchanges that may occur within a group performance setting.

2.2.2 Digital Musical Interfaces

In general, digital interfaces generally offer significantly less feedback to the performer. A MIDI keyboard may feature weighted keys, but cannot reveal any other information about the physicality of the sound being produced, compared to the great resonating body of an acoustic piano.

2.3 Tactile Feedback Principle

In 1978, Claude Cadoz proposed the tactile feedback principle in conjunction with his work at ACROE[5], Grenoble, France, where along with Jean-Loup Florens, he developed the first Retroactive Gestural Transducers (haptic devices). Their aim was to provide new insights into music creation by focusing on the instrument-performer relationship as fundamental to both the learning of the instrument and the development of the music itself, rather than simply providing improved ergonomics of gestural control in sound synthesis [1]. Cadoz claimed that any musical interface into the digital world must succeed on three levels: the gesture used to manipulate the device must be genuine in that the performer must be familiar with the type of movements being used with the controller. Secondly, the device must be able to accurately sense the characteristic behaviour of the gesture and information must not be lost. Finally, he claimed that the device must offer some resistance to the performer, which is in relationship to the nature of the simulated gesture process [1]. He calls this final aspect feedback, and deems it necessary to achieve mastery or perform with finesse.

2.4 Types of Haptic Devices

Human-computer haptic interfaces may be described as any device that incorporates an element of force feedback through actuators: mechanical systems that can offer a wide range of accurate motion, such as motors. Rovan and Hayward distinguish these devices from what they call tactile stimulators [12], which consist of, for example, small groups of pins that tap at the skin, vibrating at controllable frequencies to achieve different intensities. Thus Revesz's distinction between active and passive perception manifests itself in these contrasting systems: the vibro-tactile systems allow the user to passively experience sensations.

There is a huge amount of evidence to suggest that haptic perception can speed up learning [3], [9], thus allowing the relationship between performer and instrument to develop at a much faster rate than without feedback present. When describing his Modular Feedback Keyboard, Cadoz claimed that the aim was to create a 'synthesis of the instrument' [1], as well as the sound. Thus it would allow experimentation, musical play and would successfully couple the performer, instrument and space [1]. As Pedro Rebelo, researcher and composer at *SARC*, Belfast claims, it is useful to view the link between a performer and instrument as a 'multimodal participatory space (and not one of control)' [11]. The following sections will discuss the author's attempts to realise this idea as both composer and performer.

3. FEEDBACK-ASSISTED PERFORMANCE

3.1 Developments

There have been a minimal[6] number of instruments designed with vibrotactile feedback in mind. Marshall and Wanderley, CIRMMT, McGill University, describe the *Viblotar* and the *Vibloslide*[8] which each use small inbuilt speakers to produce both vibration, as well as sound, as feedback for the performer. As with acoustic instruments, in both these examples the sound source is located within the body of the physical instrument itself[7], and not dislocated in loud speakers: the physical feedback emerges concurrently with the sonic.

The aim of using of the vibrations of the speakers was to create "vibrations in a DMI [digital musical instrument] that are produced in a similar way to those of an acoustic instrument". Certainly this approach is an important one, in that it uses the paradigm of traditional instruments as a starting point for introducing haptic information to new digital instruments. The following two case studies offer an alternative approach where the vibrotactile feedback is not intended to emulate the feel of playing acoustic instruments, but rather as a signalling and suggestion system for the performer.

3.2 Case Study: Composition for Prepared Piano and Live Electronics

This work arose out of several compositions for prepared piano and electronics, for solo performer, where the performer would be in control of both the piano and the live electronics. As Emmerson claims, digital music interfaces should be both consistent in their response, as well as sensitive, so that even subtle movements and gestures may be accurately detected and used to affect the sound [4]. Thus it seemed plausible that using a touch-based acoustic instrument, namely the piano itself, as the interface into the digital world could be the solution to achieving mastery of the entire system[8]. By controlling all processes from the piano, the pianist may retain their touch-based sensitivity whilst yielding enough useful control data, via various analyses of the sound, to affect the digital signal. From this emerges what pianist Xenia Pestova describes as a 'further continuation of extended techniques' [10].

3.2.1 Score Following

Building on previous work involving a machine-listening system for prepared piano and live electronics, the goal with the new piece, *kontroll*, was to create a situation where the

[5]Association pour la Création et la Recherche sur les Outils d'Expression

[6]Marshall found instances of vibrotactile feedback implementation in less than 6% of new instruments at NIME from 2001 - 2008[7].

[7]Although external amplification is also permitted to increase sound quality.

[8]Rather than attaching MIDI controllers to the piano, which may disrupt the performance.

Figure 1: Simple glove with vibration motors, which connects to a laptop via an Arduino.

need to look at a laptop screen for visual feedback would be minimized or completely eradicated. In a previous composition, *transient* (2010) it was necessary to watch for the clock, score position and whether various triggers had been activated on the laptop screen. While certain trigger points were flexible in time, they had to occur within a certain time-window, and thus the Max/MSP interface had to been constantly checked. In the subsequent piece, these obstacles would be overcome by sending haptic feedback, in the form of vibrations, to the hands of the performer, providing the required information via a different modality.

3.2.2 Methodology

The score of the composition was created in Max/MSP, where various preset stages were created which would enable or deactivate different DSP modules, and change how control data derived from analysis of the piano's acoustic signal was used. Advancing to a new section would, in most cases, be triggered by the pianist (either performing a particular gesture at a specified dynamic, or by maintaining a specified amount of silence). Other events would advance according to a fixed timeline. Using an Arduino[9] and three small pager motors attached to the left hand via a simple glove, vibrations were sent to the performer indicating:

- a five second warning for an approaching change in score position, increasing in vibration intensity
- a strong short vibration when the performer had successfully triggered a new section of the piece
- the guide tempo of a section.

The pager motors used were Samsung disk coin-type vibration motors[10]. By selecting extremely light motors (0.99 grams each), no additional noticeable weight would be added to the hands of the pianist. The motors were connected directly across the ground and digital/pulse-width modulation pins of the Arduino, as they operate at a meagre 1.5V. Information was sent to the three motors using the Maxuino helper patch[11] for Max/MSP, allowing all computation to be contained inside a single programming environment. Using pulse-width modulation, a very apparent increase in intensity could be experienced.

Motors were fixed onto the glove (which was extremely thin and elasticated), positioned on either side of the back of the hand, with the third positioned directly below on the wrist. This allowed for discreet observable information to be accurately perceived whilst playing.

3.2.3 Outcomes

The result was extremely beneficial to the execution of the performance: the ease with which I could ignore the screen and concentrate on the performance was immediately apparent. The vibration signals were non-evasive and did not distract from the actual playing. There was a strong sense of being fully coupled to the system as a whole, as the score of the piece was being *applied* directly to the body, offering more security in the often unpredictable world of live electronics, and allowing for a more focussed performance.

3.3 Case Study: Improvisation for Laptop and Game Controller

As a trained pianist, most of my musical expressivity involves working with the hands, and thus for laptop performance I often repurpose generic game controllers as my interface. For the second example, the vibrotactile feedback system that was developed for *kontroll* was used in a more active manner, worn in conjunction with a game-pad for laptop improvisation. While used as a signaller of structure in the previous work, the haptic information was now used to direct the performer with more musical, and particularly rhythmic information.

While many game-pads or rumble-pads do offer resistant force-feedback, this was not present in the one that was used. Instead, it was sought to achieve a high level of control using only micro-movements of the hands and fingers. Thumbs pressed on the two joysticks could freeze and loop the sound, but the slightest movement could throw this off.

3.3.1 Tactile Score

The device alone *without* haptics worked fairly well as a solo improvisational tool, triggering samples within Max/MSP which were sliced into segments of several milliseconds, and then processed in various ways. Yet, to create a more interesting deployment of the gestural rhythmic aspect, the vibrotactile glove provided short pulses of 300 milliseconds to the performer indicating that short sounds should be played. The interval between these bursts was determined algorithmically, and changed over time. Thus the illusion of different paces throughout the improvisation was created, along with more unpredictable intervals between gestures. Similarly, longer signals, which would increase with intensity, were sent to indicate that a section should be repeated for the duration of the physical sensation. A variable timeline was established along which either of these two situations could occur, but this would not be known to the performer prior to the start of the piece.

3.3.2 Development

The next part of this work will be to develop musical suggestion which is dependent, at least in part, on what has been, or is currently being played by the performer. Rhythmic patterns would certainly be an obvious starting point here, as these are perhaps the most easily repeatable events when working with unpredictable digital musical instruments. Furthermore, rhythms can be easily represented by short bursts of vibrations. The problem with translating more complex variables, such as spectral content, is not only

[9]An open-source electronics prototyping platform board: www.arduino.cc
[10]Available from www.pagermotors.com
[11]http://www.maxuino.org/

Figure 2: Vibrotactile feedback used in conjunction with generic game controller.

the issue of how to most meaningfully map parameters, but also where to draw the line between useful information and sensory overload.

4. CONCLUSIONS

It is clear that there is a strong case for utilizing the different aspects of the modality of touch within digital music practice in order to challenge ideas about musical creativity, as well as to address the limitations of current systems used to mediate between the digital performer's gesture and sound synthesis. With careful experimentation and clever coupling of instrument and performer, the possibilities for new musical expression are certainly promising. From the examples shown above, it is clear that using vibrotactile feedback for performance strategies is a largely untapped area that is worth proper exploration.

4.1 Future Developments

Further research in this area will examine different parameters that may be successfully used within this type of feedback system, including:

- testing on different parts of the body
- exchanging information amongst a number of performers in an improvisational setting
- mapping other musical parameters to the feedback.

This last topic possibly deserves the most dedication, and work is in progress to develop ways of representing a more complete musical picture tangibly, looking at aspects such as density and spectral shifts[12], to assist with musical interpretation. Indeed Schroeder et al. describe experiments designed for group interaction, where these parameters are represented visually as an abstract image[13]. Moreover, Chang and O'Sullivan suggest looking toward audio-visual theories, such as those proposed by Michel Chion, to develop ways of linking both the tactile and auditory sensations; techniques such as masking and synchronization[13] are proposed [2].

[12]These are perhaps less consciously perceived, compared to amplitude, frequency etc.

[13]For example, synchronization would involve the sound and the sensation occurring at the same time.

4.2 Concerning the Listener

It is hoped that this type of vibrotactile interface can be used with non-performers, who will listen to music, whilst also experiencing it in the form of vibrations. Indeed Gunther and O'Modhrain, implementing this idea with their *Cutaneous Grooves* project, go so far as to suggest that this is a 'potential new art form' [6].

After developing the tactile feedback system and experiencing the ease with which signals can be transferred to the skin, it is hoped to explore the idea of using this information to enhance the listening experience, by coupling it with various physical sensations.

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