Improving Gestural Articulation through Active Tactual Feedback in Musical Instruments

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Abstract

In this paper an experimental setup is described, which will be demonstrated at the symposium. Various movement sensors are used in combination with tactile actuators, which provide feedback on the movements made. The aim is to investigate the application of active haptic feedback to improve gestural control of electronic musical instruments. The project is part of ongoing research which aims to improve human-computer interaction at the physical level by applying tactual feedback. The paper describes the background and some of the theory, rather then presenting results. The purpose of this paper is to introduce the ideas, set-up and approach.

1. Background

Musicians rely strongly on their sense of touch when playing traditional instruments, which helps them to control and articulate the sounds produced. In these cases, there are three sources of information for the player:

- kineasthetic feedback: the internal sense of the players own movement (proprioception)
- passive tactual feedback, the shape of the instrument and the elements touched (strings, keys)
- active tactual feedback, through the vibrations or other changing properties of the instrument

As with other electronic systems in general, players of electronic musical instruments such as synthesizers lack the information channel of active tactual feeback, unless it is explicitely built into the system. Due to the decoupling between control surface and sound source through the MIDI protocol, players are not inherently in touch with the means of sound production. The third feedback modality of a traditional instrument as mentioned above is missing. However, this decoupling can also be used as an opportunity because of the two-way nature of the link between interface and sound source, by designing and applying the active tactual feedback.

Ever since the invention of the famous Thereminvox around 1920, an instrument played by moving one’s hands in the air in two planes near a pitch and a volume antenna, gestural controllers have been popular in electronic music. However, from the three feedback modalities above now only one remains, the proprioception. It is therefore more difficult to play accurately.

1.1 Tactual Perception

The human sense of touch gathers its information through various channels, together called *tactual perception* (Loomis & Leederman, 1986). These channels and their sub-channels can be functionally distinguished, although in practice they often interrelate.

Our sense of touch has three sources: the signals from the mechanoreceptors in the skin (our cutaneous sensitivity) informing our *tactile* sense, the mechanoreceptors in the muscles and joints (our proprioceptors) inform our *kinaesthetic* awareness of the location, orientation and movement of body parts, and the efferent copy signal that occurs when a person is actively moving by sending signals from the brain to the muscles (Gibson 1962). *Haptic* perception

involves all three channels, which is usually the case when a person manipulates an object or interacts with a physical interface.
The feedback discussed in this paper mainly involves the tactile sense, particularly addressing the fast adapting and diffuse mechanoreceptors in the skin. This is often called the Pacinian system (named after the Pacinian corpuscles that are the relevant mechanoreceptors), and is important for perceiving textures but also vibrations – its sensitivity overlaps with the audible range (Verrillo, 1992).

1.2 Tactual Feedback Modalities

In addition to the player's internal feedback, the instrument has to be designed to supply feedback information about the musical process manipulated. Reflecting the tactile and kinaesthetic sensory perception modalities, the system can address these modalities with (vibro-)tactile feedback and force feedback, respectively. The current research set up focuses on applying various forms of tactile feedback to display information to the player.

2. Gestures and Feedback

The movements of the player can be detected by various motion sensors, which are used as input by the system. This then generates both the sounds and the feedback information displayed through tactual actuators. The elements of this interaction loop are described in this section.

2.1 Gestures

A gesture can be defined as a multiple degree-of-freedom meaningful movement. In order to investigate the effect of the feedback a restricted gesture may be choosen. In its simplest form, the gesture has one degree-of-freedom and a certain development over time.

2.2 Motion Sensing

In the last decades several gestural music controllers have been developed. Sensing techniques can be those that are worn by the user (On-Body) or placed in the room 'looking' at the performer (In-Space). Several sensing technologies are available for movement tracking:

- *ultrasound* as used in Michel Waisvisz "Hands" and Laetita Sonami's "Lady's Glove".
- *infrared light* such as the Dimension Beam instrument, photocells, and the Sharp Ranger as used in our research.
  laser beams as used in instruments like the Termanova (Hasan et al, 2002) and the LaserBass (Bongers, 1998).
- *radiowaves* as used by the Theremin instruments and replicas, some of the MIT MediaLab instruments and the Solo piece by Joel Chadabe (1997).
- *camera tracking* with systems such as STEIM's BigEye, the Cyclops object in Max, and the EyesWeb system (Camurri et al, 2000).
- *inertial sensors* such as accelerometers and gyroscopes which measure acceleration and rotational speed respectively, from which position can be inferred.
- *magnetic field sensors* are used for small range movement sensing.
  tilt switches can be used to deterimine the inclination of an object or body part.

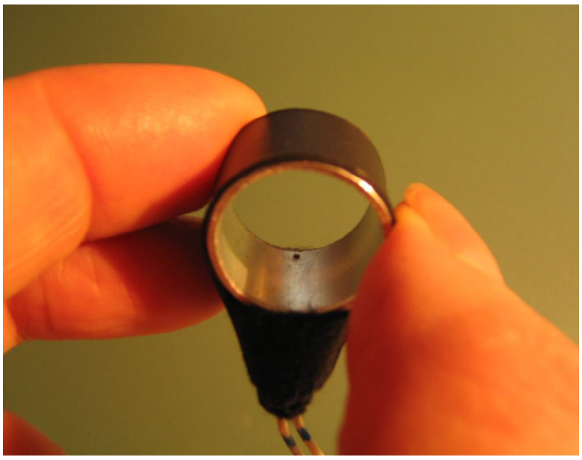
An inclusive overview of sensing techniques is beyond the scope of this paper, and is covered elsewhere in more detail (Bongers, 2000).

2.3 Tactual Feedback

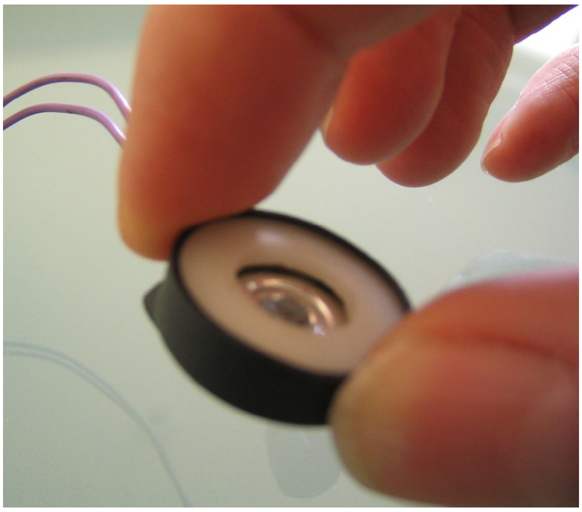
As mentioned above, there are several forms of tactual feedback that can occur through the tactual modes as described, discriminating between cutaneous and proprioceptive, active and passive. Various technologies are available for tactual display, from 2D input devices with force-feedback (such as game joysticks) to multiple degree-of-freedom apparatus such as the Phantom, and custom built systems, which all have been used to investigate the effects of added tactual information feedback with positive results (Hardwick et al, 1996), (Oakley et al, 2001), (Chafe and O'Modrain, 1996), (Akamatsu and MacKenzie, 1996). For (vibro-)tactile feedback electromagnetic actuators (Chafe, 1993), in combination with little loudspeakers can be used. (Bongers, 1998, 2004).

3 The experimental set-up

The goal is to feel something in a certain position or area when moving one's hand in space. A ring is worn with two tactile actuators. One actuator is a small electromagnetic device which can be used to produce the 'attack' of touching the virtual string or object.

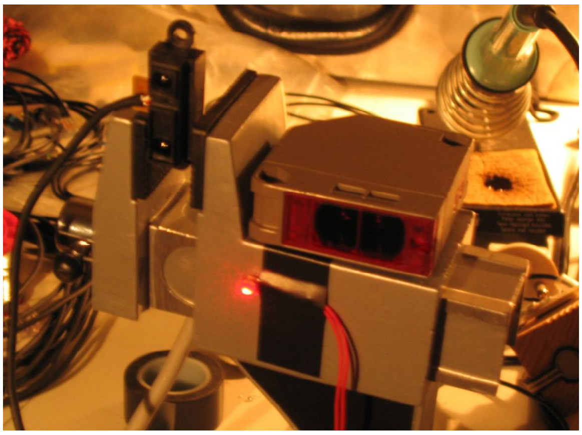


The other actuator is a small loudspeaker acting as a vibrotactile element, producing further articulatory feedback from sound parameters such as pitch and envelope. This method has been used for earlier research in which it was proved that performance of pointing tasks with a mouse can be improved by supplying this kind of feedback (Bongers and Van der Veer, 2004).



The vibrotactile actuator consists of a small (Ø 20mm) loudspeaker, covered by a ring with a hole in it through which the vibrations can be felt with the fingertip without it being dampened by the finger tip pressure.

Currently we are exploring a combination of sensing technologies. To create the experience of playing and touching a virtual string we use a combination of a laser beam (and light sensor) to detect the hand of the player being in a certain line in space, and an infrared proximity sensor (Sharp Ranger) to detect the position in the line. (The original LaserBass, developed by the first author at Sonology about ten years ago for the Dutch composer Florentijn Boddendijk who still performs with it, is using ultrasound for the position sensing.)

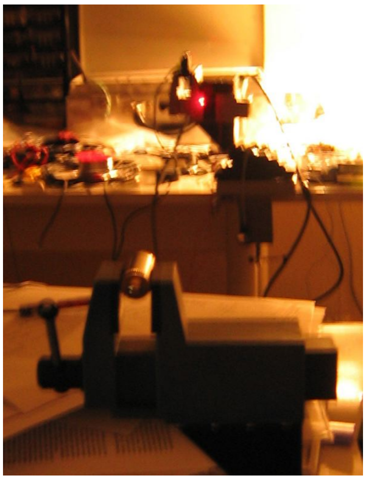


The signals from the sensors are measured through Teleo Making Things hardware, read through the USB port in a Max/MSP patch running on a Apple PowerBook G4 computer, generating the responses. This results in the audible sound and the tangible sounds (virbrotactile feedback) using the sound outputs of the computer, and using the same Teleo hardware the attack can be made tangible with the tactile ring.

4 Future research and conclusion

Latency and speed are important issues in a musical context. For our purpose of generating tactual feedback this is even more relevant, in order to create a convincing experience of touch. Our first experiments so far therefore involve measurements of these issues, and informal results are promising.

For the main experiment, subjects will be given a musical task (such as playing a phrase) under two conditions: one with and one without tactual feedback. Performance parameters will be measured both qualitiative as well as quantitative. The hypothesis is that under certain circumstances it will be easier to play a phrase accurately. In the first phase we will concentrate on one or two degrees of freedom, but in the near future it is hoped to explore the possibilities for applying articulatory feedback in a threedimensional space. Linking to one of our other projects, we will also investigate the application of tactual feedback in real-time video performance.



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