Haptic Music Exercises

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ABSTRACT
Pluck, ring, rub, bang, strike, and squeeze are all simple gestures used in controlling music. A single motor/encoder plus a force-sensor has proved to be a useful platform for experimenting with haptic feedback in controlling computer music. The surprise is that the "best" haptics (precise, stable) may not be the most "musical".

Author Keywords
Music control, haptic feedback, physical interaction design.

ACM Keywords
Input/output devices, interactive systems, haptic I/O.

HAPTICS IN MUSIC
Since 1978, Claude Cadoz [1] has used an active force-feedback keyboard to explore the "instumentality" of dynamics in computer music. At Stanford's Center for Computer Research in Music and Acoustics (CCRMA), Brent Gillespie [2], built a piano-like keyboard and solved some of the control problems. Chris Chafe and Sile O'Modhrain have shown the value of haptic feedback in faster response and more accurate modulation [3,4]. Charles Nichols [6] has built a force-feedback violin bow using friction models from Vincent Hayward [5].

Mathews and Verplank have developed a "controllers course" for inventing new devices for computer music. [7] This year we built a new teaching device: the "FORCE-STICK" to introduce some simple haptic effects.

HARDWARE
A force-sensitive resistor (FSR) is on top of a short stick attached directly to the shaft of a motor. It measures the radial force applied by the user. This is the same principle used in The Plank [8]. We use a surplus Reliance Electric ES364 with a peak-torque spec of 65 oz-in and encoder resolution of 1000 pulses/rev (4000 counts). See Figure 1.

Pascal Stang [9] designed a board for Atmel AVR mega16 microcontroller and an H-bridge motor amplifier. With the AVR, we read the encoder A/B signals and output PWM to the H-bridge. We use Pascal's library of AVR programs and compile with AVR-GCC.

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LOCAL HAPTICS – REMOTE SYNTHESIS
The microcontroller computes the forces based on simple dynamic models running locally on the AVR. Complex synthesis or sample play-back is done remotely on a PC with Pd [10]. In some simple cases, the sound comes from the local vibrations in the FORCE-STICK.

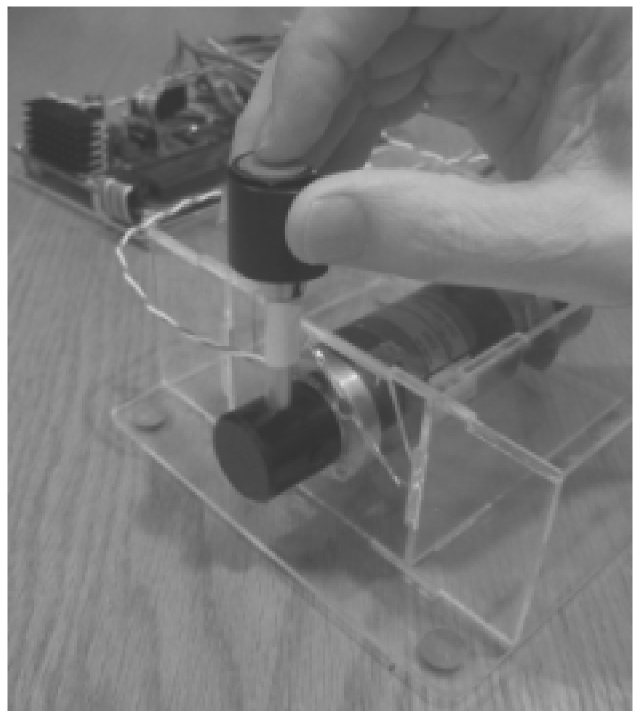

Figure 1. The FORCE-STICK with FSR under index finger.

EXERCISES
The exercises start with working dynamics and music synthesis. Then the students explore the range of effects achievable with simple parameter adjustments (e.g. mass, damping, spring). At the same time we try different sounds that may or may not match the feel.

Wall
A simple spring (without damping) acts as an effective drum head or percussive instrument allowing bouncing or drum-rolls. Stiffer walls and a looser grip make for faster and extended bouncing. A softer wall feels like a big gong.

Bmps

A triangle wave of tangential force proportional to the radial force provides good scrapers or rub-boards. When stick position is mapped to pitch, the "valleys" or detents between shallow bumps work as note anchors.

For simple, static shapes like Wall and Bump, a set of diagrams has proved useful. The tangential force (F_T) from the motor is proportional to the radial force (F_R) measured by the FSR. This "slope of a frictionless surface" is a function of position (x). The "slope" plot is not easy to understand; more understandable is the "profile" that it feels like.

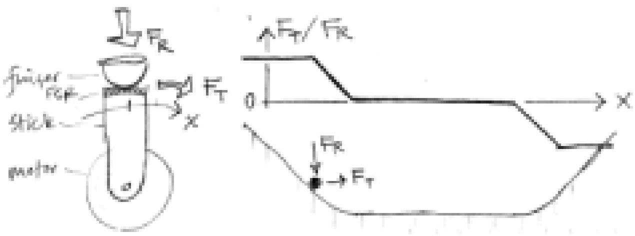

Figure 2. Slope (F_T/F_R) and profile for Wall.

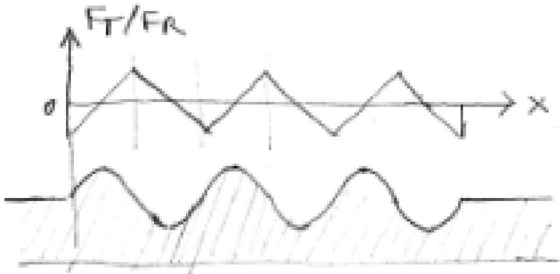

Figure 3. Slope (F_T/F_R) and profile for Bumps.

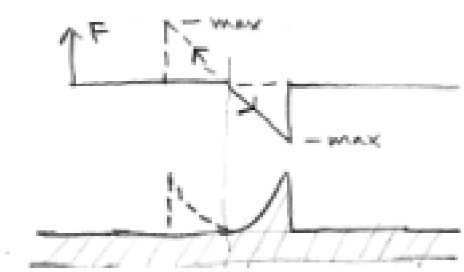

Figure 4. Slope (F_T/F_R) and profile for Pluck.

Pluc k

A pluck is simulated with a simple spring that releases at a maximum force to start a string simulation. Light forces and multiple plucks allow strumming.

Fic tion

Simple stick-slip friction simulates bowing or rubbing. Think of stick-slip as just a very fine series of plucks. We either couple to a string model in Pd or use a simple version of the Karplus-Strong model on the microcontroller.

Ring

A simulated pendulum is swung against a bell. The swing of the pendulum is easier to control with force feedback than without it. The collision of clapper and bell can be felt (and heard!) from the motor. A simple spring-mass-damper behaves like a pendulum swinging. By varying the spring, mass and damper, we control the natural frequency and damping

Spin

A virtual wheel or turn-table is spun by pressing the FSR against its BUMP or STICK-SLIP surface. Scratching a recorded sound file is quite satisfying when you can feel the turn-table torque and slip of the virtual platter against the turn-table.

EXPERIENCE

Mapping physical effects to music is fun and surprising. It is easy to show that more precise control is possible with active force feedback than without it; in fact, some sounds are impossible without the active force interaction. Effects like stick-slip friction are the direct source of rich, expressive musical sounds on instruments as diverse as violins and Tibetan bowls, Indian tabla and wine glasses. Vibrations and chaotic turbulence make control difficult but they also make music.

ACKNOWLEDGMENTS

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