The Haptic Capstans: Rotational Force Feedback for Music using a FireFader Derivative Device

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ABSTRACT

The Haptic Capstans are two rotational force-feedback knobs circumscribed by eye-catching LED rings. In this work, the Haptic Capstans are programmed using physical models in order to experiment with audio-visual-haptic interactions for music applications.

Author Keywords

haptic, force feedback, capstan, knob, physical models

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing, H.5.2 [Information Interfaces and Presentation] User Interfaces—Haptic I/O

1. INTRODUCTION

Within the computer music community, force-feedback instruments have been studied since as early as 1978 [6], and many developments have since been made [5, 9]. While many haptic force-feedback devices for music have been linear, some prior devices have been rotational [4, 6, 8]. Early work by Verplank et al. focused on do-it-yourself hardware for building interactive audio-haptic interfaces [11, 12]. For high-quality haptic force feedback, it is crucial to employ accurate, fast and low-noise sensors. Rotary encoders can meet these requirements as long as they have sufficiently many "counts" per revolution. For instance, Maxon motors can be purchased with integrated rotary encoders having 1024 counts per revolution, which in a quadrature configuration, provide position sensing accuracy of about $360°/4/1024 \approx 0.09°$. The present work introduces an extension to the *Open Source Haptics For Artists (OSHA)* repository, which enables compatibility with simple rotational motors with integrated encoders.[1]

2. DESIGN

Leveraging the new "`RotaryDevice`" extension to the OSHA repository, the Haptic Capstans (see Figure 1) were realized through an amalgamation of DIY fabrication, open-source software and hardware, off-the-shelf electronics, multiple software libraries, and surplus motor stock. The name was inspired by the rotating nautical capstans used to apply force to ropes and cables on ships, as well as the capstans that are used to move tape on a tape transport. In a music performance context, the Haptic Capstans resemble dual turntable and DJ controller setups. The circular LED lighting interfaces were realized using NeoPixel RGB LED rings that were programmed using the FastLED library.[2] The LED light was diffused by mounting them behind semi-transparent panes of white acrylic plastic (see Figure 1).

3. OBJECTIVES

Initial explorations with the Haptic Capstans aimed to **utilize supplementary models as an aid to performance**. This objective was motivated by work such as O'Modhrain and Chafe, who suggested that pitch accuracy when playing a theremin could be improved by attaching an elastic band between the sensor and the player's hand [10].

With two motors at hand, we were also interested in **exploring interfaces that clearly express their own inherent behaviors via internal virtual models**. One prior example of this is the *Sound Flinger*, which allowed users to throw virtual masses using four force feedback sliders. The masses temporarily attached themselves to the sliders, dragging the sliders around as they bounced on virtual springs [7]. Another is *Coral*, an installation in which a virtual swarm and its rod-based physical interface could enter into a positive feedback loop [3].

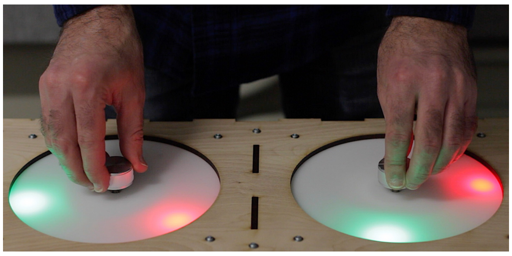

Figure 1: `Wiggling Masses` and `Rasp` models with LEDs on the Haptic Capstans.

4. EXAMPLES

4.1 Wiggling Masses and Rasps

For the following two models, the rotational angle of the motors is represented on the embedded LED ring by green lights, while the position of the virtual masses is represented by red lights. To implement the LED rings, the models are implemented as Synth-A-Modeler models instantiated within HSP [2, 1].

With the `Wiggling Masses` model, the two knobs ( ) are virtually connected to `ground` ( ) by a link ( ) and

[1] `https://github.com/eberdahl/Open-Source-Haptics-For-Artists/`

[2] `http://fastled.io`

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connected to each other by a chain of `links` as shown in Figure 2. Two virtual `masses` (●) are suspended between them. Each of the four moving objects (the two `masses` and two knobs) pluck a virtual `waveguide` (see Figure 2) as it passes through its point of origin. Since both knobs are part of the same model, movement of one knob will push/pull the opposite `mass` and knob. The user can also release one knob while manipulating the other, which inherently changes the behavior of the model as the released knob can move freely. These properties are considered especially interesting as they tend to provide for seemingly emergent dynamical properties: the user can feel and see the effect that gestures on one knob have on the other.

In the `Rasps` model (not shown), two virtual `masses` are connected to each other by a `link` and tossed back and forth between the two knobs, plucking a `resonator` several times along the way. Due to the unpredictable nature of this model, the visual display provides an indispensable reference for the location of each `mass`. There is an inherent sense of tension, as releasing a knob at an inopportune time may send it flying in the wrong direction as the `masses` pass the knobs.

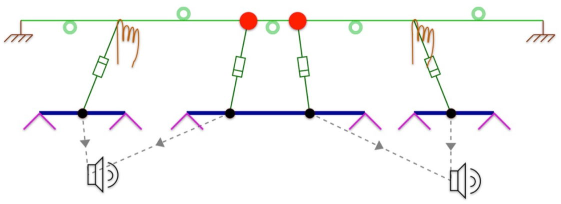

Figure 2: The physical model *Wiggling Masses*.

4.2 Strum Demo

For the Strum Demo, a composition that was originally written to be performed on FireFaders, Andrew Pfalz's "Of grating impermanence," was arranged for the Haptic Capstans (see Figure 3). Each player performs their part by strumming a virtual twenty-string harp. A laser cut arm attachment was used in place of the metal knobs. This attachment allowed for a greater range of motion, which helped make more nuanced gestures. This range could be easily customized by cutting shorter or longer arm attachments. The higher torque of the motors enabled increased perceived stiffness of the harp strings, and a supplementary virtual mass was linked to the knob, providing additional inertia which again provided for more natural strum patterns via smoother acceleration and deceleration.

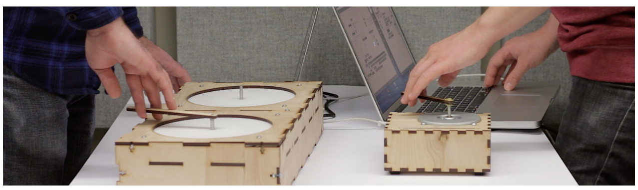

Figure 3: Rehearsing "Of grating impermanence" with arm attachments.

5. CONCLUSIONS AND FUTURE WORK

Different haptic devices have different strengths and weaknesses. By relying on standard units when designing physical models [2, 1], it becomes easier to port models between haptic devices. That is demonstrated in this work in which models for the FireFader were ported to the Haptic Capstans for rotational control and then adjusted in order to realize completely new models, which will most likely sometime in the future also be ported back to the FireFader for linear control and further development.

The authors will aim to further explore the musical possibilities available in an interface that demonstrates the heightened physicality of robust motors coupled with an eye-catching, integrated visual display. Pfalz's "Of grating impermanence" is a substantial first step, though the authors will be looking at other ways that the inherent physical properties of the models and interface can be explored, including additional attachments to physically couple the two motors to each other.

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