A Device for Implementing Kinesthetic Fingertip Guidance and Constraint on Planar Surfaces*

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I. Introduction

We introduce a compact haptic device for guiding a fingertip along a predefined path on a planar touch surface through the application of electromagnetic braking and pivoting. This device can be used to augment touchscreens and other surfaces to provide constraints that allow for increased performance in fingertip tracking tasks during vibration-heavy interactions, or to allow touchscreen navigation through touch alone.

II. Background

Touchscreen interfaces are increasingly replacing traditional physical mechanisms for human-machine interaction. From vehicle dashboards and airplane cockpits to elevators and kitchen appliances, arrays of fixed-function buttons and knobs have been replaced with endlessly-reconfigurable interactive touch surfaces. While these touchscreen interactions have improved over the years through better touch-sensing technology, refined UX design, and the inclusion of tactile haptic feedback, many interactions remain where physically-guided or constrained kinesthetic inputs are preferred or required.

The device presented here draws inspiration from cobot kinesthetic guidance systems [1]. Whereas traditional haptic devices can be considered active in that they add energy to the user or system, cobots are passive, relying on the user's physical input to actuate the system, coupled with actively-controlled electromagnetic brakes.

III. Methods

The device consists of a central pivot upon which the user places their fingertip and two electromagnetic brakes on wings located away from the pivot. During free motion, the device moves passively under the user's fingertip as they explore the touch surface. When the need for guidance or constraint arises, the device transitions to a braking-pivoting state, in which an electromagnetic brake orthogonal to the direction of motion is activated, creating a pivot about that brake, and constraining the fingertip to the arc generated by the imparted fingertip velocity tangential to the pivot. By rapidly cycling between these states, it is possible to allow the fingertip to travel along the touch surface following a constrained path (Figure 1). The position and orientation of the device is obtained through an instrumented pantograph.

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The device can either slide freely or rotate around a pivot point. In the latter state, the radius of curvature is the inverse of the distance between the central pivot and the active brake (defined as R_{brake}). Higher curvature is not possible, but lower curvature can be achieved by pulse width modulation of the brake. A feedback control method based on [2] is used to track curves.

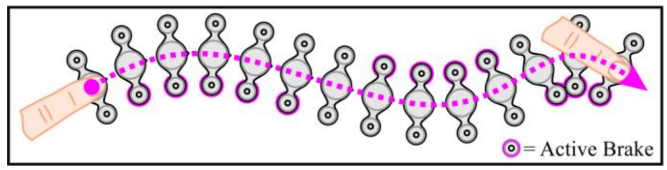

Figure 1. Diagram illustrating the generation of a constrained path for fingertip travel through state cycling.

IV. Results and Discussion

Experiments with the device have shown that, with the implementation of a closed-loop controller, the device is able to track a given path and constrain the fingertip along that path (Figure 2). While this constrained kinesthetic haptic effect is strong, the limited switching frequency of the electromagnetic brakes causes a very perceivable unwanted tactile effect. Additionally, the physical size of the electromagnets limits the device's braking radius, while their mass creates the need for a strong braking impulse to counteract the inertia of the device, leading to a decrease in the user's velocity and a diminished haptic experience.

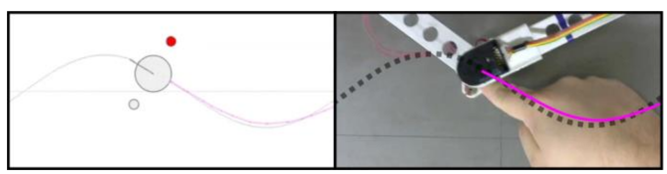

Figure 2. User interface output (left) with associated video frame (right).

While the device demonstrates the ability to use braking as a guidance source, the reliance on electromagnetism as a braking force is problematic. Work has begun on implementing electroadhesive brakes, allowing for much higher switching speeds, leading to better controls and response. This will also allow for a reduction in the mass of the device, allowing for a more satisfying haptic interaction and a decrease in the impulse needed to brake and pivot.

References

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