Haptics for Tangible Interaction: A Vibro-Tactile Prototype

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ABSTRACT

Research on tangible interaction and digital haptics has rarely intertwined, despite the natural relationship between physicality and touch. This paper addresses this relatively unexplored domain by presenting the Haptic Wheel, a freestanding single-axis rotational controller incorporating vibro-tactile cues. In addition to describing the hardware and implementation, the paper discusses the potential application of the system for eyes-free interaction, password entry and as an active puck on a tabletop system. The paper suggests that systems with active haptic feedback have unexploited potential as tools for tangible interaction.

Author Keywords

Haptics, Tactons, Vibrotactile, Rotary controller

ACM Classification Keywords

H.5.2 User Interfaces: Haptic I/O

General Terms: Design, Security

INTRODUCTION

Tangible interaction, despite its focus on physical manipulation, has had limited engagement with work on digital haptics, or touch feedback. Notable exceptions include some of the most striking tangible systems, such as Brave et al's inTouch [2]. This point is reinforced by a recent survey of tangible interaction that identifies actuation as a challenging but underdeveloped aspect of the field [6]. This paper addresses this shortcoming by presenting the design and implementation of a haptic device suitable for use in a range of tangible systems.

The device is a standalone, light-weight and low-cost rotational haptic controller, the Haptic Wheel. It is capable of delivering various tactons [3], or structured vibrotactile cues. A wheel was selected for development as it supports a rich natural interaction (turning) that can perform selections (e.g. at specific angles), navigation or control an analog property. This paper describes the hardware design, interaction techniques and applications to which this device (and the feedback paradigm it embodies) can add value, both as a standalone system and as one element of a larger tangible interface.

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RELATED WORK

A number of authors have produced rotary haptic devices. Recent examples include the Haptic Dial [4] and SmartPuck [5]. Broadly similar in design, the former uses a DC motor to generate torque profiles (varying magnitude, direction, velocity and acceleration) for virtual prototyping of controls, while the latter uses smaller battery-powered stepper motors for a similar purpose. The Haptic dial is a fixed device, while the SmartPuck is standalone, mobile and intended for a tabletop UI. Commercial systems based on this concept also exist, such as the iDrive force-feedback dial co-developed by Immersion Corporation and BMW.

What is common to these systems is a distinctive feedback paradigm based on the use of single degree of freedom end-effectors generating active rotational force-feedback. While clearly useful, this approach suffers the disadvantage that it is only capable of presenting cues to users in response to their interaction (in terms of movement or applied force). Quite simply, without a user's active input, such a device has nothing to push against and is incapable of producing meaningful output. For example, such devices are not able to render passive cues indicating particular system states. The paper explores how vibro-tactile cues [3], implemented in the Haptic Wheel, could achieve this objective more readily in the context of a mobile rotary controller.

THE HAPTIC WHEEL

The Haptic Wheel (diameter 8 cm, height 7.3 cm) is an electromechanical dial capable of continuous revolutions both clockwise and anti-clockwise. Physically, it is a standalone handle resembling the rotary control of a safe which turns on a slim base. It integrates a rotary encoder to track its absolute orientation, a binary switch mounted on its top center (for selection input) and a low-cost eccentric vibration motor to generate haptic feedback in the form of vibro-tactile stimuli. The casing is composed of a physically separate housing and base both formed of Polyjet resin using a 3D printer. The housing and base are jointed together with a bearing to minimize the friction created as the former rotates on the latter. The result is a rugged-feeling device which rotates with a level, pleasant sensation of mild, smooth friction. There is no noticeable inertia.

The electronics of the wheel include an Arduino Mini micro-controller (which manages the wheel's input and output devices), a Bluetooth communication module, (which features an LED showing communication channel status), a lithium-ion battery and charging circuits. The micro-controller can be programmed by connecting the

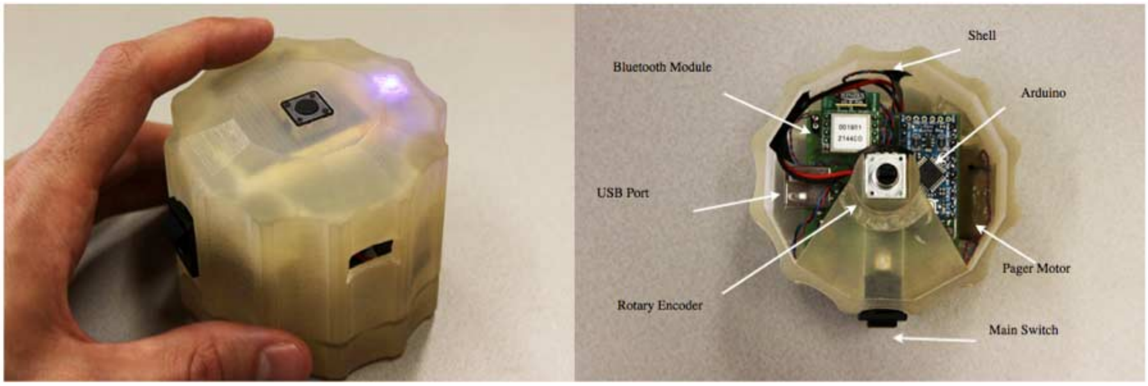

Figure 1. The Haptic Wheel in use (left) and plan view of internal mechanism (right)

wheel through a built in USB socket (which also serves to charge the battery). The wheel's software is written in the Arduino framework. Standalone programs can be uploaded or it can optionally be interfaced to a PC through its Bluetooth connection for more sophisticated applications. The cost for producing the prototype is approximately 150 USD, of which 100 USD is attributable to printing the casing and the remainder for the electronic components.

INTERACTIONS AND APPLICATIONS

Interaction with the Haptic Wheel is via rotational movements and button selections. All output takes the form of haptic sensations, either body-based proprioceptions derived from the actual act of turning the wheel or explicit tactile cues generated by the device and felt through its casing. Although its vibrotactile actuator is simple, it is capable of producing a range of discernible cues in the form of a set of tactons based on oscillating frequencies of motor activation: off, 2Hz, 4Hz, 16Hz and continuous. A short pilot study on these cues revealed that they can be perceived with an accuracy of 100% [1] and therefore can reliably indicate system states. The cues were also designed to possess a clear and discernible order from low to high frequency. Thus, ascent through the frequencies can be mapped to clockwise rotation of the wheel, while descent can be mapped to anti-clockwise movement. This mapping supports active and dynamic manipulation of the wheel.

The Haptic Wheel is aimed at a range of application areas. For example, it provides a rich mix of kinesthetic and tactile cues suitable for eyes-free interaction in visually demanding tasks such as driving. By providing dynamic physical cues in such tasks, it has the potential to reduce cognitive load and free up visual attention. A less safety critical eyes-free task is media control [e.g. 7]. However, the system is also suitable for tasks in which visually obfuscating or obscuring information is desirable. One such task is password entry [1]. In this system, users' passwords are encoded as sequences of tactons. By recognizing and selecting (via button click) each in turn, users are able to input a password eyes-free and with no possibility of visual observation (or shoulder surfing). Finally, as a hand-sized, wireless, standalone puck, the Haptic Wheel is also ideal for deployment as a tracked object or token on a tangible tabletop interface. In contrast to previous dial and wheel systems, it is low-power and mechanically simple, generating no directional forces (and thereby requiring no grounding to absorb the resultant inverse forces) while still able to present rich and digitally controlled haptic information that can complement the physical information inherent in a spatial arrangement of tokens on a tabletop.

CONCLUSIONS

This paper presented the Haptic Wheel and discussed the applications and interactions it supports. This simple, standalone and cost-effective system highlights the advantages of combining haptics with tangible interaction and suggests avenues for future research on this topic.

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