Pragmatic Haptics

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ABSTRACT
This paper explores situations in which interfaces may be improved or simplified by switching feedback modalities. Due to availability of and familiarity with audio/visual technologies, many interfaces provide feedback via audio/visual pathways when a haptic pathway would best serve. The authors present a series of interface designs in which simple and inexpensive choices allow for reduction of cognitive complexity by allowing mental simplicity rather than technological familiarity to dictate design of information transmission.

Author Keywords
Tangible interfaces, haptics, interaction design

ACM Classification Keywords
H.5.2 [Information Systems]: Information interfaces and presentation (H.5) (I.7)--User Interfaces (D.2.2, H.1.2. I. 3.6) Graphical User Interfaces (GUI); Haptic I/O

INTRODUCTION
At present, experience, available technology, and custom favor visual and audible interfaces. Given the comparative ease of implementing these interfaces, when does a haptic control make sense? Functionally, of course, touch feedback is appropriate when it simplifies a task for a user. These situations include those where the visual system is partially or fully divorced from the relevant point of action. This may mean that aspects of the interaction may be visibly obscure, or that the visual system is better devoted to goal-level rather than control-level aspects of a task. Consider crossing a street with a child. A grip on the hand is used to guide the child, but the eyes are elsewhere, looking for traffic. Pragmatically, touch feedback is most possible when easiest to implement. This comes down to a reduction in number and complexity of the mechanical actuators. For example, actuated handheld tools allow mechanisms to be centralized rather than distributed over the entirety of the target material. Furthermore, implementation can be simplified when motion is constrained. Picture the complex modifications required to allow a car to translate sideways as well as along its principal direction of motion. Finally, haptics are best employed when minimal actuation can have broad and great effect.

This work proposes an approach for developing haptic media through closing the interaction loop between haptic input and output. We will discuss how the immediacy and directness of touch can be applied to decrease cognitive load. Some of the designs we describe have been easily realized in prototypes using relatively cheap hardware. The paper begins with a brief background of related work, then discusses 3 haptic interface designs, and finally offers a set of general haptic design recommendations.

BACKGROUND AND MOTIVATION
Mark Weiser envisioned a future where computers are embedded within the user environment, hidden in surfaces and spaces [25]. The future is here. Weiser's predictions were accurate; computers are commonly integrated into our architecture, our clothes, and household appliances. He predicted that the problem with ubiquitous computing would be information overload. Indeed, computers are not just in the background, but the blinks and beeps of information are very much in the foreground of HCI [5].

A popular observation is that the visual and audio senses are overloaded [1, 3, 18]. Much work has proposed to leverage the richness of the haptics to interact with information [2, 10]. One approach to solve these problems has been to examine and expand the role of touch in interface design [9, 20, 22].

While audio and visual experience prototyping are well known in HCI [1, 6], there has been little research done for how to design and prototype pragmatic haptic applications. With the exception of designing haptic experiences in roller coaster amusement rides, haptics design research has generally occupied only a few consumer domains: researching the use of mobile vibration alerts [4, 15] combined with relatively narrow application of force feedback joysticks for gaming [26]. While most existing work consists of the application of haptics to new interfaces

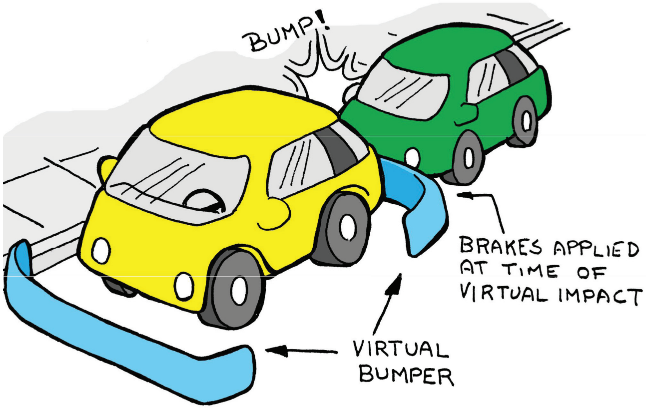

Figure 1. Bump N' Go projects tactile information about a virtual bumper.

[11, 17, 21], this paper focuses on the ample opportunity to employ haptics to simplify existing interactions [13].

There have been niches of interest in academic research. The information capabilities of the tactile channel have long been of interest to the psychophysics community [7, 12, 19, 22]. The industrial robotics community has already developed numerous solutions for representing haptic feedback and models of haptic rendering [10, 23], particularly for telesurgery and robotic manipulation tasks. The universal usability community has developed numerous tactile displays to empower deaf or blind users to use computer interfaces through sensory substitution [3, 14, 24]. The role of haptics has often bridged the art-science balance, by expressing touch through audio or visual means [8, 16], creating a secret language [6], or development of multimodal effects [21]. Social awareness and privacy issues resulted in the use of vibration alerts in mobile devices [18]. For the most part, however, the development of touch interfaces is hampered by practical issues of cost, power, and lack of standardization [23].

Design Case 1: Bump and Go

Parking (particularly parallel parking) a vehicle is a complex mental task. Primarily, the driver must be wary of pedestrians and other vehicles. The driver requires an understanding of the geometry of the situation, as well as a view of the surrounds, partially understood through the use of mirrors. He also needs a feeling for the car's dimensions, direction, and mobility, recognition of the parking space dimensions, as well as control of steering, acceleration, and braking.

Parking sensor systems ease some of these mental burdens. Ultrasonic or laser-based range sensors on either bumper convey clearance at either end of the vehicle via tone or dash-mounted camera. Such systems simplify some of the spatial and vision aspects of the problem by making obscured views of the situation otherwise available. Though frowned upon, many people cheat. Lazily, they pull forward until they bump something, and then repeat in reverse. Notice that this eases several cognitive and visual aspects of the task: understanding car dimensions, parking space dimensions, braking, view of surroundings and, if installed, attention to parking sensor indicators. They reduce complicated visual and control aspects of the problem to what is effectively a simple haptic message: BUMP.

Existing ranging devices coupled with near ubiquitous braking control systems can be used to pad a car with invisible bumpers (Figure 1). Rather than a visual or audible indicator, the system applies the brake when clearance in the direction of motion is limited. The driver can now lazily bump and go, focusing on arguably the most difficult aspect of the task, geometry. Finally, virtual bumper thickness can vary directly with vehicle speed. A very carefully moving vehicle can all but touch an adjacent vehicle.

Design Case 2: Toolpath

The cognitive effort of some tasks can be vastly reduced by changing the nature of the feedback path. For example, tracing an existing line on a flat sheet of paper requires mental focus and careful hand-eye coordination. The muscles of the hand must constantly readjust to maintain a position judged solely by the eye. Tracing a recessed line or ruler edge on that same piece of paper is a much less demanding task. In this case, the hand simply maintains a force that is the sum of two vectors-- one generally towards

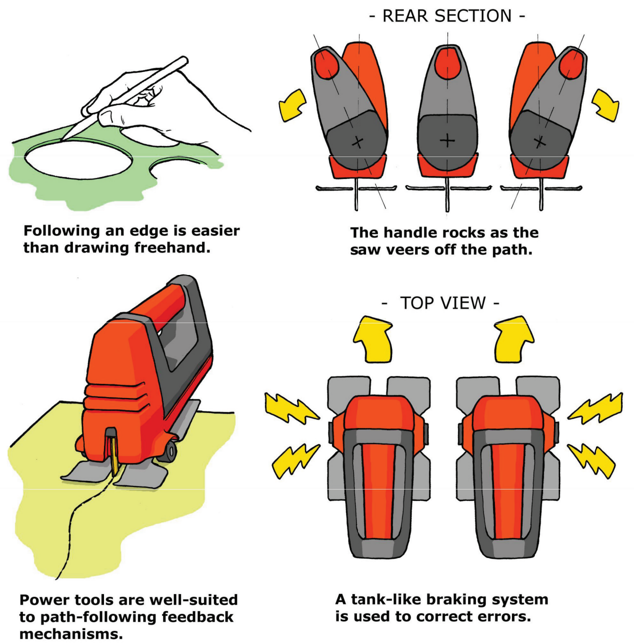

Figure 2. Toolpath allows a user to cut along a line as if it were a physical edge.

Figure 3. Formchaser translates the visual pixels into physical force feedback. The user feels contour directly on the screen.

the edge to be followed, and one generally parallel to the edge. The magnitude and direction of this exertion need not be very careful or accurate. This is now maintained largely by tactile feedback. The eye still participates, but less so on constant readjustment of position. It now looks ahead to anticipate larger upcoming changes in the template edge.

Thanks to photocopiers and printers, tracing an existing line with a pencil is not so common a task. However, handheld power tools are ubiquitous and cutting along a line on a surface is a very common task. Cutting templates exist, of course. Circular saws can make straight cuts along a fence, and router bits with bearings allow one to curve or otherwise mold an existing edge as they roll along it. Use of these templates improves accuracy and eases the hand-eye coordination effort. Care is still necessary. The vibration and forces involved in cutting can mask the resistance offered by the fence or edge, and visual effort is necessary to keep the tool to the path.

The effort involved in the above cuts and in following lines without guides may be alleviated by the use of a virtual template or edge. Power tools such as jigsaws can be modified to passively follow drawn or virtual lines on lumber. Clearly, hobby tools must not actively propel themselves along. For safety's sake, the operator must remain firmly in control. However, the tool can offer passive resistance in relative safety (Figure 2). Rubber wheels mounted on the baseplate can control direction by alternately braking. Control can be maintained by an optical line follower just ahead of the blade, or by a virtual positioning system. Furthermore, the tool body can rock slightly to the left or right, as a simple haptic indicator of turning direction. So, like a pencil alongside a French curve, a modified jigsaw can ease the mental load associated with cutting along a line.

Design Case 3: Formchaser

Formchaser is an inexpensive and simple device that gives pixels thickness (Figure 3). Essentially, it is a single point finger-held mechanism that raises and lowers the index fingertip in response to the intensity of the pixels immediately beneath that fingertip. For example, the user can effectively run their finger across an online contour map, sinking into dark-colored valleys and rising over light-colored peaks. Its resolution and response time are fine enough feel small text as a rough texture.

There are interactive aspects of the physical world that are more easily felt than seen. Textures are an obvious example. This device gives a quick form to digital texture, but it is also intended to perform the virtual equivalent of very focused tactile physical explorations. For example: sliding a fingernail to find the nigh invisible starting edge on a roll of tape, or carefully dragging the sharp edge of tweezers along the skin until one feels the tiny pull of a hidden splinter. The expectation is that this device will allow a user to paw through a very dense stream of data without the need for a visual zoom. The larger gestalt picture is preserved, but the user can still find the finer curious snags within the stream.

Finally, there is a simple yet satisfying temporal aspect to this device. Held steady, it can be used to feel the waves in a video of the sea, or ripples in a video river. Also, visualizations of music played within WinAmp take on a whole new dimension, literally [27].

CONCLUSIONS & RECOMMENDATIONS

The sense of touch can contribute much to enhance user interfaces. The examples presented herein illustrate a few principles to be followed when considering haptic feedback:

Be blunt! Both Toolpath and Bump and Go provide digitally defined task constraints. They allow the user to explore the nature of these constraints through blunt rather than delicately controlled movements. Consider the effort involved in clapping one's hands versus halting them one-half centimeter apart. The former requires a lot less dexterity and cognitive effort.

Free the eyes. When not dedicated to the control-level aspects of physical tasks, the eyes are freed to evaluate the situation-level aspects. This may include enhancing safety (seeing that a line to be cut is occluded by a cable, or that a pedestrian is approaching as you park), or simply appreciating the next step in the process (which way to turn next, or repositioning oneself to better accommodate an approaching curve). If an intensive visual task can become a clumsy haptic one, it should.

Constrain motion. Choose tasks and interfaces that offer inherent constraints on motion to limit the number of actuators involved. Controlling oriented motion along a curve is far simpler than controlling a device that is free to spin over a surface.

If it's easy, try it. Unlike the other designs, Formchaser is not a solution to a straightforward task. However, its simplicity and portability allow a simple visual to haptic transformation to be applied to any surface. The field is still young enough to benefit from this kind of mechanically simple exploration.

We have presented 3 haptic interface designs in order to describe the potential of haptics in user interfaces. We believe that these designs clarify circumstances under which haptic feedback is both appropriate and easily achieved.

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