RAPPORT DE RECHERCHE

L R I

BubbleWrap : DYNAMIC PASSIVE FEEDBACK FOR DISPLAYING AMBIENT INFORMATION

BAU O / PETREVSKI U / MACKAY W

Unité Mixte de Recherche 8623
CNRS-Université Paris Sud – LRI

11/2008

Rapport de Recherche N° 1506

CNRS – Université de Paris Sud
Centre d'Orsay
LABORATOIRE DE RECHERCHE EN INFORMATIQUE
Bâtiment 490
91405 ORSAY Cedex (France)

BubbleWrap: Dynamic Passive Feedback for Displaying Ambient Information

Olivier Bau
InSitu, INRIA Saclay & LRI
Building 490 Univ. Paris-Sud
91405 Orsay Cedex, France
bau@lri.fr

Uros Petrevski
ENSCI & NoDesign
12, passage Turquetil
75011 Paris, France
uros@nodesign.net

Wendy Mackay
InSitu, INRIA Saclay & LRI
Building 490 Univ. Paris-Sud
91405 Orsay Cedex, France
mackay@lri.fr

Abstract
Most haptic peripheral displays provide active feedback. We present *BubbleWrap*, which simulates different degrees of softness to display low notification levels as dynamic passive haptic feedback. When combined with active feedback, interface designers can easily control the level of notification to users. BubbleWrap consists of a matrix of electro-magnetic actuators, enclosed in fabric, with individually controllable cells that expand and contract. Our experiment showed that users can reliably discriminate among three softness levels, for both physical and BubbleWrap conditions. Haptic displays like BubbleWrap can help interaction designers to offer better control of attention management, from discrete and non-invasive to attention-grabbing alerts.

Keywords
Haptic Feedback, Ambient displays, Notification levels, Peripheral interfaces

ACM Classification Keywords
H5.2. User Interfaces : Input devices and strategies.

Introduction

Ambient displays take advantage of the human ability to process peripheral information while attending to another primary task (see Pousman et al. [7] for a taxonomy). A key issue for such information displays is attention management. For instance, Matthew et al. [5] provide a toolkit that helps designers manage different notification levels. The haptic channel combines tactile and kinesthetic information, offering an effective means of displaying peripheral information while keeping eyes and ears free for other tasks. For instance, Brown et al.'s Tactons [1] take advantage of haptic information to enhance the design of interfaces for mobile devices.

Figure 1:BubbleWrap prototype

However, most of these projects focus on *active* feedback. For example, when a mobile phone begins to vibrate in your pocket, you feel it and respond. This is less effective for low-level or gradually increasing feedback, because the human sense of touch is always 'on'. If, for example, we increase salience by gradually increasing the level of vibration, it would either be too annoying, or the user would habituate. Thus, active feedback alone cannot address the whole range of possible notification levels.

In the real world, the sense of touch acts as a powerful information pick-up channel. Texture provides *passive* haptic feedback through both the feel and consistency of the surface. This allows us to gain information about an object, such as when we gently squeeze a peach to judge its ripeness. We are interested in including *passive* as well as *active* haptic feedback to control the degree to which the system alerts the user, from subtly making information available to grabbing the user's attention.

We designed BubbleWrap, a textile-based haptic display that changes its consistency, simulating different degrees of softness or "squishiness". BubbleWrap consists of a matrix of electro-magnetic actuators, enclosed in a thin layer of fabric. We can control the expansion and contraction of each cell, allowing us to provide both active and passive haptic feedback. Ultimately, such fabrics could be used to cover objects, from mobile devices to furniture.

Related work

Shape-changing interfaces encode information by modifying the shape of the device. We are particularly interested in controlling the surface layer or texture. Pin-based displays use a matrix of elements that move up and down. Horev [3] describes how one might design a TactoPhone in which the back of the phone is a morphing surface for displaying animated tactile icons. His video prototype shows how it might be used to provide location information. Lumen [6] is a 2D low-resolution pin-based display that controls the height and color of individual 'pixels' using Shape Memory Alloy threads.

Hemmert et al. [2] designed Dynamic Knobs for mobile phones. The knob acts as both an input and an output device: it pops out whenever a new event occurs. In a video prototype, Horev [3] proposed a morphing cube that inflates according to the amount of data on a hard drive. In this vein, Kim et al. [4] designed the Inflatable Mouse to support pressure-based input for navigation. It displays simple animations by varying the inflation level and can be used to communicate an emotional state, e.g., heartbeats or to sound an alarm, e.g., by shrinking the mouse.

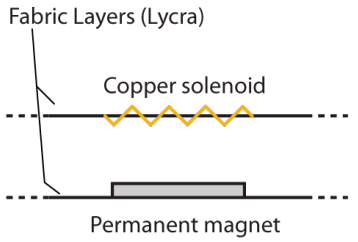

Figure 2:BubbleWrap actuators : permanent magnet + copper solenoid

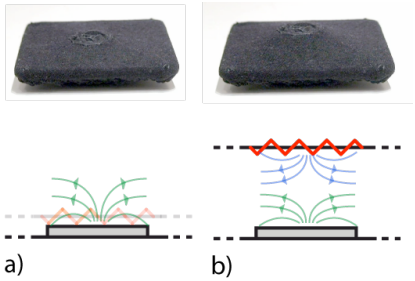

Figure 3:a) Magnetic field of a permanent magnet. b) Current flows through the coil, turning it in a magnet that is repulsed by the permanent magnet.

We are interested in using the same technology to control firmness as a way of providing passive feedback, together with vibration to provide active feedback. We seek a flexible material that can be wrapped around an object and placed next to the body, perhaps carried in a pocket or placed on the armrest of a chair. The above technologies are either too fragile, too big, or too difficult to manufacture in thin layers and we need to identify a different technology to accomplish our objectives.

Design

BubbleWrap is a textile-based haptic display that can be wrapped around existing devices or objects. The BubbleWrap prototype consists of a 4x4 matrix of extendable cells. We also created a single-cell version for evaluating whether users could easily identify changes in softness state.

Each actuator consists of a bottom layer of fabric on which is attached a 1.5x7x7 mm thin permanent Neodymium (NdFeB) magnet. A coil is sewed on the top layer (Fig. 2). Solenoid-based actuators are interesting because, in addition to their commonly used ability to vibrate, they also allow us to maintain stable states. Such actuators are easy to build, cheap, responsive and allow a good ratio of thickness to power. When at rest, the overall height of the fabric layer is approximately 5 mm.

We simulate hardness by expanding and contracting the fabric cells, using electromagnetic force. The height of each cell can be programmatically controlled by varying the flow of current passing through the coils. The neodymium magnet constantly generates a magnetic field (Fig. 3a). By controlling the amount of current flowing through the coil, we vary the force with which this electromagnet is repulsed by the permanent magnet (Fig. 3b). Since electromagnetic force resists the user's pressure, the height of an extended cell gives an impression of softness. When the height is zero, the direct resistance of BubbleWrap's backing gives the impression of hardness, relative to the expanded mode. The frequency of the inflation rate can be adjusted so as to provide either dynamic passive or active feedback.

To drive BubbleWrap's 4x4 matrix, we used an electronic board based on an Atmel atmega128 microcontroller. The prototype uses 12V at 1A. We used 16 digital outputs of the board to generate Pulse Width Modulations (PWM) signals that drive each actuator, via transistors. This type of output allows us to easily control the state change of the actuators, enabling us to display animations and vibratory patterns.

Experiment

We ran an experiment to measure the ability of users to perceive three different degrees of hardness, first with physical objects (in this case, foam) and then simulated with BubbleWrap. The results showed that users can quickly discriminate among three levels of softness (foam: 1.6sec, bubblewarp: 1.7sec). Participants were also accurate when distinguishing among those three levels (foam:97%, bubblewrap: 98%). Results suggest no significant differences between the two media in either time or error ($F(1,11) = 1.34$, $p=0.27$ and $F(1,11) = 1.12$, $p=0.31$, respectively).

Conclusion

Peripheral interfaces deal with information of different degrees of importance and haptic feedback offers an effective channel for displaying peripheral information. However, most peripheral haptic displays only support active feedback that grabs the user's attention as information becomes critical. They do not handle low-level information notification and thus only address a fraction of possible notification levels. We argue that dynamic passive feedback, when combined with active feedback, will allow designers to cover a wider range of notification levels.

We designed, implemented and tested BubbleWrap, a haptic display that provides dynamic passive feedback via softness control, and active feedback via vibrations. We evaluated the discriminability of three softness levels, both in physical objects (foam) and with BubbleWrap. The results showed that users can quickly and reliably discriminate among three levels of softness with no significant differences between the two media in either time or error.

Copper solenoids coupled with permanent magnets as actuators proved a useful and inexpensive solution for designing a fabric-based haptic display that could be wrapped around existing objects. Our future work will develop applications that explore interaction with augmented furniture.

This technology suffers from several drawbacks, especially for mobile applications: 1) temperature control is difficult, 2) electromagnetic field dissipation can affect other components if they are not well insulated, and 3) energy consumption limits its application. As an alternative, we plan to investigate electro-chemical solutions for changing texture shape and consistency. However, the encouraging results of the study suggest that texture properties like softness can be controlled programmatically.

References

[1] L. M. Brown, S. A. Brewster, and H. C. Purchase. Multi-dimensional tactons for non-visual information presentation in mobile devices. In Proc. of MobileHCI ’06, pp 231–238. ACM.

[2] F. Hemmert, G. Joost, A. Knorig, and R. Wettach. Dynamic knobs: shape change as a means of interaction on a mobile phone. In CHI’08 Extended Abstracts, pp 2309–2314. ACM.

[3] O. Horev. Talking to the hand - the interactive potential of shape-change behavior in objects and tangible interfaces. In DESFORM ’06 Workshop.

[4] S. Kim, H. Kim, B. Lee, T.-J. Nam, and W. Lee. Inflatable mouse: volume-adjustable mouse with airpressure-sensitive input and haptic feedback. In Proc. of CHI ’08, pp 211–224. ACM.

[5] T. Matthews, A. K. Dey, J. Mankoff, S. Carter, and T. Rattenbury. A toolkit for managing user attention in peripheral displays. In Proc. of UIST ’04, pp 247– 256. ACM.

[6] I. Poupyrev, T. Nashida, S. Maruyama, J. Rekimoto, and Y. Yamaji. Lumen: interactive visual and shape display for calm computing. In Proc of SIGGRAPH ’04, page 17. ACM.

[7] Z. Pousman and J. Stasko. A taxonomy of ambient information systems: four patterns of design. In Proc. of AVI ’06, pages 67–74. ACM, 2006.