Some Challenges of Designing Shape Changing Interfaces

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Abstract
In this paper we describe some challenges we find in the design of shape changing user interfaces through our own work and thoughts on the current state of the art in HCI. Due to the large set of possibilities for shape changing materials we are faced with a too-large constraint system. Without a good understanding and the beginning of a standardization or physical language for shape change it will be hard to design interactions that make sense beyond those in very limited, one-off applications. We are excited by the challenge that this poses to researchers and look forward to understanding how to use programmable and shape changing materials in the future.

Keywords
Shape change, transitive material, organic user interface, programmable matter, dynamic matter

ACM Classification Keywords
H.5.2 User Interfaces: Interaction Styles;

Introduction
Designing interfaces for materials that can radically change form is a new challenge in HCI. Although there has been a lot of work done to understand the physicality of objects and relationship between people

and interface components within the field of Tangible User Interfaces [4], much of this work has flourished within a constraints system of static physicality. The original concepts of phicons that some of the early TUI work was based on would have to be rethought should the material that phicons are made from be able to reconfigure itself under computational control.

To take this idea a step farther, it could be argued that all interaction is only possible due to constraints, and this is particularly true within HCI. Pixels can change to any color within their available color space, in order interact with them in a meaningful way researchers of early graphical user interfaces developed standardized widgets like the menu bar and icon system. The WIMP paradigm has been notable for its consistent widget set. These interaction objects are a set of constraints on the way that the pixels respond—the software GUI operating systems is a useful constraint set for pixels with almost infinite representational ability.

The emerging fields of transitive materials [2] and organic user interfaces [6] have taken up the issue of better understanding how to make interfaces with physical materials that can dynamically, and under computational control, change form. This is like the pixel problem above, except much larger—there are countless ways in which materials could change form in real space (as opposed to the 2D plane most pixels are confined to).

In this paper we will discuss our experience creating an interface that utilized passive, organic shape change and then conclude with more thoughts on the challenges posed by reconfigurable and shape changing materials in interface design.

SPEAKCUP

As an experiment in simplicity we created SpeakCup [figure 1], a digital voice recorder in the form of a soft silicone disk that relies on shape change as input. The design arose from our earlier investigations in reducing interface *BABL* (buttons and blinking lights) [1]. To record sound with SpeakCup the user deforms the disk into a cup, so that it can *hold* the sound. Pressing the cup inside out will then *release* the captured sound [figure 2]. Our contribution is a demonstration of using shape change as an interface strategy. We are interested in shape change as a way to privilege simplicity in interaction design and also as a means to incorporate physical metaphor or analogy into new devices.

Using shape change as an input to computational systems is nothing new, the mouse changes shape when you click it and so do keyboards. Shape change is the dominant form of human-machine interaction but in most cases the change in form and the action incurring the change are only loosely connected to the desired response. Hutchins, Hollan, and Norman described this as *the gulf of execution* [3], in other words it's the gap between a user's goals for action and the means to execute those goals. Interfaces (by definition and observation) get in between users and their goals. Weiser's vision of *calm computing* [7] has been a serious challenge—it is not easy to make functional interfaces disappear!

One way to create invisible interfaces is to design devices that function like the real, un-digital world [5]. But in some cases the un-digital world is not as versatile as the digital world, so how do we go about providing valuable expressive power and reducing the

gulf of execution at the same time? There are some answers for this question in Ishii and Ullmer's *tangible bits* [4] as well as in [5]. In this paper we describe a small exploration in the use of shape and metaphor to address these questions.

We first imagined SpeakCup during a design exercise in which we challenged ourselves to create interfaces with minimal feature sets without relying on abstract buttons or blinking lights [1].

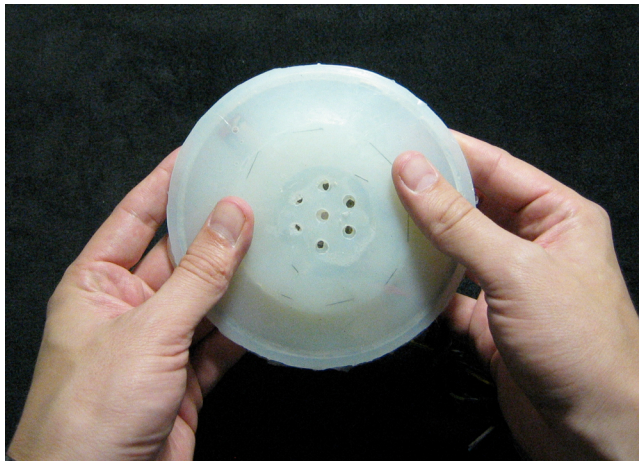

Figure 1. SpeakCup

Implementation

SpeakCup's body is made from a six-inch disk of platinum cure silicone rubber. A ring of aluminum is embedded inside the outer rim of the disk so that it stays round when deformed. A combination microphone/speaker is embedded in the center of the disk. Red and green LEDs are wired around the perimeter of the microphone/speaker. Two flex sensors that change resistance when bent span the diameter of the disk embedded in the silicone and facing in opposite directions to sense deformations on either side. SpeakCup is wired to a protoboard where the electronics and batteries that power it are located. We used a cheap RadioShack voice recorder module with 20 seconds of memory to store and playback sound. We rewired this module's buttons, running them through analog electronics to connect the flex sensors and drive the LEDs.

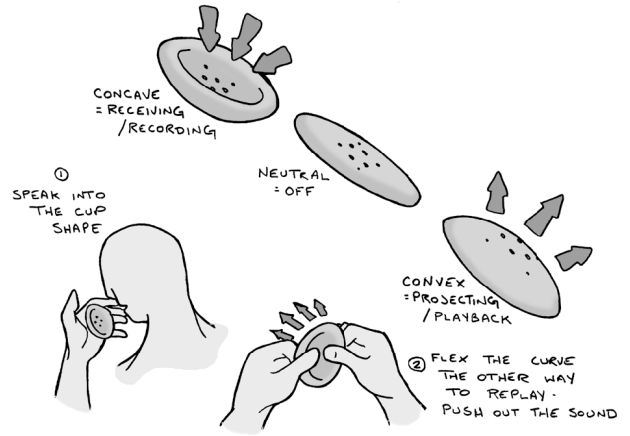

Figure 2. SpeakCup interaction design

Interaction Design

We rely on metaphor to inform the use of SpeakCup. Sound is imagined to be a physical substance that can be *contained* and *absorbed* into the medium of a malleable disk. The disk has seven holes on one side, deforming SpeakCup so that these holes become the bottom of a cup triggers the sound recording. Once in

cup form, red LEDs pulse within SpeakCup's body[1]. The LEDs get brighter as the user's voice gets louder, mirroring the amplitude of recorded sound.

When the user removes pressure from SpeakCup's center it springs back to disk form. To playback the recorded sound the user then presses in the opposite direction, pushing the holes out to release the stored sound. During playback the brightness of the green LEDs portray the amplitude of the sound.

Conclusion

SpeakCup is an example of a very simple interaction design that uses passive shape change in a physical object to convey meaning. Imagine using a similar design theme with active, reconfigurable materials and implementing all of the functions found in audio editing software but in physical form. How would you do it? One could image using some analog of a GUI but have it displayed on the object itself, though this approach would seem to be quite a crutch and does not take advantage of new material properties.

It seems that we do not yet know how to scale up complex interactions with dynamic physical materials. To understand how to do this will be a major challenge over the next few decades of human-computer interaction research.

[1] Although during the design exercise we initially conceived of SpeakCup without LED feedback we added this feature during implementation because it provided clear feedback for the user.

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