Design of Spatially Aware Graspable Displays

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ABSTRACT
We propose spatially aware portable displays which use movement in real physical space to control navigation in the digital information space within. This paper describes two interface design studies which use physical models, such as friction and gravity, in relating the movement of the display to the movement of information on the display surface. In combining input and output aspects of the interface into a single object, we can improve control and provide a meaningful relationship between the interface and the body of the user.

Keywords
interaction design, industrial design, 3D interfaces, LEGO

INTRODUCTION
Imagine holding a newspaper. You move the paper up and down, closer and further from your eyes, and manipulate the pages as you read your way through it. Or, instead of many folded pages, consider a long continuous painting mounted on a scroll. You lay the scroll on the floor, rolling it open on one side and picking up slack on the other. Your own body and the physical qualities of the paper medium determine how the information is designed and how you find your way through it.

In designing digital analogs to these experiences, we examine the boundary between the real world and a virtual world created by the computer. Any display creates an internal visible logic in the way the user controls the movement of information in the space within its surface. By connecting aspects of the virtual world to real world objects, we allow the user to literally feel his way through the computer generated world. The objects which inhabit our working spaces should be legible in their function, provide clear feedback to the user and be flexible in their application.

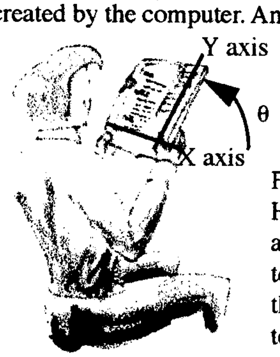


Figure 1. The virtual newspaper. Here the user is tilting the display about the X axis causing the text to slide down. The steeper the tilt the faster the movement of the text.

These two designs, a scroll painting and a portable newspaper, erase as much as possible the division between input (control) and output (feedback). The display itself is aware of its location in space and relative to the users body. The graphics can appear to slide beneath the display as it rolls back and forth, or be pulled across its surface by gravity as the display is tilted.

In traditional computer interfaces the graphics display is separate from the input devices. The user manipulates objects out on the desk and views the resulting changes on a display surface which has no clear relation to the work space itself. This means that there is always a feeling of disconnect between what the hand does and what the eye sees.

Although head mounted displays or immersive systems provide a well integrated experience, the user cannot perform tasks in the virtual space while engaging in activities in the real world. Our approach is similar to systems such as Fitzmaurice[1], in which a palmtop display reveals virtual information associated with real objects in space. His system used gross location to bring relevant information to the display. Our system provides more refined gestures, such as tilt, to let people browse a large information space.

The Scroll of Frolicking Animals (Chojugiga)
The Chojugiga[2], which dates beck to 12th century Japan, is a narrative painting in the form of a scroll. Scrolls have the property of being both continuous and linear and so impose interesting constraints on the manner in which information is revealed. Two different designs were considered.

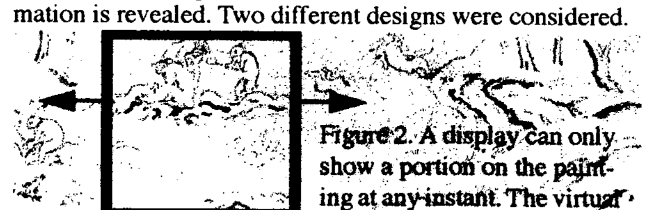
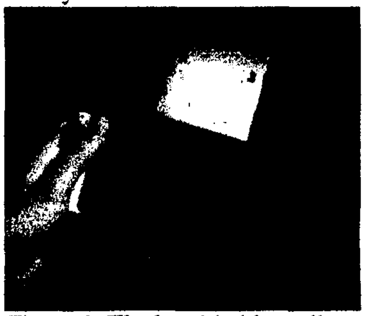


Figure 2. A display can only show a portion on the painting at any instant. The virtual frame can slide back and forth along the painting to reveal different sections.

In the first, the display was placed on a platform between two cylinders which rotated in tandem [Figure 3].



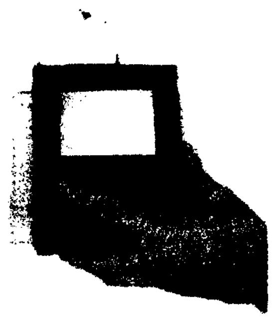


Figure 3. The hand-held scroll above is controlled by two cylinders. To the right, the display platform itself is rolled back and forth on the floor.

To use this virtual scroll, the user holds the display in both hands, rotating the cylinders with her thumbs. The image of the scroll on the display moves with the turning of the cylinders. The virtual scroll seems to unroll from one side and roll up on the other. The user has fine control over the movement of the painting, and like the actual scroll, must work through the entire painting in sequence.

In the second design, the cylinders are removed and wheels are added to the display platform. The assembly is placed on the floor and rolled back and forth. To move the painting forward one foot, the display has to roll one foot. The image appears to be held by friction to the floor as the display slides back and forth above it. This has the benefit of impressing on the user, in a physical way, the unusual length of the painting. To view the entire scroll, one has to roll the display eight feet along the floor. This design was very engaging for the user and we have had many sponsors get down on the floor and report a positive experience.

Hand Held Newspaper

While respecting the physicality of the scroll was important, many applications neither require, nor benefit from such a literal interpretation. In the newspaper study, a mock-up of a news reading device was modeled in balsa wood and acrylic [Figure 4]. It contains a portrait display, a single thumb button and a storage area for news stories that have been "downloaded" into LEGO bricks. Users navigate the paper by engaging the thumb button, which acts like a clutch, and moving the display relative to their own body. Several different motions are recognized. Tilting the paper up and down scrolls the text vertically, tilting left and right moves the text horizontally, and pushing the whole display away from or close to the body zooms the text in and out.

We studied several functions which related the tilt of the display to the movement of the text. When the display is tilted around the X axis, "gravity" pulls the text up or down across the display. This was seen as the primary motion in normal use as it corresponds to reading down a vertical column of text. Several equations, such as:

$$\text{velocity} = \theta,$$

$$\text{acceleration} = \theta,$$

$$\text{velocity} = \theta^2, \text{ and}$$

$$\text{velocity} = \theta^3$$

were tried. The last equation proved to be the most effective, because it allowed the user to hold the text still at any given point, scroll very slowly one line at a time with a small tilt and still be able to scan past many stories in a second with a greater angle of tilt. Even this rather complex mapping is simple for users and requires no specific explanation. In a short period of use, the user can browse and read easily without much conscious thought about navigation.

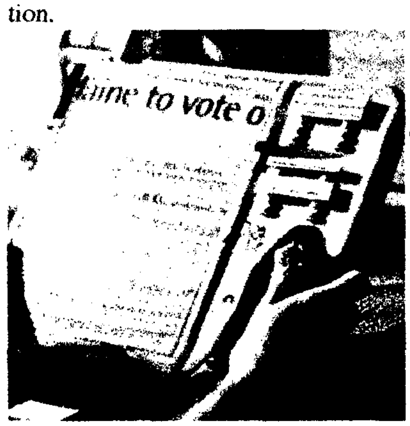


Figure 4. Newspaper design prototype. The user engages the clutch with his right thumb and moves the display about in space to navigate around news stories.

In addition to scrolling up and down one newspaper column, the user can slide the text left and right to move to parallel columns of related news stories. Pushing the paper away from the body results in a smooth zoom out, giving the reader and overview of many news stories. The headlines becomes more visually prominent and the body of the news story becomes lighter to show general massings of text. By pulling the display close in to the body, the user can zoom back into a particular story.

CONCLUSION

People are used to holding books, newspapers and even scrolls in their hands and moving them about. These physical objects are powerful interface objects that are legible in their purpose and use. By using a spatially aware display we can give meaningful form to the space which resides on the other side of the screen. When the user's hands and body are engaged in an appropriately physical manner, we can bring the user closer to the virtual world contained in the computer. The virtual information on the display appears to be held directly in the hands of the user. We have demonstrated in a limited way the utility of engaging the users hands and body in their interaction with information.

REFERENCES

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