TouchMark: Flexible Document Navigation and Bookmarking Techniques for E-Book Readers

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ABSTRACT

We present TouchMark, a set of page navigation techniques that preserve some of the physical affordances of paper books. TouchMark introduces physical tabs, one on each side of the display, to enable gestures such as page thumbing and bookmarking. TouchMark can be implemented on a variety of electronic devices, including tablet computers and laptops, by augmenting standard hardware with inexpensive sensors.

KEYWORDS: Document navigation, page revisitation, bookmarks, flexible displays.

INDEX TERMS: H5.2 [User Interfaces]: Interaction styles.

1 INTRODUCTION

With the advent of the Amazon Kindle [11], electronic book readers have recently emerged as a serious competitor to paper books. The success of e-book readers is, at least in part, attributable to the way in which their displays mimic a paper reading experience. However, when compared to paper books, most e-book readers leave a lot to be desired with regard to navigability. For example, placing and locating bookmarks on the Kindle requires users to navigate through a set of menus using a 4-way button controller. This process does not mimic common page navigation techniques used in real paper documents. According to O'Hara and Sellen [13], one of the reasons why navigation is superior in physical documents is because the physical interactions allow users to build up incidental knowledge of the location of information within documents. Paper navigation involves the physical handling of the information through flexing and turning of pages, which is not possible with the current generation of rigid E-Ink displays. With the dawn of flexible display technologies such as Flexible E-Ink, and Flexible Organic Light Emitting Diodes (FOLEDs) [6], opportunities are emerging to improve some navigational shortcomings by adopting physical affordances of the gestures deployed in flexing real paper documents. Although there has been considerable research in the adoption of physical interaction in e-book readers [4, 9, 14, 15, 17, 18], it has so far proven difficult to demonstrate the efficiency of these techniques empirically, as compared to traditional techniques such as scrolling and menu navigation. Part of the reason for this is that there are some inefficiencies in the way physical paper is handled. For example, a physical page turn is very slow compared to a simple refresh of a page on an electronic screen. Our approach is to mimic the look and feel of flexible document navigation without attempting to copy the inefficiencies inherent with physical handling of paper.

In this paper, we discuss a specific set of navigational flexing techniques, mostly focused at bookmarking. Bookmarks ease navigation between previously visited pages. According to Alexander et al. [1], an average of 10 bookmarks cover approximately 80% of document location revisitations. In the TouchMark design, we limited the number of bookmarks that can be deployed, and provided a single physical means to access bookmarks. TouchMark supports the use of physical gestures such as *thumbing* to navigate to the previous or next page, and *fingering* to place and retrieve bookmarks in a document (see Fig. 1). It does this through two flexing touch sensors, or *tabs*, that are attached on the side of the display and that mimic the feeling of a previous or next page. The left tab provides access to the previous page when touched from above and to the previous bookmark when touched from below. The right tab mirrors this behavior for forward navigation.

2 RELATED WORK

2.1 Electronic Book Readers

Wilson and Landoni [18] compared the navigational feature set of four electronic book reader applications. In their recommendations, they indicated that bookmarks should be simple to achieve, and should adhere to the paper book metaphor. According to their study, careful design of button and dial placement for page navigation improves performance in such tasks. In their evaluations, users of devices that employed dials commented that they felt they could read faster. Simple "page forward/page back" buttons were also considered intuitive, but button size mattered. It appears this is one of the ways in which the Amazon Kindle may be considered to fall short: its page turning buttons are placed on the side of the screen. Their width, and thus their Fitts' Law target size, are minimized so as not to consume valuable screen real estate, making acquiring and pressing these buttons with the thumbs a less than lightweight action. Marshall et al. [12] observed that most paper document navigation interactions are lightweight.

Harrison et al. [9] describe a user interface for a document navigation task that features a similar approach to page thumbing as TouchMark. Their interface detected flicking movements by fingers through pressure sensors deployed on the top left and right corners of the display. After a flick was detected, the document was moved to the previous or next page,

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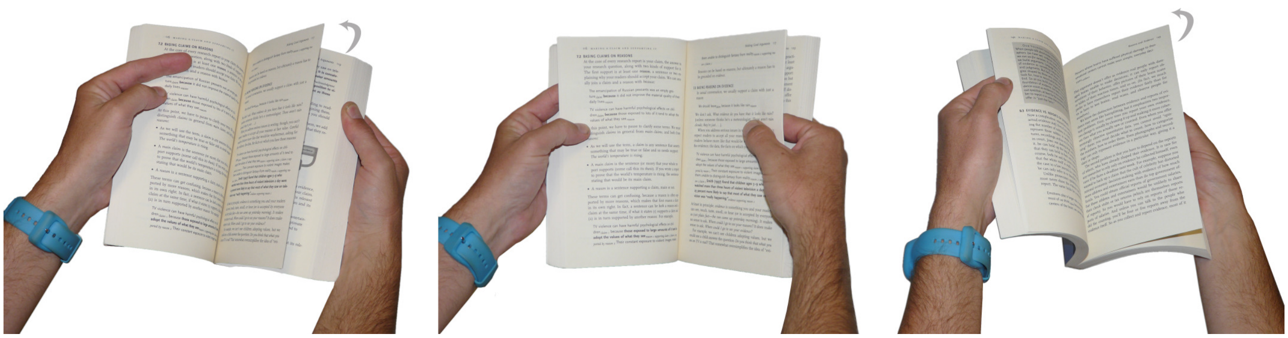

Figure 1. Common physical navigation behaviors: Thumbing to the next page, bookmarking a page with the fingers, and moving back and forth between two fingered bookmarks.

depending on the direction and location. While this technique simulated the kind of movement used when flicking a physical page with the finger, it is not necessarily the most efficient technique for paging through a document. The reason for this is two-fold: Firstly, the movement required in completing the gesture takes more time than the theoretically most efficient technique, an in-place tap. Second, the pressure sensors they used required a certain amount of force to be deployed, which led to friction. Consequently, users reported this technique was not as lightweight as flicking through paper pages.

Chen et al. [4] discuss their use of flipping and fanning navigational techniques for electronic book readers. In their system, two small displays are joined together through a hinge, providing some of the physical affordances of a paper book. Their interface mimicked the turning of physical pages.

However, the reason why physical page turning is elegant as a navigational interface is that real paper is extremely lightweight. Their techniques required the entire display to be folded, thus requiring gross motor movements. The authors indicated that they might have borrowed "too literally" from book interactions, particularly given the size and weight of their device.

One of the few projects to propose actual physical deformation of the display as a navigational technique was Gummi by Schwesig et al. [14,15]. Gummi is a flexible display mockup in which bending of the display was used for zooming in and out of information displayed on the screen. The interface was implemented using a rigid form factor display and a flexible sheet of acrylic augmented with two pressure sensors. Authors did not report on use of this interface for page navigation.

In PaperWindows [10], Holman et al. simulated the use of flexible display surfaces for page navigation by augmenting real paper with projected images. This was accomplished by tracking the shape and location of paper documents using computer vision. Pages could be navigated by folding over a paper sheet. This action required gross motor activity, reducing its efficiency.

Similar in nature, Watanabe et al. [17] discusses Bookisheet, a set of flexible input devices made out of sheets of thin acrylic augmented with bend sensors. Bookisheet could simulate the turn of pages through bends. Bookisheet changes between discrete jumping and continuous scrolling modes based upon the degree of bend between the two pages that compose the device. Bookisheet also features "finger-bookmarking" which provides temporary bookmarking while a sensor is pressed.

2.2 Navigation Techniques

While they may be more elegant, it appears difficult for physical navigation techniques to improve upon the efficiency of some of the highly refined techniques deployed for navigating documents in traditional Graphical User Interfaces. As per our review, when designing physical navigation interfaces, there are two important caveats that may stand in the way of developing a highly efficient technique. Firstly, it is important to literally keep the physical interaction lightweight, avoiding any strain placed on the fingers through friction or mass. Secondly, for efficiency, it is important to avoid the large movements often observed in traditional navigation of paper documents.

This is because GUI techniques, such as Footprints [1], require no physical motion of the display, and deploy highly optimized inputs for hand movements. Footprints built upon traditional scrolling interfaces by automatically creating document location markers whenever a user pauses at a particular location in a document for more than two seconds. The left and right arrow keys allowed users to traverse backwards and forwards through these markers in the order in which they were most recently visited. This is a highly efficient method as long as the fingers are kept on the keys.

Space-Filling Thumbnails (SFT) [3] is a highly efficient document navigation system. It allowed the user to switch between two display modes. The first mode is a thumbnail view of all of the pages of the document, arranged left to right and top to bottom on a single screen. A particular page can be selected for viewing by clicking on it with a mouse. The second mode is a detailed view of a single page. In this mode, a page is resized to take up the entire viewing area so that the text is best readable. Cockburn et al. [3] demonstrated that SFT was faster in all page visitation tasks and was also strongly preferred by users relative to six scrolling techniques, including: scrollbars, Thumbnail-Enhanced Scrollbars, Rate-based scrolling, Speed-Dependent Automatic Zooming, RSVP-based Flipping, and Multi-Page Flipping.

3 TouchMark

The TouchMark document navigation interface was developed to address the need for "quicker, more effortless navigation techniques" [13]. Our design process was initially informed by an informal observational study of students reading paper copies of journal articles in a library. We observed that students would often use thumbing behaviors to find a particular page. Another behavior we frequently observed was that page revisitation was often accomplished by placing fingers in between pages and then flipping back and forth between these locations. These observations are consistent with prior work [9,16]. In a document location revisitation study, Alexander et al. [1] found that 31.5% of the documents opened in Microsoft Word

Figure 2. HP Touchsmart with two TouchMark tabs.

included intentional location revisitation, but that current revisitation tools were rarely used. We decided to focus on designing a physical navigation technique that people would want to use and that would reduce navigation time while preserving physical affordances of fingering pages. Harrison et al. [9] found thumbing in place to be an intuitive method for page up and page down navigation. Its appeal is explained by Zhai and Kristensson [19]: in-place tapping of a button is theoretically the most efficient technique for selection, if the target of that selection is already known. We wanted to take advantage of this finding by designing a tab interface that minimized the physical movement required to navigate documents.

3.1 Bendable Touch Tabs

TouchMark consists of a regular HP Touchsmart tx2 Tablet PC augmented with two physical touch sensors, or *tabs*, which are used for page thumbing and bookmarking actions. Figure 2 shows the two TouchMark tabs on the Tablet PC, one on each side of its display. The tabs were placed at the approximate average location of the index finger when the tablet PC is held in portrait mode. Tabbed touch sensors differ from those in Harrison's embodied interfaces [9] in that they are floppy, lightweight, and require minimal pressure or apparent movement to actuate, mimicking physical affordances of paper pages.

Bendable tabs mimic gestures for flipping pages within paper books and page bends on flexible displays. Bending does not require an additional button, and is easily distinguished from touching, reducing false positives.

Five main objectives in our design of these tabs were:

a) To keep them lightweight, so as not to require any effort in bending the tabs;
b) To locate them at an appropriate position for the fingers to interact with them in place;
c) To allow for minimal movement by the finger;
d) To apply knowledge about the use of physical page thumbing;
e) To design for minimal mental effort.

The initial TouchMark design included tabs for each of a user's ten fingers. Each finger, except for the thumb, could then be used to place a bookmark. We also experimented with a clutch button to allow buttons to be released without changing the

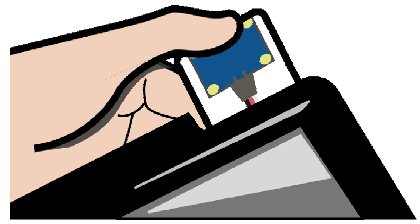

Figure 3. Thumbing the left TouchMark tab to page back.

Figure 4. Inserting a bookmark by squeezing the tab.

Figure 5. Navigating one bookmark back in the document by touching, then releasing the back of the left tab.

document location. We conducted an informal user study and focus group with graduate students to test these initial design iterations, and observed that users found the clutch to be "too complex". We also observed that most users used only index finders to place bookmarks. As a result of this, we simplified the design to two tabs.

3.2 Interaction Techniques

The tabs were implemented using a Phidgets capacitive touch sensor attached on the side of the screen using a flexible rubber hinge. The Phidgets control software communicates with the TouchMark application software to control paging and bookmarking behavior through simulated key presses. There are two sides to each tab, one facing up (front face) and one facing down (back face). Each face is touch sensitive. Although flexing the tabs is not sensed, per se, there is a strong affordance of flexing that yields touching and releasing gestures when thumbing through paper pages (see Fig. 2).

3.2.1 Page Up and Page Down

Figure 3 shows the page up action, which consists of touching, then releasing, the front left face. As with paper documents, this causes a move back one page. Touching then releasing the front right face causes a page down action in the document.

3.2.2 Bookmark Navigation

Figure 4 shows how bookmarks are placed by squeezing a tab. Squeezing consists of simultaneously pressing, then releasing, both front and back faces of either the left or the right tab. Our intention was to select a time threshold that would prevent user error when users would not touch front and back face perfectly simultaneously. We determined through trial and error that an optimal value for this filter was 250 milliseconds. Once a bookmark is placed it exists until the document is closed. After a bookmark is placed, the release of the front button does not cause a page up or down navigation to occur. This prevents the user from navigating away from the current position every time a bookmark is placed.

Figure 5 shows how the back left and right faces of the tabs can be used to navigate between the bookmarks. The back left face navigates to the closest bookmark towards the beginning of the document, from the current position in the document. If no bookmark meets these criteria, no navigation occurs. The back right face navigates to the closest bookmark towards the end of the document. These bookmark navigation interactions are intentionally similar to the page up and page down interactions, and serve to mimic the kind of fingering techniques observed when flipping between bookmarks when comparing between pages in real paper documents. Page-by-page or bookmark-by-bookmark navigation forwards or backwards within the document can be accomplished alternating between the left and right front or back faces, respectively.

3.2.3 Rapid Page Comparison

With TouchMark bookmark navigation, the time that is required to traverse any given number of bookmarks increases linearly with the number of bookmarks. We designed a special interaction technique to avoid users having to skip through many bookmarks when comparing between distant pages. If the back face of either tab is pressed while navigating a document, when it is released, TouchMark will navigate the document back to the page that was visible when this back face was first pressed. This page does not need to have been bookmarked. This was done to mimic navigation of physical paper documents by placing fingers between the pages. This interaction does not create a bookmark, and is available to allow for a lightweight visual comparison between pages.

3.3 Bookmark Visualization

In TouchMark, bookmarks are visualized as thumbnails on a vertical bar that is displayed beside the scrollbar. The positions for the bookmarks on this vertical bar are uniformly spaced so that there is horizontal alignment between the scrollbar and the bookmark thumbnail associated with the visible page. The height and width of the bookmark thumbnails was selected to preserve the relative dimensions of the document page image from which the thumbnail was produced, while providing a reasonable sized target for a user to select.

Bookmark thumbnails appear as resized images of the document pages to which they refer, except when on display, in which case they appear in black.

4 Discussion and Conclusions

We presented the design of TouchMark, a flexible bookmarking and page navigation interface designed for future e-book readers based on flexible e-ink screens. TouchMark features tabs on either side of the device that are used for document navigation and bookmarking. We believe TouchMark may be an efficient method for bookmark selection and navigating short distances within documents. In future work, we will evaluate TouchMark as presented in this paper. We also plan to design a new version of TouchMark that includes a flexible display.

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