Studying Paper Use to Inform the Design of Personal and Portable Technology

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CHI 2008, April 5 – April 10, 2008, Florence, Italy
ACM 978-1-60558-012-8/08/04.

Abstract
This paper introduces design guidelines for new technology that leverage our understanding of traditional interactions with bound paper in the form of books and notebooks. Existing, physical interactions with books have evolved over hundreds of years, providing a rich history that we can use to inform our design of new computing technologies. In this paper, we initially survey existing paper technology and summarize previous historical and anthropological analyses of people's interactions with bound paper. We then present our development of three design principles for personal and portable technologies based on these analyses. For each design guideline, we describe a design scenario illustrating these principles in action.

Keywords
Tangible User Interfaces

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces.

Figure 1: People can use a variety of tools and techniques to mark pages of a notebook.

Introduction: Why Paper?

Bound pages – books, notebooks and sketchbooks – are arguably one of the most important social artifacts created by humans. Although many researchers, novelists and journalists predicted the eventual disappearance of paper throughout the last half century [7], not only has paper remained in use [11], it often bears more legal weight than its digital counterpart. Some of our most critical ventures, such as voting and banking, require paper records to maintain accountability and security. The implication is clear: the physicality of paper is important [7, 8, 11]. But how can we learn from its form, physical interaction, and use?

Our nuanced physical interactions with bound books have evolved over hundreds of years, providing a rich historical background that we can learn from and apply to new computing technologies. Sellen and Harper note that "one can treat [paper's] use as an indication or a way of learning about how things might be done differently and, in particular, how technology might be better designed" [7]. Observations and analysis of our interactions with paper sketchbooks, notebooks and bound books can help us identify elements of paper that we can apply to the design of new interaction techniques.

Paper-Based Technology

Researchers in human computer interaction and ubiquitous computing have investigated how books can be augmented to address additional needs and social functions. Augmented notebooks have largely relied on additional physical interfaces or external devices that enable interactions traditionally foreign to our behavior with books. For example, Stifelman's augmented audio notebook required note takers to interact with input pads (i.e. touch sensitive pads installed along the note book's y-axis) to interact with captured audio [9]. Other audio notebooks have added audio capabilities requiring an external device for input as well as output [6, 12]. These tools focus on providing a new tangible, visual input and output for triggering audio information but do not take advantage of the physical form of paper itself. ButterflyNet [13], a system for field biologists, provides a tangible method for integrating both digital and paper-based information. Although the tactility of paper plays a role in the design of ButterflyNet — paper is the medium of the interface — the physical traces people leave with their hands on the paper pages are still largely unexplored.

Historical Analysis of Paper

In order to understand how, when and why we use books, historians and anthropologists have long studied the physical attributes of books, including their material form, their environmental setting and the physical context of their use (e.g., a person's physical position while reading or writing) [2, 3]. By studying people's techniques for marking books, researchers have investigated how particular passages have influenced the absorption of their content and sparked innovation [6]. Hiroshi Ishii has described physical paper as leaving behind "vestiges of [one's] physical presence," adding emotive and affective value to the paper's built-in informational value [5].

Many interactions with bound pages are possible depending on their form and function. Interactions

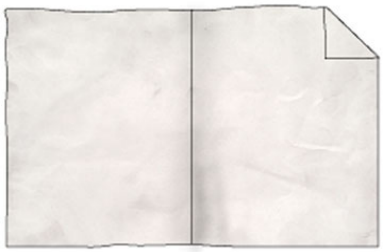

Figure 2: Folding the corner of a page can mark the page, its content, and its context.

Figure 3: A malleable countertop allows the chef to create surface crevasses to hold each cooking ingredient.

are performed (or not) depending on the physical constraints of the paper as well as an individual's practices and values. Traditional manipulations of bound pages include: dog-earing and folding pages, underlining or highlighting passages or areas of pages, mark making, note taking, sketching, book-marking, and tabbing. Such interactions may be achieved through implicit or explicit means: a person may consciously dog-ear a page to keep his or her place or mistakenly dog-ear a page and implicitly find the page later on.

Historian Lorraine Daston believes we should analyze diverse aspects of books in order to understand how scientific ideas have been formed. She describes studying differences in various book editions, their print runs, format, distribution, and hints of reading implied by folding, ripping, and annotation in margins [3].

By studying our physical interactions with bound books, human-computer interaction researchers can apply an understanding of existing interactions to the design of new personal and portable tools that support existing social and information processes. Here we discuss three physical traits of bound pages, design principles informed by our interactions with such traits, and preliminary design concepts based on these principles. We chose to focus on technology for the domestic environment because of its cultural richness, and broad applicability to portable technology design. By understanding the complex consequences of, and motivations behind, our interactions with traditional bound paper we can inspire future designs of personal, portable technology.

Dog-Earing and Folding

Observation

'Dog-earing' is the physical gesture of folding down (or up) the corner of a page in a book. The practice was invented by those who use books (rather than those create them) and serves a variety of practical and social functions. We creatively fold pages in our books to mark our place, keep track of ideas [2], or even point to a particular word [4]. Some users will not only crease, but permanently damage the paper itself: noted biologist Charles Darwin ripped pages in his notebooks to use as markers [3].

Myriad functions are performed through folding pages of books. The ability to flexibly associate form with function is a rare characteristic of physical material. Unlike paper, digital note-taking applications (e.g., blogs or word processing software) limit our ability to spatially manipulate information. These folding interactions apply to the whole page but can be ambiguous since users must create their own taxonomy of meanings for different folds.

What enables us to create these connections? Just as folding over the corner of a page changes its thickness, stiffness and form, it also allows us to find that page more easily. By altering the form, texture and weight of materials, people can perform multiple actions, some less conscious than others. Changing material properties of objects can take advantage of our tactile memory, or subtly draw attention to an object, helping people find information more easily.

First Design Principle: provide ways for users to temporarily alter the physical medium of an interface.

Figure 4: A book jacket's surface protects the internal pages while making external information public.

Figure 5: A device jacket can present personal information while protecting the device from nicks and scratches.

Design Scenario: Malleable Countertops
Concept: The counters in a kitchen are mutable surfaces: the chef can temporarily change the topology of cooking surfaces, adjusting their function and form.

A man begins chopping vegetables on his kitchen counter in preparation for a multi-course meal with friends. As each ingredient requires a different amount of time to cook, he keeps the vegetables in small, separate piles on his kitchen counter. To activate the malleability of his countertop surface, he pushes on the counter's edge and triggers its flat, fixed surface to become a flexible form. The man presses down on the countertop beside a pile of mushrooms and creates a small, bowl-like crevasse. He slides the pile of mushrooms into the bowl-like form. He proceeds to do the same for the remaining vegetables, using the counter's surface as an implicit container for each ingredient. As his guests arrive, the man increasingly plays with his preparation techniques, transforming his cooking process into a performance of function and form. By scooping the vegetables with his hands, he turns the countertop crevasses into slide-like forms and easily transfers vegetables from the countertop to the frying pan. Once finished, he pushes the counter's edge, and returns the surface to its original, fixed state. Using the countertop surface, he alters his cooking environment to fit his culinary and creative desires.

Dust Jackets

Observation
Dust Jackets, traditionally made of cloth or paper, are covers intended to protect books. Most often removable, dust jackets attach to a book using two flaps folded around a book's outer most pages. Jackets are often illustrated or typeset with information about the book's contents, author(s) or its reader(s).
A book's dust jacket serves both practical and social functions: it protects our bound material from dust, dirt, rips and scratches while hiding the content of our bound material from our neighbors. Moreover, our use of dust jackets may undermine its protective purpose: some people shield precious jackets with additional plastic covers.

Whereas the content written on bound pages is viewed by the person reading or writing on them, the book itself is a social artifact, concurrently presenting itself to other people in its environment. As one person reads a book, another person nearby may glance at the book and determine from its spine or dust jacket what type of book it is, what the title is, who the author is, whether or not it is well-reviewed, and even (for locked journals) that the book is not meant to be opened by anyone except the person with the key.

By designing external covers for portable technology, designers can provide practical methods for safekeeping that also become public presentations of self [10].

Second Design Principle: use covers and exteriors to personalize the standard look and feel of objects, outwardly presenting a user's interaction while maintaining a private interior.

Design Scenario: Dynamic Jackets
Concept: A 'jacket' that covers a mobile device—such as a cell phone—displays a dynamic visualization of activity enacted by its owner while protecting the device from unwanted marks and scratches.

Figure 3: Designers can leverage the sides of an object to spatially orient the user, as demonstrated by tabs on the sides of books, spines, and pages.

Figure 4: While a desk's surface is often cluttered, its edges are under-used.

A woman wishes to control the presentation of one of her most-used possessions—her cell phone. Her friends personalize the surfaces of their cell phones, music players and PDAs with a variety of materials, from colored plastic covers to hand-knit cozies. While presenting a modified exterior, these displays are static and fail to reflect their changing social environment. The woman decides to place a Dynamic Jacket around her phone, and customizes its display. She adjusts the jacket's settings to exhibit collections of digital images: when the phone is idle, the jacket loops through images from her Flickr.com photo stream; when a friend calls, the jacket displays images from the friend's Flickr.com stream. The jacket simultaneously protects her device while presenting a visual narrative of digital images: she receives implicit visual updates on her friends' activities and finds unexpected images within her own digital archive. The device jacket, thus, becomes a subtle representation of the woman and her friends' mood, interests, and activity.

Page Tabs

Observation

Page tabs are the material that attaches to individual pages in order to help us organize the contents of our books. Unlike bookmarks that materialize as strings or ribbons, tabs are most often made of page-like material that is just large enough to be pinched by a thumb and forefinger. Using such tabs, pages can seem to 'jump out' of the side of a book, indicating where the marked page is located. By calling attention to points along the depth of a book, we can get a sense of where we have left marks, rather unconsciously differentiating the marked content using our spatial memory.

The depth of the book, the dimension that indicates its thickness, can also imply the 'weight' of its contents (i.e. its number of pages). The depth can help a reader get a sense of where they are in the book relative to its front and back cover, its beginning and end. When pages contain tags or markers along this axis, the depth can help people recall on which page a certain piece of content lives. Not only does this call upon our knowledge of related, nearby content displayed on the page, but also the tactile memory of where that passage is located in books.

Third Design Principle: allow users to navigate and interact with a tool using its edge—the traditionally idyll surface adjacent to its core surface of interaction.

Design Scenario: Table Tabs

Concept: Tabs along the side of everyday tabletops that allow people to record and recall activity conducted on the tabletop surfaces.

A woman sits at her desk at home, sorting through piles of old photographs and craft materials. She is creating a scrapbook to celebrate daughter's first baby and wants to remember the stages of the book's creation. Beginning a new page, she lays out photographs on the desk and lifts a 'tab'—a protruding, physical flap—on the edge of her desk. By lifting this tab, the woman records a digital photograph of the tabletop surface. Several weeks later, the scrapbook is complete and in the hands of her daughter. The woman returns to her desk, wishing to revisit a page in her completed book. She presses the same tab on the desk that she previously used to record her crafting process. An image taken at the time the scrapbook was created is displayed on the desk's surface, illuminating a view

of the woman's materials while crafting. Without disrupting the woman's use of the desk as a flat surface for craft activity, the tabs allowed the woman to store and navigate information she collected while crafting.

Conclusion and Future Directions

As we demonstrated, existing physical interactions with bound paper can be used as inspiration for the design of physical interactions with other media. In our future work, we intend to further refine and develop our preliminary concepts for the design of personal and portable technology based on our design guidelines.

We hope to stimulate additional attempts at understanding instrumental, existing technology to inform the design of new technology. The analysis of the historical and present physical interactions has the potential to uniquely motivate design and innovation.

Acknowledgements

We would like to thank Flickr.com users Ian-Fuller, no-typographic, net_efekt, Mertz, Russell-Crosswy, scrapbit, Scott-Kuperus, Mike_Mertz, KateMonkey, mush and hawkexpress for use of their images.

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