A Tangible Page Flipping Interface for Reading Digital Documents

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ABSTRACT

Current interfaces for navigating digital documents use a standard point-and-click cursor to indirectly manipulate pages. We are presenting an interface that allows for direct and natural manipulation of a digital document by making utilizing the user's ability to expertly navigate a book. This device allows for controlling the degree of bend in a virtual page (in two degrees of freedom), turning pages, and flipping rapidly through multiple pages. We describe the design and implementation of the device as well as the set of interaction techniques it supports. The resulting interface is an effective alternative to the mouse for navigating digital documents.

Categories & Subject Descriptors: User Interfaces; Methodologies and Techniques
General Terms: Human Factors; Design
Keywords: reading, document navigation, tangible user interface

INTRODUCTION

Digital documents have many well-known advantages over their paper counterparts in terms of information processing, share-ability, etc [1]. However, navigating these documents can be a chore, and so paper continues to be the medium of choice for reading [5]. Part of the reason for the continuing dominance of paper is the computer interface's lack of tangibility and of directness [6]. When you read a paper document, you can feel the paper, you can physically turn a page, you can flip through the whole document, or in one motion open it to a remembered place. These are physical actions missing from the standard computer interface of mouse and keyboard. These features are important because they aid in learning and efficiently using a system [6], free up the attention needed to find a scroll bar with the cursor and click on it, and provide users with a memory for where information is located [7]. How can reading on-line utilize these qualities?

The solution is to develop an interface that more resembles a tangible document or a book. People interact with books every day, they know how to use them and are comfortable with the interaction. This familiarity is exploited by our prototype interface.

The prototype consists of physical pages that have sensors built into them to detect degree of bend. The sensors transmit the degree of bend information to the computer that uses the data to bend/turn the virtual pages of a document. The physical pages have the properties of paper (tangibility, flexibility, some memory, etc) and when bound together they take on the physical properties of a book. Therefore, users get the familiar tactile advantages of paper books, intuitive knowledge of spatial layout, and the comfort of not having to reach for the mouse. These benefits coupled with a direct link to the virtual document make navigation in virtual space as easy as reading a book.

GESTURES

The gestures the book interface needs to capture are those most commonly used when reading a book. These include turning a page from the top corner or middle, the bend and snap of a page being flipped, and the position of a page relative to the

a) corner bend b) flipping bend

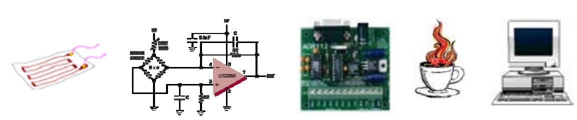
binding. These gestures can be used to determine absolute (one virtual page mapped to one physical page) or relative positioning (flip half-way through the document) within a document as well as the velocity of page movement during flipping. Together they can be used to create an illusion that the book interface is mechanically attached to its virtual counterpart.

RELATED WORK

There are various approaches to capturing page turning. One such is radio frequency identification (RFID) [4]. This technology consists of a small, flexible tag embedded in a book page and a detector in the book cover. When a tag enters the detectors field (i.e. a page is turned) the detector alerts the computer. However, although there would be no problem with slow page turning, the processing required makes RFID too slow for page flipping, as detection delay can be over 100ms (10 detections a second) and pages can be flipped much faster. Another detection technology is conductive ink [3]. Ink with particles of metal in it is drawn by pen over a normal piece of paper. When the page is bent, the resistance of the ink changes like that of a strain gage and is detected in the same manner. If the designer had a printer with conductive ink, any layout could be used for maximum bend detection in any axis. At the present time it is difficult to find conductive ink, and there are some complications in the process of application that made this technique unsuitable for our research. A simpler approach is needed.

SYSTEM ARCHITECTURE

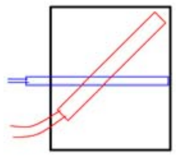
We decided on this system architecture, designed to capture and clean-up signals representing degree of bend induced by the gestures mentioned above. It starts with sensors on a physical page creating a signal that is sent to a signal conditioning circuit. A data acquisition (DAQ) card connected to the computer serial port samples the circuit output for each sensor. Java code processes the raw data and updates a visual display of the document being read.



SYSTEM HARDWARE

Prototype

The prototype consists of a single page with two sensors bonded to it. The sensors are 240-ohm strain gages that can detect miniscule stretching or compression by varying their resistance accordingly. One strain gage is



positioned in the middle of the page and through the spine of the book. The other strain gage is at a 45-degree angle starting at the top corner of the page. This configuration allows detection of page turning (from the bend in the corner sensor), flipping (from the bend in the horizontal sensor), and which side of the spine the page is on (the horizontal sensor minus the projection of the 45 degree sensor onto the horizontal axis). These motions represent the important gestures used when interacting with a book. Each sensor is bonded to the page (a plastic transparency) with double-sided tape on the bottom protecting the exposed metal strands and packaging tape on top. The voltage across the strain gage is the signal passed to the signal conditioning circuit and then to the DAQ. Since the tiny variations in voltage are influenced heavily by noise, it is necessary for the software to smooth the data using finite impulse response [2] techniques. This processed data is then used to manipulate a visual representation of the physical page displayed on the screen.

Full Implementation

In its next evolutionary step, the interface would consist of some hundreds of these pages, each with its two sensors. The DAQ would sample every input channel at a rate faster than the user could flip the pages of a book. In addition, the DAQ would connect to a wireless transmitter that would serve as the input to the computer. The display would consist of a digital document that would give the illusion of bending and turning directly with the physical page.

TYPICAL USER SCENARIO

A user wants to look up a part number for a capacitor he needs for a design. He goes to the electronics distributor's web page and clicks to open their 1000 page catalog. He remembers that capacitors are near the middle of the catalog and so opens his book interface near the middle. The on-line catalog opens in the middle to resistors, the section before capacitors. The user then flips quickly though 50 pages of resistors before catching a glimpse of the capacitor section. He then slowly turns the pages of the interface until reaching the particular part he wants, writes down the part number, and then closes the book interface, which closes the on-line catalog.

DISCUSSION

Problems

Sensor Bonding: One of the main goals of our project is to retain the physical properties of paper in the interface. This means that paper, sensors, and connections all have to be flexible, thin, and robust. Strain gages are usually bonded to steel with special adhesives that are too rigid for paper. A substitute had to be found that was as flexible as paper and yet strong enough so that the strain gage remained anchored to the page at full deflection. Too much sliding would negate the small change in resistance being measured.

The bonding problem can be solved with two different types of tape. Double-sided scotch connects the metallic side of the strain gage to the transparency page. Clear packing tape goes over the non-metallic side of the strain gage and surrounding parts of the page. The double-sided scotch tape keeps every point of the strain gage in contact with the underlying page and the pressure from the packing tape keeps the strain gage bound to the double-sided scotch.

Noise: Since the signal from the strain gage sensor is on the order of millivolts any transients on the signal line will significantly disrupt the amplifier output by saturating the device. Saturation happens because the noise can be up to 4 times the signal strength, so a desired signal output swing of 0-5 volts would result in noise output swing of 0-20 volts (well beyond the rail supply of the amplifier). The output of the op-amp is also filtered to keep a clean line to the analog-to-digital converter (DAQ card), which might under sample the signal and, therefore, record only noise. For these reasons, low pass filterers are installed across the amplifier input and output.

Scaling: Every page requires two sensors minimum to detect all meaningful gestures. Each sensor requires a Wheatstone bridge and amplifier circuit, which in turns needs an input channel on the DAQ card to be read into the computer. The DAQ card and computer program both need to be able to sample each channel at low frequencies (25-50Hz) and update the display in real time. These requirements are significant in that the amount of hardware resources and hardware space needed quickly becomes unacceptable after a few pages (high hardware to page ratio).
One solution to the scaling problem is MUXing the sensor signals before conditioning and MUXing the amplifier outputs before they go to the analog DAQ inputs. The sensor signal MUX would have to have very good resolution so as not to round the small voltage signal. Digital control of these circuits would have to have fast switching times to keep delay down, but the switching would still have to be two times slower than the DAQ sampling rate to satisfy the Nyquist sampling theorem.

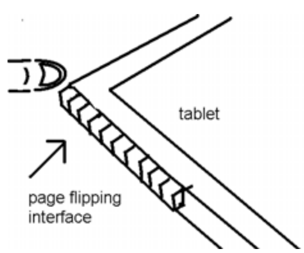
Mapping: When the document being read has more pages than the book interface, how are virtual pages mapped to physical pages? A mix of relative and absolute positioning could be used to solve this problem. Situations that require relative positioning would be opening the book to somewhere near the middle corresponding to the document opening somewhere near the middle or flipping through the pages corresponding to a proportional advancement in the document. Situations requiring absolute positioning would be turning a single page. In combination, these two types of mapping would cover a document much larger than the physical interface.

Envisioned Applications

Book Replacing Mouse: The book interface would be used in lieu of a mouse for flipping through documents with pages fitted to the screen. Each page is fully modeled and virtual pages act as if physical pages. The user can flip part of a page to check the contents on the bottom of the next page, skim through chapter headings, or any other action available to an actual book reader.

Projecting onto the Book: In this iteration of the book interface, the digital document would actually be projected onto the physical devices blank pages. This setup would create a truly direct interaction where the user is not forced to look at a screen separated from the device. The book analogy would be complete, the tactile and spatial properties of paper combined with the information processing of a computer system.

Tablet Device: If the book interface were shrunk down to just the tips of a page with one sensor each, it could be used as a device much like a trackball on a laptop. In the picture below, each right-angle corner is the tip of a bend sensor. When the user runs a finger over the page tips, the document being read advances a proportional amount and stops when the user stops flipping the sensors. Bookmarks could be left between pages and multiple fingers could hold different positions in the document much like the physical counterpart. This application would be more portable but would have lessened functionality in that a full page is not being modeled but only the flipping action and single page turning.



Authoring: When a paper is being authored, the book interface can be used to help organize and structure the work. If the book interface represents a blank sketchbook there are no restrictions on the order and spacing of the different parts of the paper. The end could be written first and placed at the end of a virtual document with some blank pages in front of it. Since readers have a good intuition for the spatial layout of the content of a book the virtual placement of the ending would have some meaning for them. It is interesting to consider what functions could be created for moving information around and other editing techniques.

CONCLUSION

In summary, my system has been shown to provide a natural, intuitive interface for navigating on-line documents by realizing the benefits of tangibility and users familiarity with books.

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