Realistic books:
A bizarre homage to an obsolete medium?

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Abstract: For many readers, handling a physical book is an enjoyably exquisite part of the information seeking process. Many physical characteristics of a book—its size, heft, the patina of use on its pages and so on—communicate ambient qualities of the document it represents. In contrast, the experience of accessing and exploring digital library documents is dull. The emphasis is utilitarian; technophile rather than bibliophile. We have extended the page-turning algorithm we reported at last year's JCDL into a scaleable, systematic approach that allows users to view and interact with realistic visualizations of any textual-based document in a Greenstone collection. Here, we further motivate the approach, illustrate the system in use, discuss the system architecture and present a user evaluation. Our work leads us to believe that far from being a whimsical gimmick, physical book models can usefully complement conventional document viewers and increase the perceived value of a digital library system.

1. INTRODUCTION

Digital libraries invariably present their documents in a manner that is rather bland. Most collections show electronic text, frequently formatted for the screen in a way that is crude compared with typeset book pages. Designers of electronic books [1] pay more attention to the look and feel of the pages, with crisp text, clearly formatted and attractively laid out. Many digital library collections offer page images rather than electronic text, and although occasionally rather beautiful, these are presented in a flat, two-dimensional manner.

Noting this, we reported at JCDL last year on a project that generated the dynamic behavior of individual page-turns using a model based on a mass-spring structure defined on a rectangular grid of particles [2]. This was inspired by the British National Library's "Turning the pages" project (see http://www.bl.uk/collections/treasures/treasures.html), a rare attempt to provide a reading experience that more closely resembles a real book. Readers sit at a large screen showing a double-page spread of what appears to be a physical rather than an electronic book. They flick their finger across the touch-sensitive screen to metaphorically pick up a page and turn it. Pages look three-dimensional; the book's binding eases almost imperceptibly as each page is turned; page edges to right and left indicate how far through you are. The simulation is compelling, and users rapidly become absorbed in the book itself, turning pages unthinkingly. But the main drawback is that the British Library painstakingly photographs in advance a slow animation of every page-turn, for every book. Our last year's project extended the idea by dynamically texture-mapping the current page's content onto a full three-dimensional model of the page-turn, making it possible to turn the pages of any book served up by a digital library.

The present paper moves on from "how to turn the page" to "how to use the book." We aspire to give readers a sense of having a real book in their hands, and provide natural ways of interacting with it. Bibliophiles love books as much for the statements they make as objects as for the statements they contain as text. Indeed, early books were true works of art—exquisitely-calligraphed poems inscribed into monumental stone steles in China; ancient scriptures etched onto palm leaves held together by string threaded through holes in India; and Western art treasures like the *Book of Kells*, painstakingly lettered by Irish monks at the scriptorium of Iona 1200 years ago.

Beautiful books have always been prized for their splendid illustrations, for colored impressions, for decorated illuminated letters, for being printed on special paper, or uncommon materials, for unusual bindings, for their rarity and historic significance. And beauty is functional: these books give their readers an experience that is richer, more enlightening, more memorable than the prosaic, utilitarian—often plain ugly—web pages offered by today's digital libraries. This argument went down rather badly with the referees of [2]—indeed, we have taken our subtitle from one referee's eloquent dismissal of our work. Nevertheless, we persist in our belief that realistic books have a great deal to offer readers in digital libraries.

In the next section we discuss what we mean by "realistic documents" and consider what they might have to offer readers in a digital library. It is easy to speculate, however; so we quickly turn to a demonstration in the following section of what it is like for a user to interact with the prototype that we have built. Then we go on to discuss aspects of the implementation, which presents difficult technical challenges. We then review related work in using the book metaphor to help users gain a better understanding of the information space they are working with. Finally we present the results of a formative user evaluation study of our prototype, and draw some conclusions about the utility of our work.

2. REALISTIC DOCUMENTS IN A DIGITAL LIBRARY

By a "realistic document" we mean a dynamic representation of a physical document that imitates the way it looks in nature,

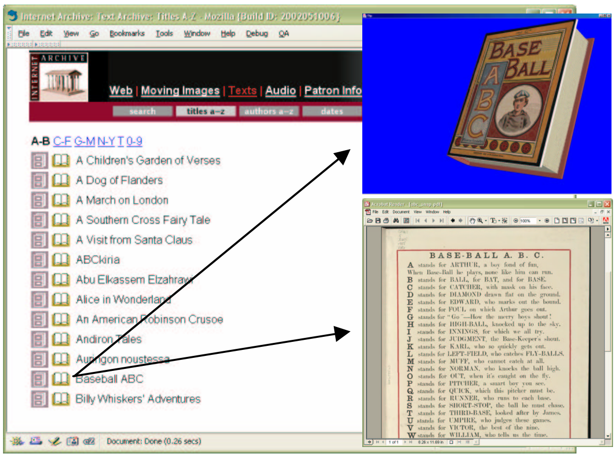

Figure 1: Alternative ways to view a book.

Figure 2: Don't judge the book by its cover … look inside!

achieved by interactive graphical techniques—albeit rendered on a two-dimensional screen and manipulated using a two-dimensional pointer. While a full "virtual reality" view that allows readers to interact with a model of the book using three-dimensional sensory equipment (such as a data glove) would be interesting, we use dynamic two-dimensional projections of the object, and explore the hypothesis that these can greatly enhance the reader's experience compared with a conventional scrolled or paged two-dimensional view.

The books

We restrict our attention to properly bound, page-based books. Books provide sufficient challenge for an exploratory project, though it would be quite feasible to extend the techniques to deal with ancient papyrus scrolls (in fact, one of the British Library examples, the Diamond Sutra, is a scroll), or with modern stapled documents. In addition, for practical reasons, we consider only hard-bound books.

We provide the user with interactive access to a three-dimensional model of a book and its pages, viewed as a two-dimensional projection and controlled by a standard mouse or touch-panel. The aim is to convey the impression of handling a physical book. However, we do not attempt to model the idiosyncratic details of particular instances of actual books. Rather, we use a generic model with parameters such as page size and thickness, number of pages, texture of paper, cover image, and so on.

Reading the books

We do not imagine that digital library patrons will spend significant amounts of time actually reading books in this form. They will (metaphorically) handle the book, heft it, flip through the pages, sample excerpts, scan for pictures, locate interesting parts, and so on. They do this to get a sense of numerous meaningful properties of the book: its thickness, layout, typographic style, density of illustrations, presence of color plates, and so on. When it comes to actual *reading*, page by page, we expect most readers to switch to a more conventional two-dimensional view, optimized for legibility and convenience of sequential access.

We believe that people have valuable, and enjoyable, interactions with books without necessarily reading them from cover to cover. And even when they do read a book right through from beginning to end, they invariably take a good look at the outside—and inside—first. For example, early on Amazon.com provided front and back cover images for each book, and progressed to the table of contents and subject index, then to sample chapters, and now to complete page images of many books in their stock. These clues help provide readers with a sense of what it is that they are going to acquire (purchasing in the case of Amazon.com, plucking from a shelf in the case of a digital library).

Augmenting the books

Real documents give many clues to their age and usage patterns. Pages change color and texture with age, becoming yellow and brittle. In this way, certain kinds of metadata (age, usage) have physical counterparts in terms of visual cues. It is natural to try to emulate such features in a simulation and see whether they can be used to enhance the reader's experience.

But simulations can easily transcend reality. It is possible to use more conventional metadata to augment the physical model.

Consider division into sections. Some dictionaries and other reference works have finger-tip recesses cut into the physical book to correspond to logical sections and their ordering—letters of the alphabet, in the case of dictionaries. One can easily imagine a simulation version of this facility. In this case simulation can provide two key advantages over real life: the process can be applied to any book for which the corresponding internal metadata exists, and it is instantaneously reversible—it can be switched on or off according to the user's taste and current needs.

It is easy to imagine further enhancements. Section headings could pop out of the side of the book, either to form a complete table of contents that is keyed to physical locations within the book, or as rollover text when moused. Many user interface aids operate on a document surrogate—e.g. TileBars [12] display the result of textual searches by coloring areas that contain hits to the various search terms—and these adapt very naturally to a physical book model, where the edges of pages are colored to indicate clusters of terms visually. A conventional index, or index of automatically-extracted keyphrases [13], could be keyed to page locations in the book. Realistic documents in a digital library can do far more than simply mimic their physical counterparts.

3. DEMONSTRATION

The series of snapshots in Figures 1–10 demonstrate some of the features of the implementation. In Figure 1, the reader is examining a digital library collection of e-Book novels—an experimental prototype for the Internet Archive [14] powered by Greenstone [3]. They are searching or browsing through the

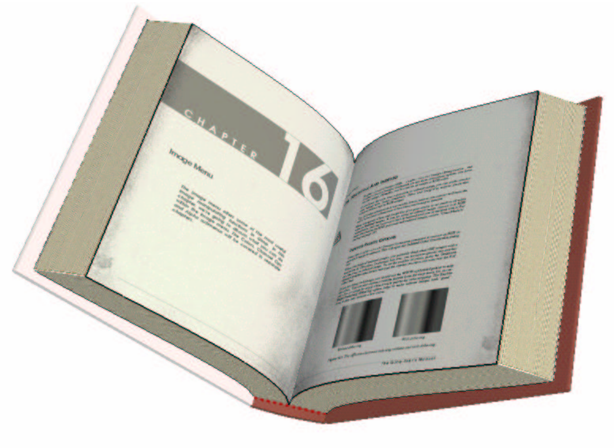

Figure 3: Detailed modeling includes flexing the spine.

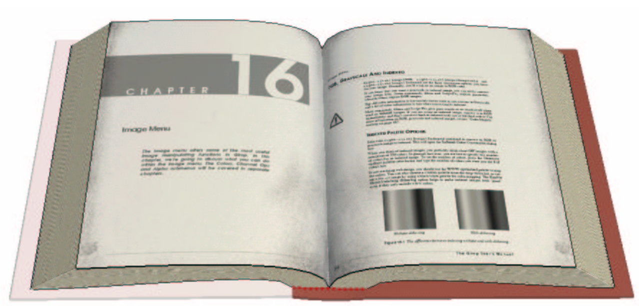

Figure 4: The book fully opened.

collection using Greenstone's standard web-based user interface. Finally they have located a document of interest, selecting *Baseball ABC* from an alphabetical list of titles. The lower arrow shows the default behavior when the open book icon is clicked: after a short delay to download the file to the user's computer it launches Acrobat Reader to produce a conventional two-dimensional rendition of the book. Switching the web browser's helper application to our three-dimensional book visualizer, the upper arrow shows an alternative route, which presents a three-dimensional view of the book. Again, prior to the book's appearance, the file has been downloaded to the user's computer and subjected to some initial preprocessing.

Natural features of the model

The inset in Figure 1 shows the initial view of the book. In the visualization the user is always looking towards the book, and can spin it around in three dimensions to view it at any angle. People often heft objects to literally "get a feel" for them. In this implementation the mouse is used to control the book's orientation, and there is no sense of weight or touch, but nevertheless one does gain a distinct impression of handling a physical object. The cover (and pages) of the book, as we shall see shortly, can be colored and/or textured to visually represent properties such as age.

You cannot riffle through the pages of this book with your fingers. But you can click on the edge of the book, grab it at a certain position, and open it using mouse or touch-screen. In Figure 2 the user has, with the left mouse button, grabbed a page edge about three-quarters of the way through and started to open the book at that point by moving the mouse to the left. The opening follows the mouse as it sweeps leftwards. Alternatively, the user can click on the front cover and sweep left to open the book at the first page. Repeating the process on the newly exposed right-hand page performs the next page turn; clicking and dragging the facing page returns the user to the previous page.

With the book slightly more than half open (Figure 3), the user lets go and the left part continues to fall, eventually coming to rest as shown in Figure 4. The user could equally well have continued the opening sweep, bringing the book to its final position with their grip still on it, or reversed the direction of the sweep partway through and returned the book to a closed position. If the book was less than halfway open when it was released, it falls closed. The model exhibits the same behavior whether it is one or many pages that are being turned.

The model is over-simplified: it ignores momentum when the book is released. We decided that the benefit obtained by modeling this additional aspect was not worth the implementation cost. The simulation feels right when the book is released from a stationary position, but if the page is moving upwards it seems like it abruptly hits an invisible barrier before falling back to its rest position. While users initially find this unnatural departure from the physical world surprising, they rapidly get used to the book's behavior under these circumstances.

Some users never actually release the book partway through a page turn, which is why we did not bother to model it fully. In contrast, however, the behavior of the spine during a page turn is far more central to the credibility of the visualization, and so we have taken pains to model this detail accurately. Notice how the pages in Figure 3 bend into the spine, and in Figure 4 how the angle of the spine relative to the cover changes as the book opens further. Although you cannot really see this in these static figures, the spine even bows slightly during the turning process to adjust to the pressure that the two covers exert on it, just as a physical book does.

The user continues to examine the book. By the time Figure 5 is reached, they have settled into viewing a sequence of consecutive pages, involving single page turns. The sweeping and releasing actions are the same as for opening the book: you initiate a page-turn by clicking on the exposed page. Interaction is modeless: users can switch between the various forms of page access at will. Incidentally, as Figure 5 illustrates, the pages are slightly transparent, but they do not have to be. In Figure 6 the user has once again used the page edges to shift to a later section of the book. Rather than clicking the next page, they have clicked further through the book. Compare the curvature of the turning pages in this figure with the rigidity of Figure 2. When the hardback cover is not part of the section being turned, the pages naturally flex. The curvature varies as the turn progresses.

In Figure 7 the book has been spun so that it is viewed edge on. This shows the salient parts that constitute the geometric model of the book. The left and right covers are rigid and flat, to model a hardback book. The same principles, of course, could be used to model a soft-cover book. Even in a hardback book, the spine itself is not rigid: it can carry a variable, but small, amount of curvature as discussed above. The book's pages divide into three zones, open left, in transition, and open right.

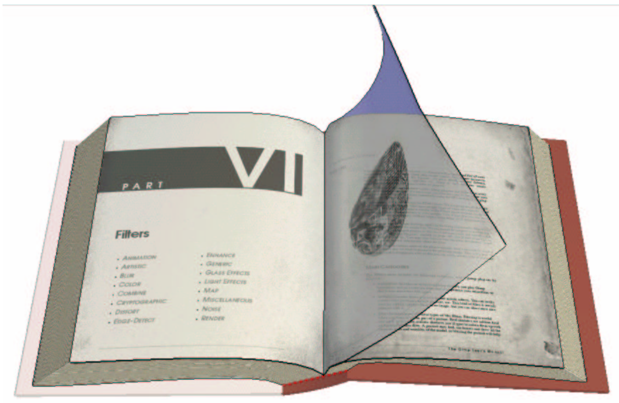

Figure 5: Turning a single page.

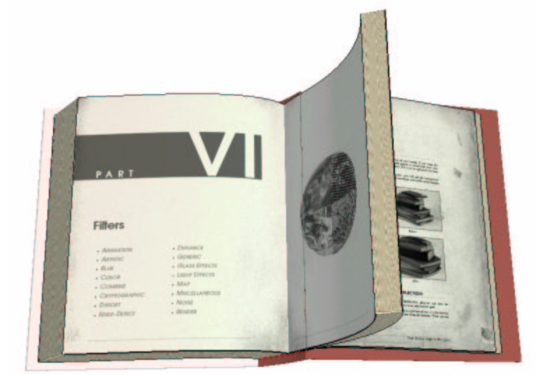

Figure 6: Turning a wodge of pages

Artificial features: use of metadata

As well as imitating nature by modeling physical aspects of books, the book vizualizer also incorporates artificial features that are based upon visual metadata. Figures 8–10 show snapping to anchor points, aging of paper, and navigation by flipping.

In Figure 8 the user has switched on markers down the right-hand side of the book, which correspond to the start of each chapter. Clicking in the page-edge region now snaps to the closest marked point and opens the book there. In our model, snapping to anchor points and placing marks down the edge of the book can be independently toggled on or off. In Figure 2 the snapping option is on but the markers are off. Then, whenever the book is opened it appears to "coincidentally" open to the beginning of a chapter, without any visual distraction.

Figure 9 shows the aging option. It is intended to be linked to the book's usage log. Pages that have been accessed more than others appear grubbier around the edges. Compare Figure 9 with the open pages shown in Figure 4. The start of the chapter in Figure 4 has been accessed a few times—some dirt is evident—but not so often as that seen in Figure 9.

You can begin flipping through a book by making a sweeping gesture with the right mouse button. This begins an animation in which individual pages, or groups of pages, turn one by one until the end is reached. The larger the gesture, the more pages are turned per flip. Figure 10 is a montage of what is seen. The image at the top left shows the start of the first flip, which turns pages 200–250 together, while the one at the top right shows the same group of pages later in that motion. Flipping continues with the next 50 pages. The image at the lower left shows pages 300–350 being turned, and, at the lower right, pages 400–450. The animation is interrupted by any mouse click. An alternative to fixed page flipping is to use anchor points, resulting, for this book, in a traversal of the book chapter by chapter. Uninterrupted, the activity continues until the end of the book has been reached, whereupon the book closes.

Computational features: progressive animation

In parallel with everything described above, the visualization progressively refines the quality of the two-dimensional images mapped to the pages modeled in three-dimensions. There is an obvious tension between the quality of the images used in the mapping and the time taken to generate them. Even for a slim book (30 pages), it takes around a minute to generate all the book's pages as high resolution images—depending somewhat on the ratio of text and illustrations to the book.

Progressive refinement is used to resolve this tension. In an initial pass, the book's cover is generated at high resolution, and all its pages are rendered at the lowest resolution used by the visualizer. Then, in a pre-emptive fashion, key pages (such as chapter openings) are generated at progressively higher resolutions. Then pages that precede and follow these key points are also refined to the higher resolution.

The user's behavior affects the order of refinement. Whenever the user employs the page-edge technique to turn to another section of the book, a new key point of the highest priority is created if the images at that position have not already been refined.

4. VISUALIZATION IMPLEMENTATION

The system is implemented in Java and uses the GL4Java class library (from *www.jausoft.com*) to access the three-dimensional graphics rendering capabilities of OpenGL. Figure 11 gives a conceptual overview of the entire book visualization system. In addition (not shown), a configuration file is read that initializes a wide range of parameters. Viewing parameters range from the size of the window that opens to the amount of ambient light present in the world and the user's initial viewpoint. Book parameters range from the number and thickness of pages to the material properties (diffuse, reflective, *etc.*) of the paper and cover. Table 1 gives the complete list of parameters.

To display and manipulate a book on the screen, control is based around the interaction module, which responds to user input through keyboard and mouse clicks, and updates the screen accordingly. Three auxiliary modules support the interaction task. The image generation module is responsible for producing the flat two-dimensional rendition of a page. The animation module maintains the three-dimensional representation of the book onto which the 2D image representations of pages are mapped. The visual cues module, which is optional, augments the visualization with additional information. For example, it can age pages according to how often they have been accessed.

When generating 2D images of pages, raw book data in the form of a PDF file is manipulated by a processing pipeline that extracts single pages. We explain this in more detail in the next section. In the animation module a three-dimensional model of a book is used to support the visualization. Figure 12 shows its constituent parts, and echoes the structure already previewed in Figure 7. It divides the geometry of a book into the left and right hand parts that are open, and a middle section for a page

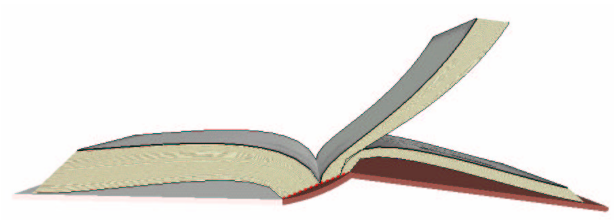

Figure 7: Edge-on view, showing salient parts of the geometric model.

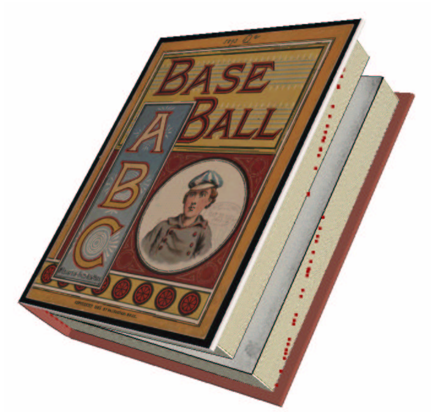

Figure 8: Anchor points mark the beginning of each chapter.

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*The window size: width and height

*The viewing parameters
 viewport size: width and height
 field of view
 camera position

*Book internal configuration
 +obvious
  the thickness of a paper (pt)
  the maximum cover thickness

 +non-obvious
  the roundness of the book spine
  the cover margin

*Starting page number

*Page Content
 image format(PNG, JPEG, TGA)
 maximum and minimum image size

*lighting
 light position
 ambient light color
 diffuse light color
 specular light color

*material
 page shininess
 cover shininess
 cover specular
 cover color

*Animating page drop
 minimum display interval (in millisecs)
 maximum display interval (in millisecs)
 angle step

*Animating quick flipping
 angleStep
 display interval
 pausing interval in milliseconds

*Flicking gesture
 gesture size(number of pixels between
button being pressed and button being
released)
 two threshold values: maximum and minimum

 gesture duration(time between button
being pressed and button being released)
 two threshold values: maximum and minimum
```

Table 1: Parameters for visualizing books

(or set of pages) that are partway through a turn. The fourth and final part is the book's cover, including the spine that links the left and right hand sides together. The situation where the book is being closed is handled as a special case in which there is no middle section of pages.

The model is seeded by settings in the configuration file. For instance, the sizes of the left and right portions of the model depend on the total number of pages, the thickness of the pages and where the book is initially opened. Beyond this, the model keeps state based on directives from the animation module. A page turn is decomposed into a series of discrete calls that update the angle of the middle section of pages in the model. For particulars about how, within this model, aesthetic issues such as the curling of a page is implemented, see [2].

The image pipeline

Figure 13 shows the process by which images for the book visualizer are generated. Managed by the image pipeline controller, a PDF file is read and its logical structure identified and stored in memory. We use *itext* for this purpose (*itext.sourceforge.net*). Following this, images of individual pages are generated on demand, based on requests made to the image pipeline controller from elsewhere in the system. The same page can be generated at different resolutions—this is needed to support progressive refinement—and each request stipulates the page number and desired resolution. To optimize subsequent requests, the image pipeline controller maintains a cache of the images generated.

The implementation currently uses *itext* to determine page break information only. However, there is the potential to do far more. Depending on how a PDF document has been generated it can encode additional logical structure such as section and subjection headings (enabling an automatic table of contents to be generated), running headers and footers, and so on. Such information could be exploited to further enrich the interactive features of the visualization.

Controlling the interaction

Various processes and activities in the visualization can perform concurrently, and so the interaction module is threaded. Figure 14 shows the three threads used and their interrelationship. The main thread takes the lead role and is responsible for refreshing the display screen and intercepting all mouse and keyboard input. It can also spawn threads—typically as a result of interpreting mouse gestures—for progressively refining the quality of the images mapped to the pages, and for animating page turn effects such as a page being dropped or flipping through a sequence of pages. The main thread can

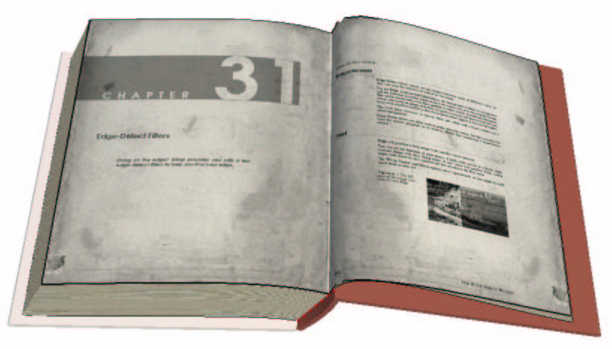

Figure 9: Pages become grubbier the more often they are viewed.

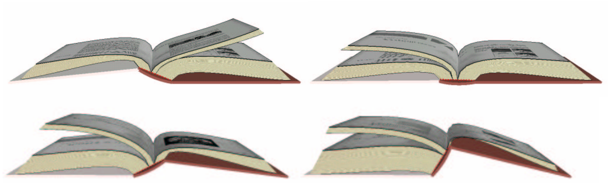

Figure 10: Flicking montage. Order of sequence top left, top right, bottom left, bottom right.

interrupt a child's thread, otherwise it continues to its natural conclusion and terminates.

Using this configuration a user can, for example, start a page turn (main thread), and then, partway through, release the page (main thread starts animation thread) causing it to drop back to a resting position. While the page is dropping, the user might switch on progressive refinement (main thread starts progressive thread), which results in higher resolution images of the falling page (and exposed pages left and right) being dynamically mapped in as they become ready. The page finally comes to rest (animation thread stops). However, the progressive thread is still active and starts generating higher resolution images for other pages

5. RELATED WORK

There have been many earlier attempts to use the book metaphor to help the user gain a better understanding of the information space they are working with, as well as enhance the reading experience.

The WebBook system [4], for example, collects up web pages and builds three-dimensional interactive books. The work was carried out in an attempt to give users a better sense of how pages are related. In conventional web browsing, users can become focused on the page and its links and can easily be unaware of any higher-level organizational distinctions such as the relative location of a page within a site structure.

WebBook does not attempt to provide the degree of realism that we aspire to. To turn pages, the user simply performs click actions with the mouse—clicking on the left-hand leaf goes back a page, a click on the opposite side moves forward in the document. While our system allows users to grasp and manipulate groups of pages to move to different parts of the book, in the WebBook, the user indicates the desired jump by clicking on the right or left edge of the document. We use a realistic gesture to initiate and control the speed of flipping through a book; in WebBook, this interaction is again based on discrete events—pressing scan control buttons placed at the bottom of the book or holding down a mouse button—and parameters that the user must set.

Systems that employ the book metaphor for more conventional documents also focus on presenting a stylized book representation rather than producing a simulated analogue. For example, the VisualBook [5] uses simple line drawings and graphical devices to simulate the book's form, and users interact with tools to move around the document.

Some of the more sophisticated visualization and interactive features we have employed have been discussed in Section 2. Employing page staining to indicate usage is an example of "read wear" [6]. Employing a flicking gesture to control page flipping was inspired by Moyle and Cockburn's scheme for a more natural approach to Web browsing [7].

In the Digital Library community there has been interest in using visual representations not just to represent books, but also to represent collections of books. Cubard *et al* [8], for example, propose to present books on shelves. Users can select a book from the stack and open up a three-dimensional representation to take a look at its contents before selecting it for further reading.

Although our system allows users to interact directly with books, the approach provides a rather less tangible experience than that seen elsewhere. The XLibris system [9] aims to provide the sorts of physical directness seen in real books. Reading is carried out on a tablet-sized PC which the user can easily hold in their hands. Users can reposition the device, as they might a book, to gain a more comfortable reading experience. The device also includes a tangible interface to turn pages—grasping sensors on either side of the device moves the reader forward or backward through the document; if the user retains hold of these sensors the pages flick, at a rate that depends on the amount of pressure applied. The MagicBook system [10] takes notions of tangibility to the extreme. A real physical book is used as a mechanism for presenting digital content. Users can read the book itself, flip through pages and by using a handheld viewer can see animations, images and other text superimposed.

6. EVALUATION

We have carried out a formative user evaluation study of the system. Our aim was to gather impressionistic data of the approach's usability and usefulness. As well as general feedback on the interactive elements provided, we were interested in the effectiveness and usefulness of the visualization in providing information on a book's size, age and usage—as well as the content it holds.

Participants

Eight participants were recruited. All were computer science students with extensive experience of interactively browsing and searching online materials. None, though, had used any 3D book systems before.

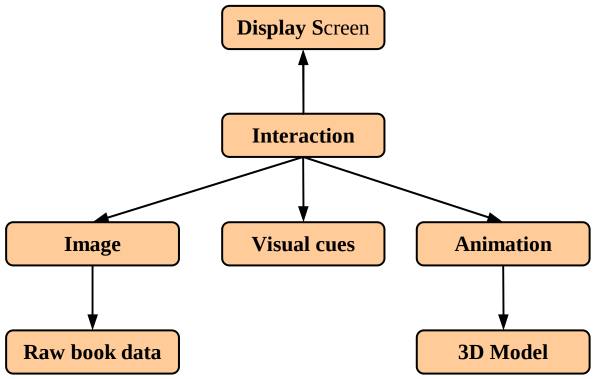

Figure 11: Conceptual overview of the book visualizer.

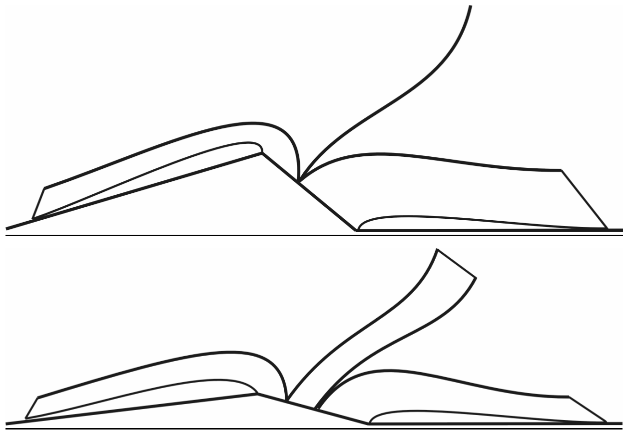

Figure 12: Geometric book model.

Materials

Visualizations of two books were generated for the study. One was a small work of fiction with 34 pages. It was made to look new, its pages crisp and white, with little usage coloration. The second example was a much larger technical book of 604 pages. It was given an old, well-used feel. Salient attributes of the two documents are summarized in Table 2.

All the pages for each book were compiled to the highest resolution before the study. For Document A, we placed anchor points throughout the book, each falling on pages that contain images. For Document B, anchor points coincided with the start of each chapter.

Procedure

Participants came individually to the study. Before seeing the system, they were asked to complete a profiling questionnaire that asked them for age range, gender, and experience with computers, on-line browsing, and other three-dimensional book systems. Next, the usability researcher (the first author) gave a short demonstration using a third document visualization. Participants were shown how to orientate the book, turn a page, grasp and flip a set of pages, and control the flick animation.

Users were then asked to use the system to view Document A followed by Document B. In each case, when the document appeared on the screen, the researcher asked the user to manipulate the document and tell him about its characteristics. The researcher did not mention any specific attributes as being of particular interest. As users explored the document, they were encouraged to "think aloud" by voicing their thoughts and feelings. Their comments were written down as they were made.

After completing both tasks, participants filled out a questionnaire. They were asked for comments about the effectiveness and utility of the system in communicating the size, age, usage and content of the documents.

Results and discussion

We analyzed the comments, looking at the overall response to the system and then at the specific reactions to the way in which document attributes were visualized.

Attribute	Document A	Document B
Size	Thin (34 pages)	Large (604 pages)
Age	Young (white pages)	Old (browning pages)
Usage	Low (less marking)	High (more marking)
Content	Fiction	User Manual

Table 2: Attributes of the two documents employed in user trials.

Overall response

All participants enthusiastically appreciated the realistic nature of the visualization and the interactive features provided. Some comments that typify the positive response to the presentation were:

- *"Is this document scanned from the real book?"*
- *"It is life-like."*
- *"This electronic book is like a normal book."*
- *"This book is very special. It is not boring. I can interact with it."*

Perhaps because our participants were highly experienced users, most made suggestions for additional features. Some examples:

- *"It should provide different options of flipping through the pages. For example, flipping page by page, or chapters by chapter. Flicking page by page is fine with small book whereas in a large book this is not so useful."*
- *"When the mouse moves over the anchor point it should provide some kind of 'tool tip' on the anchored points, that says what chapter is this page."*
- *"It does not have a goto function."*
- *"It does not have a search function."*

All these suggestions can be accommodated using the framework we have developed. For example, the page flipping could use any number of anchor point sets—one for chapters, one for figures, one for most used sections of the book and so on—and the user could select whichever they wished to use.

Communicating size and content

The visualization was most effective in providing users with information about the document's size, and the style of content. All users made accurate comments about the length of both books and were able to quickly refer to the different styles and

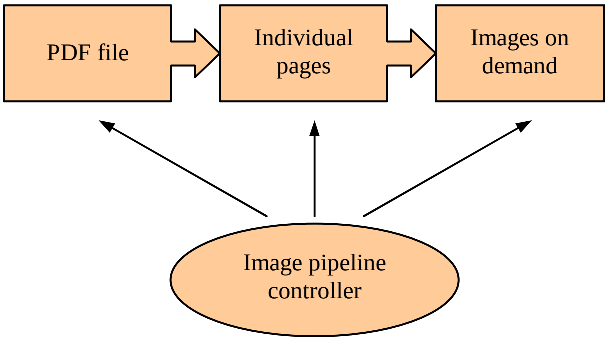

Figure 13: The image pipeline.

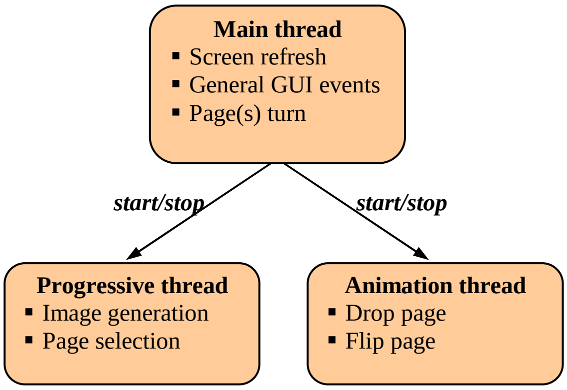

Figure 14: Threaded control for interaction.

information in the two documents. Some sample comments were:

- *"It is a small book, 20 something pages."*
- *"You can tell how thick the book is just by looking at its edge."*
- *"When you fully open the book, you still can tell how thick the book is. You can tell through the page's curvature whether it is bending or is in a straight line."*
- *"Although the resolution makes the books a little hard to read, it is not hard to tell from the graphics and layout that the two books are not the same one."*
- *"You could differentiate between technical and non-technical books."*

Communicating age and usage

While participants were using the books, although most noticed visual cues to age and usage, few made explicit reference to the attributes, as these sample comments indicate:

- *"Page looks yellow"*
- *"I can see the coloration"*
- *"Some pages are dirtier than the other pages"*.
- *"Does this mean more people are reading this page? If so, I think a folded edge would be better.*"

In the post trial questionnaires, most participants made comments about how these features might enhance the overall sense of realism as well as aid them in using the materials:

- *"If you are searching for a recent publication you could tell at first sight whether this book is any use or not (looking too old)"*
- *"Maybe useful to know how up-to-date the content is."*
- *"I guess the age of the book is only relevant when you're looking at an antique book, like hundreds of years old."*
- *"Faster access to possibly 'interesting' parts of the book (If a couple of people read this section, it must be worth it)."*
- *"It is good to know the pages that people often read because it's a good indication of the source of information and importance!"*

Of the two attributes, age and usage, the latter was seen as the most effectively presented and useful. From a utilitarian point of view, participants seemed to feel that a simple textual representation of the book's age would suffice for all practical purposes.

7. CONCLUSIONS

We have built, demonstrated, and evaluated a system that physically models books. We claim that it offers readers something more than traditional computer-based paging or scrolling systems. Furthermore, we have enhanced the model using metadata to further enrich, and facilitate, the browsing experience. We emphasize that when it comes to reading a book page by page, or studying it intensively, we expect many readers to switch to a more conventional two-dimensional view, optimized for legibility and for sequential access.

But have we been engaged in a whimsical development that provides little added value to the experience of using a digital library? We have subtitled our paper with one referee's eloquent, but arguably dismissive, comment on an earlier version of this project, and we feel obliged to address this explicitly.

It is certainly true that we pay homage to the book. In bygone days, noblemen paid homage to their ruler by going to great lengths to indicate their full support. They were not paying "lip service" but demonstrated their unwavering commitment to the King or Queen. Likewise, we have paid homage to the book by going to great lengths to build an actual system that illustrates our vision—one that is far beyond the mock-ups or proofs of concept exhibited by some other work. We describe what is, rather than what could be.

But we certainly do not see our approach as "bizarre." It is systematic and scaleable. We have worked hard to close the gap between vision and reality. We have produced a realistic, interactive presentation that is capable of being used to display text-based documents in a digital library on demand. Given the computational requirements for graphical processing, this has been an interesting challenge.

Neither do we believe that the book form is obsolete in this digital age. From a purely utilitarian point of view, our user study indicates that three-dimensional visualizations may well be effective at communicating interesting and useful document features to the reader. Certainly the scheme could lift to a new dimension the book previewing seen in online retailers like Amazon, where what is being viewed acts as a surrogate for a physical book.

But it is shortsighted and misguided—if not absurd—to view any technological artifact in purely utilitarian terms. Life, including our interactions with digital technology, involves—or should involve—far more than merely maximizing efficiency and effectiveness. The subjective impact of the user's experience—how much pleasure they enjoy, how engaged they become, *etc.*—should never be overlooked or down valued. Our users were intrigued and enthusiastic as they played with the books. Other work, such as that on three-dimensional presentations of desktop spaces, has shown that while these schemes may not help people achieve their goals any faster, they are highly preferred subjectively, and ultimately more successful [11].

We would be delighted if the familiar, comforting, enjoyable and useful nature of the book visualization went some small way towards helping to open digital libraries up to a broader audience than technophiles—including children and others with little enthusiasm for bland information experiences.

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