3Book: A Scalable 3D Virtual Book

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ABSTRACT
This paper describes the 3Book, a 3D interactive visualization of a codex book as a component for digital library and information-intensive applications. The 3Book is able to represent books of almost unlimited length, allows users to read large format books, and has features to enhance reading and sensemaking.

Author Keywords
3D books, 3D UI, sensemaking, eBooks, Electronic Publishing

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces—Graphical User Interfaces; I.7.4 [Document and Text Processing]—Electronic Publishing; H.5.4 [Information Interfaces and Presentation]: Hypertext/Hypermedia—Navigation; User Issues. **General Terms:** Design, Human Factors.

DIGITAL BOOKS

Digital documents and books are rapidly evolving, and it seems likely that for the present and near future there will be a coexistence of paper and digital formats, including some that attempt to capture characteristics of both worlds. For example, the British Library has developed a museum-oriented electronic 3D book that allows a feel for turning the pages of historical parchment codex manuscripts, including the Lindisfarne Gospels and Leonardo's Notebook [2]. The pages can be turned by finger (in the Library itself) or by mouse in a reduced-size Web version.

An electronic simulation of a codex book (that is, a collection of pages bound on one side) like the British Library system allows the electronic book to look and feel at least somewhat similar to its physical correspondent. Such a metaphor for presenting books emphasizes to the user the correspondence between the physical artifact and the electronic artifact. "Turn to the picture in the middle of page 124," has the same meaning whether on a physical book, a computer, or possibly special electronic portable document readers. It also honors at least some of the accumulated culture of the book. The reader would lose some of the experience of the Lindisfarne Gospels if she could merely scroll them or click on thumbnails in Adobe Acrobat.

To these uses one can add the use of 3D virtual books as design elements in their own right. For instance, virtual books could be used to proof real books for print runs. Virtual reality systems and the several ongoing explorations of 3D workspaces, e.g., [11], would strongly desire a 3D representation of a book. Electronic versions of large text books used as reference, such as medical texts or conference proceedings (in fact, libraries of such texts), would also be compatible with the 3D book metaphor.

Our own experience with virtual books began with a system called Catalogues [3] (Figure 1a). Catalogues were online user manuals in which users configured system preferences and features by turning the pages and shopping from the Catalogues. We used this system as the basis for a product TabWorks™ [10] (Figure 1b) that shipped on Compaq computers as a simpler Windows shell. Like Catalogues, TabWorks used a book metaphor (with tabs on some of the pages). Users collected applications and files on the pages, which turned but did not animate. We used a more elaborate book metaphor, called WebBooks, for our Web Forager system [6] (Figure 1c). The WebBook allowed users to make 3D books out of Web pages as part of a 3D browser for the Web. WebBooks, Web pages, and piles of pages were suspended in a 3D workspace. The workspace could contain multiple books, storing some of them in a bookcase. In a later paper [15] (Figure 1d), we created a virtual 3D book of part of a real, scanned-in book and added computation over the content, using cocitation and other analyses over the bibliography to recommend which reference the reader should read next.

Although these systems were generally successful, they had two limitations. First, they were not up to supporting an interactive virtual 3D book on anything like the scale of a full real book. In the WebBook, pages were all kept in main memory, limiting the number of pages that could be in the workspace. As books became larger than about 40 pages, the system would slow noticeably—a book on the scale of a medical textbook would have been out of the question. The books also lacked features for accessing large format books, such as an index or table of contents (although it did have keyword search).

These limitations parallel the limitations confronted by other attempts to simulate books. Larger books have generally been implemented in 2D, with suggestive 3D features like page turning or tabs. For example, FlipViewer™ [9] is a 2D-based simulated book product with animated page turning that holds collections of objects such as photographs. XLibris [12] used sensors to create the illusion of page turning on a tablet computer containing a 2D docu-

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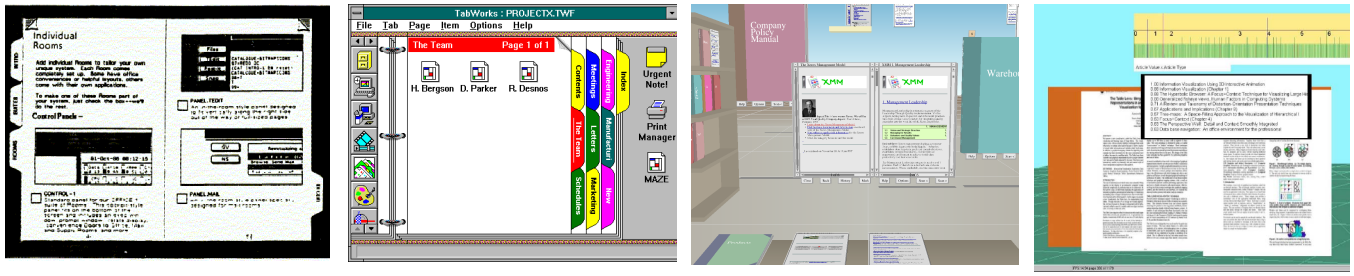


(a) (b) (c) (d)

Figure 1. Previous book-like interfaces: (a) Catalogues [3], (b) TabWorks [10], (c)WebBook [6], (d)Early 3Book [15].

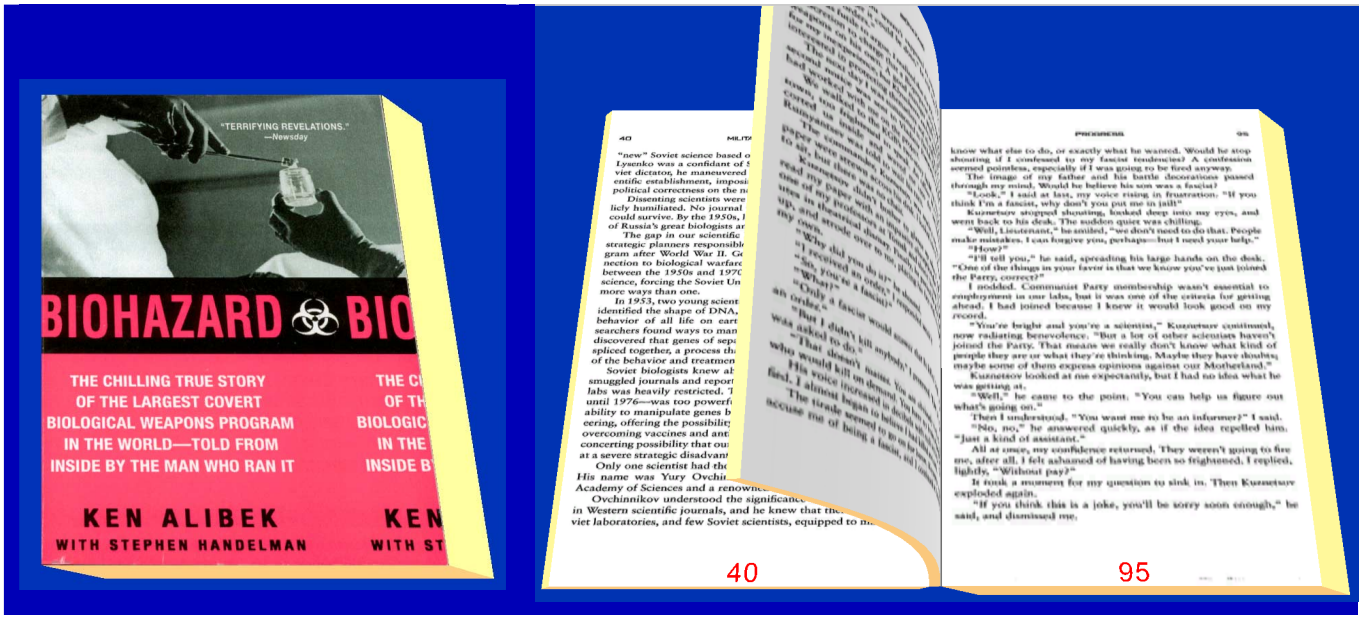
ment. Aside from the paper-like metaphor, XLibris was notable for its support of the user's task of active reading by allowing users to highlight, underline, and annotate text with a pen, and automatically create an annotation notebook. True 3D books have generally been small. The Silicon Graphics Demo Book [14], for example, was among the first to create a true 3D book. It simulated non-rigid page flipping with animation, but was only a few pages and not used with actual book text. The British Library Lindisfarne Gospels and others referenced earlier are also 3D books, but only about 40 of the pages are included—not entire books. The animation images are actually photographs of intermediate points during page turning [8]. One version of the system consumes 304MB for only 20 book pages. Furthermore, a magnifying glass feature is necessary to examine the text; continuous reading would be awkward.

The initial goal of this work is to overcome the limitation of scale—to create a true 3D codex book that can operate at the scale of the largest published paper books and that can accommodate the layouts of these books, including large formats at least the size of conference proceedings. The book component would then serve as the base for future experiments on digital libraries and systems to aid sensemaking in information-intensive tasks.

THE 3BOOK

We have developed a prototype 3D electronic codex book called the *3Book* (If the 3 is reversed it spells EBook). To compare it against a typical real book, we scanned in the paper book *Biohazard* by Ken Alibek [1] (Figure 2a). This book has 300 pages (about 118,000 words) and probably represents the most common book dimensions.

Figure 2b shows the 3Book open to a double page of text as the reader turns a block of pages. The reader can turn individual pages by touching them or turn blocks of pages by touching the fore edge of the book. The ability of the 3Book to operate on a full book at interactive speeds depends heavily on the underlying engine. Our system is currently implemented on top of VTK 4.2 [13]. To facilitate integrating with other sensemaking components, we choose Java as our programming language and access VTK through the Java native interface (JNI). At a preprocessing stage, for each book page we sample its scanned image to



(a) (b)

Figure 2. 3Book. (a) 3Book in closed position, (b) Turning a block of pages.

yield three separate textures of resolutions 256x256, 512x512, and 1024x1024. We use JPEG to represent these textures because it is a space-efficient and well-accepted image format. As a result, the whole content of the book takes about 240 MB, which can be easily stored in a CD-ROM. During run time, when a new texture of a page is needed (e.g., the page newly becomes visible due to page turning), one of its textures is loaded into the memory *on the fly*. Our strategy of determining which texture to use provides a tradeoff between quality and speed. This multi-resolution strategy is aimed to alleviate the problem that it takes considerable time to read a high-resolution image.

A key benefit of the multi-resolution strategy is that we can now manipulate the book at interactive speed. For example, as soon as page turning is started, we read in low-resolution textures from disk and map them to those newly visible pages. At the same time, a separate thread is launched to load the corresponding high-resolution textures from disk. At the end of the page turning, those low-resolution textures are replaced with high-resolution textures to enhance image quality. On a Dell Workstation 340 with nVidia GeForce4 TI 4600 graphics card, the first frame usually appears within 0.1 second and the animation speed reaches about 27 to 59 frames/second (16 to 37 ms/frame) during the page turning. Clearly, our hardware requirement is very modest even by consumer standards.

LARGE 3BOOKS

We were able to represent a typical full-sized book as a 3Book, but what about a larger book? As a further test, we built a 3Book of the physical book, *Readings in Information Visualization: Using Vision to Think* [5] (Figure 3a). This book presents very strong challenges. It has a large number of pages (700), a large page format (8-1/2" x 11") containing 700~1100 words per page, for an estimated 700,000 words.

Even a large laptop with an LCD screen of 9" by 12" requires that an opened *Information Visualization* (Figure 3b) be reduced to 80% of the physical book height of 11" by 17", shrinking 10pt type to 8pt. In fact, the situation is even worse, because room must be left on the screen for other parts of the interface (Figure 3c), and even with a resolution of 1600 x 1200 pixels, coarseness of the pixel grid (especially if the book is at a slight angle as shown) further degrades the book image.

Our solution is to allow rapid zooming of the book by the reader, when needed, into a "rocker page" form (see Figure 3d-3f) where about 2/3 of the height of a page (for a book the size of our target book) is large and readable. If there is not enough horizontal room, the non-viewed page is bent back, allowing all of its page width still to be visible. Figure 4 shows state transitions for the reader. The reader can rock between the two pages (for example, to consult a figure). The reader can also move the focus forward down the page (with a single click) for sequential reading. If the focus is at the bottom of a verso (left-hand) page, moving the focus forward automatically rocks the book and moves to the top of the next page. If the focus is at the bottom of a recto (right-hand) page, moving the focus forward automatically turns the page and moves the reader to the top of the next verso page. If the new page is in landscape instead

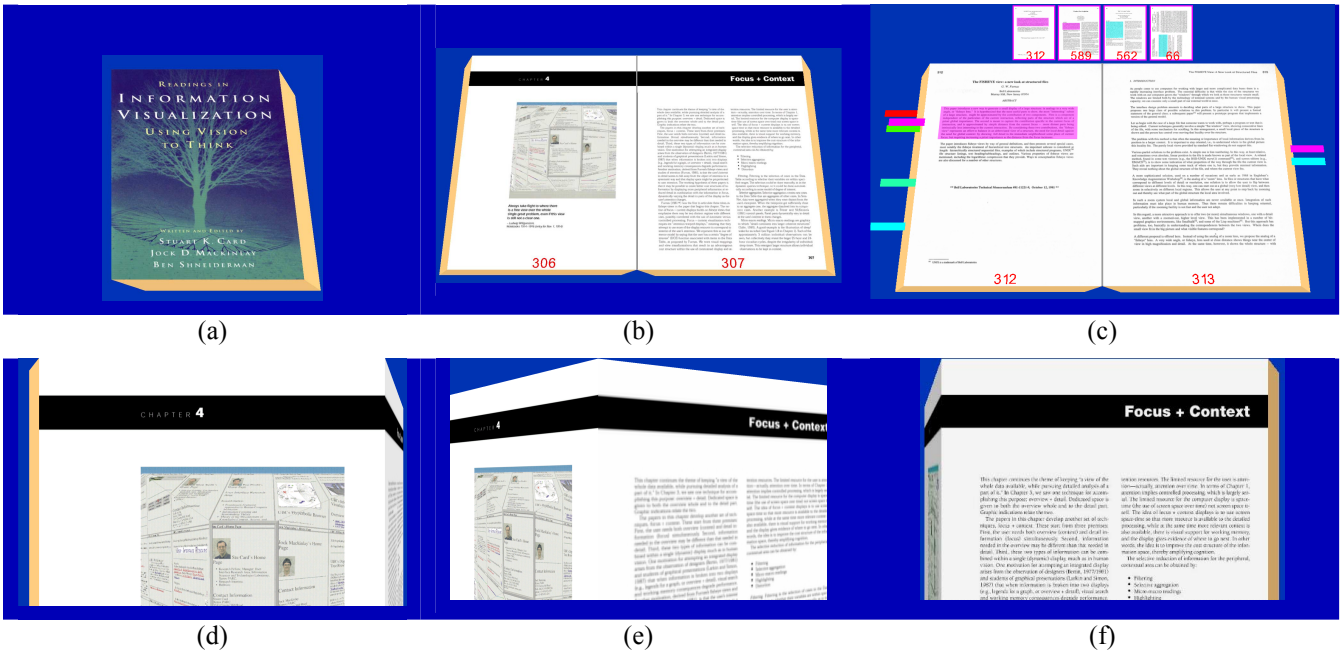


Figure 3. Rocker pages. (a) Large 3Book, (b) In open position, (c) 3Book with highlights, bookmarks, and slid-out pages, (d) Recto page bent back and verso page zoomed into reading position, (e) Rocker page in animated transition from verso to recto page, (f) Recto page in reading position.

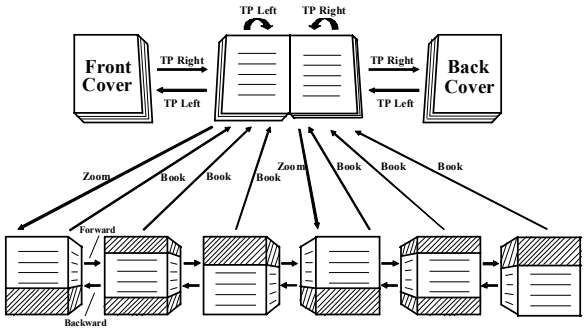


Figure 4. State transitions changing pages and views for reading large 3Book.

of portrait orientation, then the book also automatically animates to the correct reading position. Focus can also be moved backward in the same way. At any time, the reader can turn the page, or go to some known page number. This method was worked out after testing and refining about a dozen methods.

Measurements show that although the book *Information Visualization* is about seven times larger than *Biohazard* in terms of number of words, it still operates below the critical animation threshold of 100 ms/frame cycle and at essentially the same speed (Figure 5).

SUPPORTING THE READER'S TASK

To allow the 3Book to participate in simple sensemaking activities, we provided means for the reader to bookmark locations, to compare multiple locations, and to extract items of interest out into a text editor. We allow interesting pages to be slid out of the book for further comparison (Figure 3c). We provide smart indexes based on information scent and word co-occurrence models that dynamically change in response to reader interest and need [7]. These provide features that support each portion of a simple model of the information sensemaking: cycle foraging, reading, organizing, and writing [4].

Now that we have achieved adequate performance for the 3Book component, we are finally in a position to use this component in systems where we can study and refine reader effectiveness, especially for sensemaking and can develop the multiple-document workspace.

We expect the next several years to see unparalleled growth in personal and shared digital libraries and other digital document collections. At the same time there will be continued rapid improvement in computer graphics capabilities that make practical graphically agile representations of books such as the 3Book on personal computers or on special purpose portable document readers.

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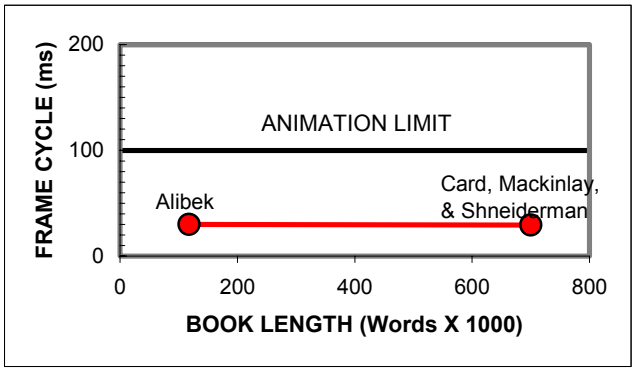

Figure 5. 3Book performance, showing its ability to scale with book size.

REFERENCES

1. Alibek, K. (1999). *Biohazard*. New York: Dell Publishing.
2. British Library (2004). Turning the pages. http://www.bl.uk/collections/treasures/about.html.
3. Card, S. K., and Henderson, D. A., Jr. (1987). Catalogues: A metaphor for computer application delivery. *INTERACT '87,* 969-964.
4. Card, S. K., Hong, L., Mackinlay, J., and Chi, E. (2004). 3Book: A 3D electronic smart book. To appear in *AVI'04.*
5. Card, S. K., Mackinlay, J. D., and Shneiderman, B. (1999). *Readings in Information Visualization: Using Vision to Think.* San Francisco: Morgan-Kaufmann.
6. Card, S. K., Robertson, G, G., and York, W. (1996). The WebBook and the Web Forager: An information workspace for the World-Wide Web, *CHI '96, 111-117.*
7. Chi, E. H., Hong, L., Heiser, J., and Card, S. K. (2004). eBooks with indexes that reorganize conceptually. To appear in *CHI'04 Late Breaking Results*.
8. Chu, Y-C., Witten, I. H., Lobb, R., and Bainbridge, D. (2003). How to turn the page. JCDL '03, 186-188.
9. E-Book Systems (2004). http://www.flipviewer.com.
10. Moll-Carrillo, H. J., Salomon, G., Marsh, M., Suri, J. F., and Spreenberg, P. (1995). Articulating a metaphor through user-centered design. *CHI '95,* 566-572.
11. Robertson, G., van Dantzich, M., Robbins, D., Czerwinski, M., Hinckley, K., Risden, K., Thiel, D., and Gorokhovsky, V. (2000). The task gallery: A 3D window manager. *CHI'00*, 494-501.
12. Schilit, B. N., Golovchinsky, G., and Price, M. N. (1998). Beyond paper: Supporting active reading with free form digital ink annotations. *CHI '98*, 249-256.
13. Schroeder, W., Martin, K., and Lorensen, B. (2003). *The Visualization Toolkit: An Object Oriented Approach to 3D Graphics, 3rd Ed.* Clifton Park, New York.
14. Silicon Graphics (1993). Demo Book, Silicon Graphics, Mountain View, California. Computer program.
15. Woodruff, A., Gossweiler, R., Pitkow, J., Chi, E. H., and Card, S. K. (2000). Enhancing a digital book with a reading recommender. *CHI'00*, 153-160.