Developing Electronic Textbooks

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Abstract

Rapid technological advances in computer technology open up new possibilities for the engineering education market in the preparation of "Electronic Textbooks". Computer based "tools" in engineering textbooks are prevalent even today; these tools range from computer styled algorithms and code snippets, to fully developed software applications with graphical user interfaces on floppy disks attached to the back covers of books. The next logical step in publishing is to dispense with the paper book entirely, by distributing textbooks via electronic media such as CD-ROM. Electronic Textbooks use the full range of multi-media technologies in the learning and teaching process including video clips, computer animations and fully functional numerical engines as integral parts of the textbook material. This is very appealing since interactive media provide teaching tools that appeal to divergent learning styles.

The advantages of Electronic Textbooks lead to several challenges. Special attention must be paid to the development of user interfaces; navigation is of particular importance when non-linear exploration is encouraged. These issues are being addressed at the Sandia National Laboratories by an electronic documentation development team. This team includes experts in engineering, in human factors, and in computer hardware and software development. This paper will present guidelines for the development of electronic textbooks based on the experiences of this team.

Introduction

Motivation

As technology advances it increases the opportunities to improve all human endeavors, from basic science and engineering to fine arts and music. Many of the most visible changes in modern society are linked to technological advances, especially those in computer hardware and software. Engineering educators have spearheaded the use of these technologies to improve the educational process for the newest generation of technology developers. Examples include: 1) instructional television or distance learning, which uses television, telephone and satellite communications to allow students to attend lectures without having to be physically in the same room with the lecturer [10]; and 2) software supplements to textbooks, which allow students to explore the ramifications of mathematical models without having to complete the time-consuming code development [7].

This paper discusses a new approach to the development of engineering education materials. The "Electronic Textbook" represents the logical progression of the printed textbook in the Electronic Age. The concept behind this approach is simple; to place all of the information contained in a textbook in electronic form. Currently, paper texts exist on the market with electronic supplements (e.g., [7]); however, this Electronic Textbook would include supplements fully integrated in the whole text. The computer hardware and software needed to make this advance possible have existed for nearly ten years, and they have been readily available

to engineering educators and students for over three years. The advantages of this type of approach has already been recognized, and is now being implemented commercially [4].

Background and Project History

This paper presents guidelines for the development of Electronic Textbooks. These guidelines are based on the experiences of a development team that was brought together at the Sandia National Laboratories to produce an Electronic Textbook in the area of vibration analysis and design. This effort began as a small pilot project involving two engineers in 1992. This project was expanded in 1993 with the addition of a college professor, a human factors expert and a computer program developer. Funding for this project ended in September 1994. The product of this project was 80% of an Electronic Textbook. This book included over 180 pages of text, 12 MATLAB® [8] applications and an MPEG movie. The MATLAB® applications were fully integrated into the flow of the book, with buttons on particular pages that would allow the reader to run an application that was referred to in the text. These applications were designed to be of general applicability; they had graphical user interfaces with edit boxes, pull-down menus and buttons to allow the reader to change parameter values and then to redo the associated calculations as detailed in the text.

The results of this initial project led to a new project at Sandia, which involves the documentation of some engineering analysis codes. One result of this second project was the refinement of the layout of the vibrations Electronic Textbook. This second project is currently in progress, and the guidelines presented below are the result of the lessons learned from this combined effort over a three and one half year time span.

Advantages

The advantages of an Electronic Textbook in engineering education are numerous. First, it allows multi-media to be included, to support and expand the information described in the static text with examples, three dimensional interactive graphics, audio clips and animated video clips. These aid the students' comprehension by giving them visual and verbal stimulation simultaneously. Second, the Electronic Textbook allows illustrative examples to be supported by computational engines or applications. These applications, if left to the student to be developed, would require a great deal of effort without any significant increase in the level of learning. However, once developed, these applications allow the students to experiment with the underlying mathematical and physical models, thereby promoting active and inductive learning, to support the reflective and deductive learning processes promoted by the standard textbook. [3]

Third, the electronic format allows for the development of many navigational modes, which can be used to promote both sequential and global learning processes [3]. Active cross referencing, which allows a reader to jump from one topic to another, helps build an understanding of the relationship between different concepts. Additionally, detailed information can be stored out of sequence from the main flow of the text, thereby promoting a streamlined main text for the global learners, while still including all of the details that a sequential learner might need. This allows for the inclusion of complete mathematical derivations that would be prohibitive in a traditional paper textbook. Fourth, the electronic format and navigational aids can be used to package the same information for several different types of users, such as traditional undergraduate or graduate students, students in short courses or worker retraining programs, and practicing engineers who need assistance in solving new or unusual problems. Finally, Electronic Textbooks are easier to distribute, on CD-ROM or the Internet, and to maintain and update.

Challenges

To counterbalance the many advantages to developing and using Electronic Textbooks there are many challenges that must be addressed. Paper books have existed for over 500 years [9] and many techniques have been developed based on this delivery system over time. Electronic Textbooks present new design

issues to enhance computer-based features. Developers must find a way to free themselves of the book metaphor, so that the many advantages of the electronic format are maximized.

Designing the User Interface

Whenever text is being converted from paper to on-line presentation, it is critical to consider ergonomic guidelines for optimal legibility to minimize eye strain. Converting a paper document to an on-line version can be labor intensive because different text formats are needed. Additionally, most human factors issues need to be addressed early in the design phase. Ideally, design specifications or guidelines in combination with a user profile should be drafted to answer preliminary questions before the actual textbook development begins.

There are numerous publications on designing on-line documentation that provide real world solutions to generic problems [1,2,6]. For example, the landscape orientation, not portrait, is the preferred field of human vision. The display of a landscape oriented page on-line is one-third larger than a page in portrait format. Also, one typed page of text on paper typically equals three to six screens of on-line documentation, so it is practical to use white space liberally on the screen and incorporate graphics as often as possible [5]. Lengthy text passages should be broken into smaller segments of cross-referenced information. However, users can be overwhelmed by a large number of information windows being open on their computer screen, so experts recommend that the number of open windows be limited to between three to five [5]. On-line monitor reading is one-twentieth as sharp in contrast as is the reading of paper text. Therefore, it is imperative to limit the use of high contrast colors and to use only one or two simple font styles and large sizes. The display should be "inviting" and easy to read on-line, to prevent readers from printing the entire document, thereby circumventing many of the advantages of the on-line document.

Navigation

A common problem with electronic documentation is disorientation of the user. This phenomenon has been found to occur with users navigating on the World Wide Web and in user testing of preliminary versions of the Electronic Textbook developed at Sandia. For that reason, it is important to develop navigational anchors in Electronic Textbooks, and to perform iterative usability tests with small groups of users to ensure that the options provided are both easy to understand and intuitive. These navigational anchors can be graphical icons; for example, a closed book, an open book, and a single page can each represent a different level in the document.

Since it is important to the users to have many routes to the same information, icons can provide a quick visual point of reference to the main table of contents, the section outlines and the detailed text pages. The main pull down menus, hypertext and buttons can provide additional navigational cues for users. Navigational cues are also important to show interrelations between topics. The consistent use of visual navigational cues help to match and confirm the users' expectations of how the information is structured.

Development Guidelines

Design team structure

The design team should include members with technical expertise in the subject area, in human factors and in computer programming and systems development. Additionally, a project manager and a technical writer would be desirable. The member(s) with technical expertise will serve as the primary author(s). The human factors expert will help to guide the development of the user interface and the navigation structure, and will administer the multiple usability tests required during the development cycle. The computer programmer will help to overcome technical problems that are inherent to the development of electronic media. The project manager will be instrumental in keeping the team on track and in keeping the project milestones in focus.

The technical writing expert would assure that the text is cogent, which is especially important for on-line documents. The combination of team members with these skills will help to create a dynamic and efficient workflow cycle. Note that these people need not be collocated; indeed, our team is dispersed in five states and we have found few disadvantages because of the distance, with email, ftp, conference calls, and monthly progress reports. Importantly, the team members must all be aware of the challenges and limitations associated with the development of electronic media and must be committed to meeting project deadlines.

Page Layout and Navigation

The two most critical features in the success of an Electronic Textbook are page layout and the navigational aids. The effectiveness of these features is measured by the willingness of potential users to use the Electronic Textbook. If the page layout is uninviting, or if the navigation is too cumbersome, then potential users will not be likely to want to use the Electronic Textbook, and the project will be a commercial failure.

Figure 1 shows a suggested text page layout, which has been developed by the authors as a result of four cycles of testing with potential users. The page background is set to a light gray to reduce glare which causes eye strain. Thin black lines are used to separate the page into three main areas. The left margin is used for navigational anchors, which indicate the current location in the book, and to allow the readers to move easily to higher levels in the book (items in the "closed book" icon) and to the subsections of the current topic (items in the "page" icon). The top margin is reserved for buttons which access global information files such as the table of contents for the entire book, the glossary and the index, and which perform global actions such as closing the current window. This layout allows the right edge to be open with a ragged right margin to facilitate on-line reading, and to increase visual retention of the page layout. The page footer includes additional navigational anchors to reiterate the information presented in the left margin.

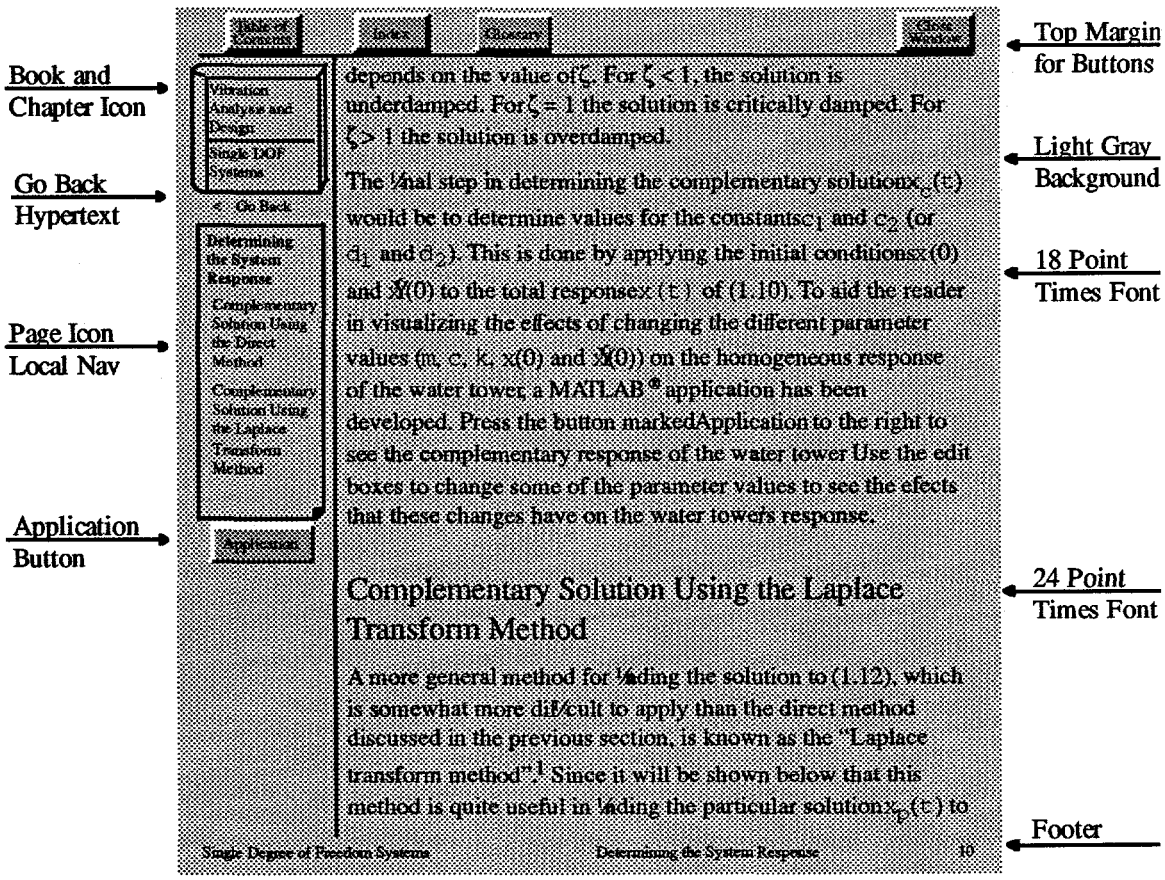

Figure 1. Suggested Text Page Layout (50% of normal size)

The text is formatted in a single font type, except for equations variables which are set in a different font type for distinction. Bold and italic type faces and underlining are avoided to increase the ease of on-line reading. A larger font size and white space are used to distinguish headings from normal text. Hypertext is displayed in blue and inactive text is black, to conform to World Wide Web standards and to limit eye fatigue that might result from pages half-filled with high color contrast hypertext. These color effects should be restricted to key portions of the text. If they are used selectively, they will prove to be highly effective visual cues without distracting from the content. Of course, graphics, movies, interactive flow charts and numerical engines should be incorporated whenever possible to maximize the electronic capabilities of the book; these interactive tools are the most distinct features of the textbook because they engage the user and enable active learning.

User Testing

Without a well planned and executed testing procedure the Electronic Textbook is likely to fail to live up to its potential. It is important to test the user interfaces and navigational aids early in the design process, and to continue to test these features throughout the development period. The results of these tests should be compiled and disseminated immediately after the testing is completed. Short tests which examine particular features of the book are more effective during the development stage than are exhaustive tests. The feedback from these tests can then be used to affect needed changes within a matter of days, and sometimes, even hours. This formative evaluation will then help to drive the next iteration of development and will also confirm when the team is moving in the right direction.

Conclusions

It should be remembered that there are no hard and fast rules for the development of an Electronic Textbook. The results presented here are meant to serve as guidelines to reduce the initial development cycle. Remember to be creative in developing page layouts and navigational aids, since the aim is to entice potential users to become actual users. Finally, test early, often and continuously, and use this feedback immediately to guide the ongoing development efforts.

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