Dynamic Authoring and Retrieval of Textual Information: DARTEXT

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***Abstract*-The super-exponential growth in the base of information creators and users with access to the Internet makes possible a variety of schemes for the creation, organization, dissemination and revision of information over the Internet. In this work, the ramifications of this technology for academic publishing, particularly in the engineering sciences, are explored. Frameworks are proposed which enable and encourage dynamic authoring and retrieval of information that, in the past, would have been associated with a textbook. A case study of the concept's application to an undergraduate course in engineering systems analysis is presented.**

I. Introduction

In the span of a very few years, we have crossed the watershed of information production and delivery using the technological bridges of the Internet, and ubiquitous information browsers such as Mosaic. The paths leading outward from this new shore are innumerable. Here, we describe one path for creating, organizing, disseminating and revising information, using these bridges and their present and future companions. While the path is general, we will discuss it in the particular context of university-level science and engineering education, and give a specific example in terms of the topic of *Engineering Systems* at Dartmouth College.

Conventional science and engineering courses in colleges and universities revolve around a set of lectures, homeworks, exams, laboratory exercises, and usually a textbook. Frequently, though less so of late, the textbook is the prime focus of the course. Lectures tend to follow the table of contents of the textbook. Homework is assigned verbatim from it. Instructors rely on published solutions to the homework.

Despite some past success, there are considerable problems with this model of instruction. While some students and faculty appreciate the permanence of a textbook, others find it constricting. Cost increases in textbooks have far outstripped inflation over the past twenty years, leading to text prices in the sciences and engineering in the range of $100. Too many students purchase a textbook, use it briefly during a quarter or semester, then sell the book, typically back to the bookstore from which it was purchased.

There is another drawback to the conventional means of authoring and publishing textbooks, which hinders the process of teaching and learning. Contemporary authors exercise an unfortunate tendency to exert conscious, complete control over the content and presentation of their writing. Typically, an author will insist on a specific, linear order of presentation of material, with each section fixed and immutable. We refer to this insistence as the "Outer Limits Syndrome": the desire to "control the vertical and the horizontal", forcing the reader to assume a passive posture in the learning process.

The intrinsic hubris of this tendency stems from two fallacies. The first fallacy is that one author, or even several authors, can 'know it all'. The majority of teachers (and students) know this to be false. Even in the most tradition-bound institutions or courses, teachers will add supplemental notes, or depart regularly from the sequence of a textbook. The reasons for these departures vary, but include a desire to establish personal control over the course material. A need to adjust the textbook to suit the local curriculum may also dictate departures. Or, an instructor may wish to prevent students from succumbing to the orthodoxy of a textbook, thus losing the edge of critical and independent thinking.

The second fallacy is that students are empty, passive slates, upon which the author writes with the chalk of knowledge. Again, students and teachers know this assumption is untrue. Formal student feedback concerning the quality of every aspect of a course of instruction is gathered at the end of many courses in the sciences and engineering across the country. These evaluations become useful in improving a course, and assisting its positive evolution. In every aspect *except* the textbook, changes can be wrought in time to create improvements for the next presentation of the course. Textbooks, however, must await completion of the process of producing a revised edition. Publishers decide prior to printing of the first edition, what the revision cycle will be: two, four, or six years in length. Frequently, even in this instance, revised editions suffer from little substantive, direct feedback from the most intimate users of the material, the students themselves.

Education research over the past decade has demonstrated traditional methods of instruction presume a single mode of teaching and learning. Professors lecture, assign homework, give written exams, ensure work is graded, and assign course grades based on a curve. Students take notes, execute solutions to closed-form problems, study, and take written exams, largely in isolation. Contrary to these patterns, progressive educators attempt to address the diverse learning modes of their students, rather than demand all students adjust their learning patterns to the professor's singular mode of instruction. Open-ended problems and laboratory exercises, group projects, collaborative homework, untimed exams, and course grades based on an absolute scale (as opposed to a curve), constitute some of the techniques currently employed.

We are attempting to incorporate these insights into a new means for the creation, dissemination, and revision of academic, textual information. However, by no means have our ideas been conceived *ab initio*. Some specific, successful attempts to correct deficiencies in teaching and learning have influenced our thinking, and deserve mention here.

Mook [Hen94] has undertaken significant reforms in the teaching of introductory physics at Dartmouth College. A key attribute of his efforts unlocks student frustration in a unique way. Students from previous classes are employed to create problems and solutions, supplementary notes, lab modules, videos, and multimedia displays which address and clarify issues these same students found difficult or confounding. The impacts are profound. The student developers are empowered to learn and communicate in new ways, and their efforts result in improved learning and teaching for subsequent classes.

Mazur [Maz91a, Maz91b] has also conceived and implemented introductory physics reforms at Harvard. He has completely changed his lecture style and format. His lectures now revolve around what he calls ConcepTests. Each one-hour lecture is broken into four segments. In each segment, a particular concept receives focus. Mazur first discusses the concept, in some detail, and occasionally with a brief example. A relatively simple, multiple choice question is then posed to the class, based on this concept. Students are first asked to think about the question, and frame their answer. They are then asked to enter their answers, on either a machine-readable card, or into a digital device which keeps statistics on student responses throughout the lecture, and throughout the course. Next, students work in pairs to discuss the problem and their individual approaches, and arrive at a common ground. Finally, the students record their answers, changed or unchanged, once more. ConcepTests succeed as a teaching and learning tool, and (since statistics are gathered) the success is measurable. The explosion of sound during the pair discussions is less measurable, but still powerful. It brings an intimacy previously thought to be impossible for a large, introductory class lecture setting.

The *Primis* system from McGraw-Hill was a publishing environment intended to enable greater flexibility in the organization and presentation of textbook information. Other publishers attempted similar projects. The central idea was to allow instructors to create their own textbook for a particular course, by selecting chapters from the 'stable' of book titles managed by a specific publisher. The market has largely rejected these products, for a variety of reasons. The price/performance ratio for these products was generally too high. Though the cost to students was in the $25-50 range, the quality of the product -- styles were uniform but very plain, colors were limited to black and white, and binding was paperback or soft-bound -- was insufficient to overcome the lower price. Instructors felt constrained by the limited number of titles held by a publisher, and by the restriction that whole chapters only from each title chosen must be used. Publishers also expected other publishing houses to collaborate, and submit material from their own lists for inclusion. When this participation did not occur to the extent predicted, the idea began to fade.

Redish [Red93, Red94] has led the University of Maryland's efforts in revolutionizing introductory physics education. The use of the computer is a principal component of this effort. The broad-based approach (of looking at a wide-range of systems which physical principles can describe) is similar to that taken at Dartmouth in the context of Engineering Systems (whose case study is described below). Such an approach can be facilitated and enhanced by the use of the Internet and related tools.

Mathematics instruction at Duke University, specifically calculus instruction, is being treated as a laboratory science [Moo92]. Calculus is no longer merely an esoteric exercise, but is coupled intimately to its original source in 'natural philosophy'. The interactivity thus wrought has broken the limiting bonds of traditional introductory calculus teaching.

A multimedia development workshop for engineering faculty will be given for the first time during the summer of 1995 [Har95]. Funded by NSF, the workshop endeavors to make authoring of multimedia, academically related works relatively simple, and to disseminate this information in substantive ways.

Few attempts have yet been made to use the new technological bridges to effect dramatic and constructive change. Some notable exceptions exist, though even these have shortcomings. Larson's work [Lar94] discusses the construction of an interactive calculus textbook. Strict control of content by the authors is implicit, even in this interactive work. Larson emphasizes correctly that graphic design is frequently a time consuming task. Shortcuts cannot be made in graphic design, without compromising impact and, ultimately, success. Proofreading is also a time-consuming task, according to Larson, which has been given little consideration by developers of hypermedia information sources. The shortcomings in Larson's approach will be addressed in subsequent sections.

Aminmansour [Ami94] has also made inroads on some of the problems we identify here. The interactive multimedia book on steel design places great emphasis on graphical interface quality, and on interactivity. Important provisions are also made to solicit and incorporate feedback from student and faculty users of the database (or 'software', in the language used by this author).

The Global Network Academy [GNA94] has taken some first steps toward publishing texts, and organizing their presentation and structure. The flexible input concepts contained in their documentation parallel some of the approaches detailed herein.

Our concept is somewhat similar to Aminmansour's, but goes further. As in [Lar94] and [Ami94], we begin with a focused database of textual information. Our emphasis is on academic subjects, and subjects (such as VLSI Design) which lend themselves to technical training. Without question, however, our concept may be extended to other arenas, since the database *content* lies at its core. And, regardless of the specific content, each database must be dynamic, living, and breathing.

The database must be flexible enough to include information in any form. Text, sound, still photos and graphics, animated or moving pictures, may all be incorporated.

To facilitate our concept, users of the database must have simple means to suggest changes and improvements, and well-satisfied expectations that their suggestions will be incorporated. Just as in a technical journal, the graphical interface -- the 'look and feel' of the database -- must be well-planned and extremely consistent. Its specifications must be public, with ample access to translators between many different formats, to allow virtually anyone to author contributions and revisions using their favored composition environment.

Retrieval of database information must be simple and low-cost. This necessity is already well-facilitated. Most academic environments have ubiquitous connections to the Internet. Many require students to purchase personal computers. Most other institutions will follow suit in the near future, as the cost of even mid-range computers with the necessary performance drops to attainable levels.

Authoring and retrieval of information, therefore, are the keys which unlock the door to the center of our concept. And it is the *content* of the information database which constitutes the core. For us, this information lies in the realm of academic science and engineering. However, our concept is completely general, and can be extended to other realms of information.

Content is our focus, but it must be supported strongly by other frameworks. As much as possible, we seek to build on the positive aspects of the Internet and the World Wide Web. At the same time, we must preserve the necessary roles filled today by publishers, textbook authors, production sub-contractors, and others vital to the textbook publication industry. And, we must add new players to the sphere of activity, to leverage new features and power made possible by evolving technology. These attributes are discussed more thoroughly in a subsequent section.

Control over the information in the database is essential to our concept. However, such control must be exercised carefully, delicately and elegantly. Too much control, and our concept becomes no better than current textbooks. Those attractive and powerful features -- interactivity, universal access, and rapid incorporation of new or revised material -- available through the Internet will be lost. Too little control, however, and anarchy will take hold, leading to an unattractive and ultimately unsuccessful product.

We intend for a professional editorial review board to have oversight responsibility for each database. This board will be similar to the review boards of most professional technical journals. It will, however, have special responsibility for the overall framework of the database. Furthermore, review board members will have a financial stake in the database, and be contributors to its content. Rapid turnaround times, between submission of new or revised information, and its incorporation into the database, must be a hallmark of the review board.

To clarify the path we envision, we have broken down our overall concept into smaller, interrelated frameworks. These are presented in the next section.

II. Frameworks

Our overall concept is depicted in Figure One. At the heart of our concept lies the *content*. We conceive of four principal frameworks in support of the content, which are at once linked intimately with the content, and each other. These are:

- Administration
- Graphics
- Intellectual Property Transactions
- Financial Property Transactions

Note that it is not necessary for all of these frameworks to reside under the umbrella of a single company. Though these frameworks constitute activities long managed by traditional publishers, in fact, it will be desirable for each framework to be owned by a small, agile firm, with support from several existing publishing houses.

In the following sections, we describe in more detail these individual frameworks. Following this discussion, we will present an example of the content for one possible database, based on Engineering Systems Analysis and Design.

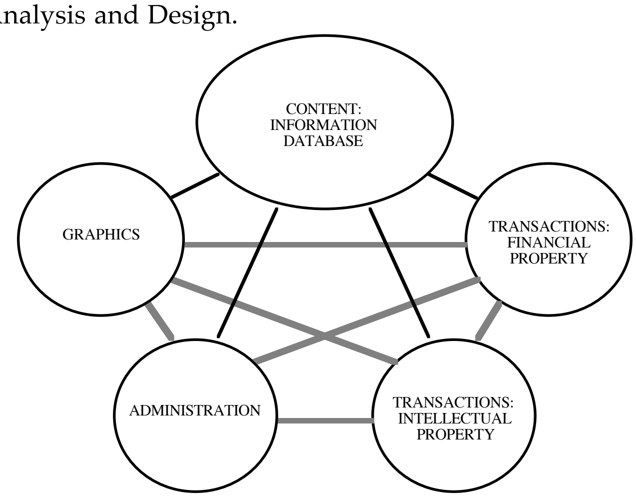

Figure One: The DARTEXT Concept

A. Administration

Figure Two depicts the administrative framework which supports the content-focused information database. This framework has several specific functions, which are listed below. This trend is consistent with the present-day 're-engineering' of the American corporation, where the responsibility for individual corporate functions are being spun off to independent companies.

Marketing, Sales, and Distribution: For any particular database to be truly successful, it must produce revenues which exceed costs. This assumption implies the need for these functions. In and of themselves, they do not differ from their counterparts in traditional publishing. However, to promote our concept, these functions must incorporate the new technology based on the Internet in order to advertise, sell, and distribute a particular database in softcopy form. Since the database, or major portions of it, will also be realized in compact disk (hardcopy) form, traditional routes of marketing, sales, and distribution must be maintained.

File, Hardware, and Network Services: The database must be maintained in appropriate ways. Its integrity must be preserved and ensured. Appropriate access for authors and retrievers must be authorized.

Physical Production: The creation of hard copies of the database, or portions of it, in paper or compact disk form, must be administered.

Acquisitions: New authors for existing databases must be sought out, and encouraged to make contributions. Authors for new databases must also be sought out. Market surveys and analyses, to determine which new databases are economically viable and should be pursued, must be made.

Legal Services: This area includes torts related to all aspects of the database, except for those agreements concerning intellectual property.

Accounting: As a matter of course, accounting will be a necessary function for all the frameworks supporting the database.

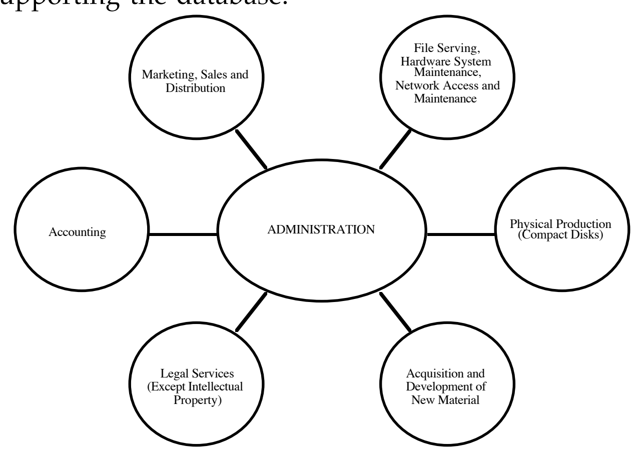

Figure Two: DARTEXT Administrative Framework

B. Graphic Design

Figure Three depicts the graphics framework for the database. We are presuming that the dominant interaction will be visual (by sight) and mechanical (by a mouse or keyboard). However, there is no reason for other means of interaction (e.g. sound) to be excluded. For our purposes here, we refer to the process of presenting the database content as 'graphic design', though perhaps 'interface design' would be a more general and enduring term.

This framework fulfills the following functions:

Database Format Specifications: These specifications refer to the 'look and feel' of the database, as perceived by browsers. It is important for these specifications to be widely available and understood, so that the broadest spectrum of potential and actual authors may be encouraged to submit material for use in the database.

Format Translators and Converters: The database must not constrain authors to use a particular, limited and limiting set of authoring tools. Nor may the database be constrained to be viewed by only a few browsing tools. Just as graphics conversion software, such as GIFConverter [Mit94], allows files of many formats to be read in, and output files of many forms to be generated, so too must the database accept input from a variety of formats, and support browsing using a wide variety of tools. It is likely that the database will exist in a single format (e.g. SGML or HTML), common to most browsing tools.

Authoring and Production Environment: While no single authoring environment can or should become an inflexible standard for all database authors, it is still reasonable for the database to recommend the authoring or multimedia production environment which would streamline the process of bringing new information into the database. As new authoring and production tools become available (e.g. ScriptX [Kal94], WebFORCE [SGI95], or works being developed at Dartmouth [O'Co95]), they will be assessed for use in the authoring environment.

Browsing and Playback Environment: Some consideration will also be made for making the database compatible with currently available and popular browsing and playback tools. Activity here will center on ensuring the database format can be accessed and presented easily by these tools.

Synthesis with New Tools: The Internet and related technologies are, today, in a state of great flux. The database must, therefore guard against being left behind by the information marketplace, by continual evaluation of new tools, beyond those used in authoring and retrieving information.

Search Engines and Other Tools: Conventional search engines are already employed in a wide variety of Web-accessible documents and information resources. Searches across the Internet are also available. Texis [Mne94] is a search engine available from Mnemotrix, Inc. which has been used largely for non-science applications over the past fifteen years. However, its ability to format a database for searching based on concepts and relationships, rather than simply on keywords, makes it best suited for our purposes.

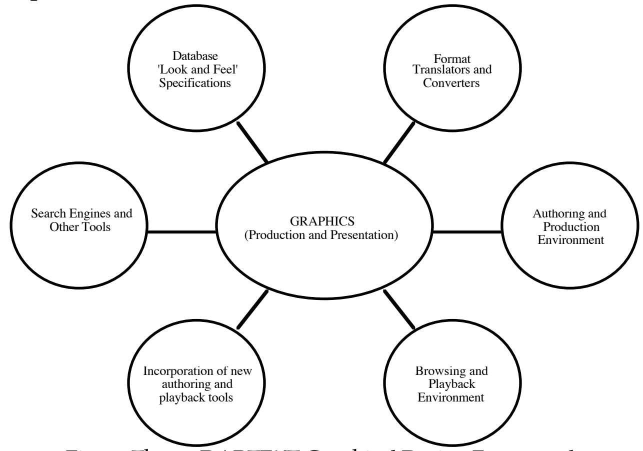

Figure Three: DARTEXT Graphical Design Framework

C. Transactions: Intellectual Property

The essential transaction associated with our concept is the exchange of intellectual property for financial property, and vice versa.

Intellectual property is created by authors, and becomes the database content. Customers access this property in a variety of ways. Since the core of the database is its content, the intellectual property framework is arguably the most important, and is shown in Figure Four.

Content Organization Specification: Within this framework, the organization of the database content must be specified, much the way a textbook is organized according to a Table of Contents, List of Figures, List of Tables, and Index. Here, though, the organization into regular entities will not be as simple as creating textbook 'chapters', with perhaps homework problems and other references listed at the end of each chapter. The place in the database for labs, exams, solutions, video demonstrations and simulations, synthesized software tools, and other new entities must be determined well in advance. Early thinking regarding the framework of the database will reap great future benefits. The database must be flexible to accommodate future submissions, while meeting the needs of present-day instructors and students.

Review of Submitted Material: We expect material submitted to the database will come from a wide variety of authors. Students of all ages and abilities, instructors at all levels, and others can be expected to become, not just consumers of information in the database, but authors and creators of information. Lowering the barriers to submission, by allowing contributions of the longest or shortest lengths to be submitted, is a critical feature of our concept.

We expect any author will use those authoring tools which are most convenient or well-known. We also expect translators between output formats for these different tools will be cheap, reliable, and ubiquitous. In a very real sense, then, many of the production tasks now handled by publishers and their subcontractors will be taken up by the authors, and their software tools, themselves.

Submission of material will take place electronically. The database will have well-publicized standards for the format of submissions, much the way academic journals have standards for font size, typeface, margins, and other attributes of printed material.

An editorial review board will examine material submitted to the database. It shall determine whether the new material fits into the database framework, and if so whether the material should take its own place in the database, or replace existing material. The board also has the responsibility to determine the database structure and organization itself, and make changes to them as changing conditions warrant.

Update Database: Any dynamic object must change in order to improve and survive. It will be the responsibility of the editorial review board to be the 'change agent'. As a consequence, some information, over time, will become obsolete. The board will determine whether newly submitted material is unique, and should enter the database on its own merits; or, whether it re-states material currently in the database in a new way. The board must be willing to take risks and experiment. They must devote a portion of the database to new formats for presentation, or new content, or even new media (for instance, adding sound and video to present textbooks; or adding smells to future textual products).

Legal Services: Legal services in this arena will focus on copyrights and licensing issues. A number of endeavors are underway to address copyright issues for the Internet [Eri94].

Accounting: Again, accounting will be necessary to manage the flow of information into the database, and the exchange of financial property (e.g. shares in the database) for it.

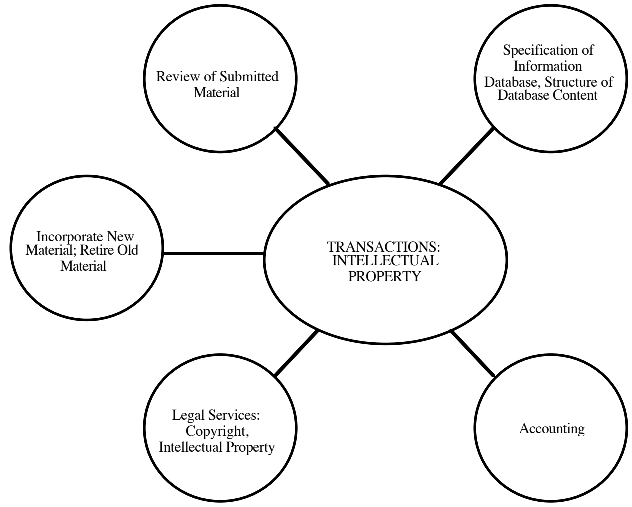

Figure Four: DARTEXT Intellectual Property Transaction Framework

D. Transactions: Finances

Once the intellectual property is created and made accessible, it must be exchanged for some other property, typically financial. Figure Five depicts the support framework for these exchange activities.

Initially, in developing our concept, we considered whether each database should be so self-regulating, that its cost would be free to the individual user. In the end, however, it became clear that each database, to be truly successful, must be operated on a for-profit basis. This conclusion was driven primarily by the realization we had chosen an intermediate level of editorial oversight, between the constricting control exercised by authors of present-day textbooks, and the virtual absence of control exercised over its content by an Internet topical newsgroup. Having chosen a middle path (with intellectual rigidity and high profits on the one hand, and intellectual chaos and no profits on the other), we developed the intention that each database exist on a for-profit basis.

Having made this decision, several options present themselves. Charges could be made on a per-transaction basis. In this scenario, a record of each piece of information accessed by the user would have to be kept, with appropriate charges made for this access, and billings sent on a periodic basis. In some sense, such an accounting scheme would build on, or be parallel to, efforts to implement interactive learning [Eri95]. We believe this choice to be too cumbersome for the maintainers of the database, and too confusing for consumers.

We prefer instead the subscriber model. Users will pay a fixed fee to purchase a compact disk containing the most current version of the database. Our preliminary studies indicate the consumer cost for this CD will be approximately $25. Users will also get access to server for limited period of time. Time extensions and/or CD upgrades may be purchased for a small, periodic fee (e.g. $5/year). Current research into distributed learning environments and their ramifications should solve difficulties which may arise from having database information on both a local hardcopy (CD), and a remote, more updated softcopy. However, our studies indicate customers prefer to receive a tangible asset in return for money, making the CD the most attractive vehicle for distribution of the database.

Authors must receive remuneration for their contributions to the database. In order to handle this necessity, we have conceived of a *stock model* to represent the intellectual capitalization of the database. The database will receive an initial capitalization of, say, ten thousand shares. Following conception and publication of the first structure and organization of the database, the editorial review board will determine how many shares of the total capitalization to make available to authors. Some shares will be held in reserve for future authors and contributors. Contributors whose works are accepted for inclusion in the database will receive shares in return. Profits after expenses, based on subscriptions, will then be distributed to the authors on a per-share basis. The number of shares held by each contributor will be set by the editorial review board, in proportion to the value of the contribution to the database. Once the initial capitalization is exhausted, it will be up to the board to determine when material must be retired (and its contributors must give up their shares), or when new stock should be issued, should the growth and use of the database warrant increased capitalization.

Since contributors of material of nearly any length can receive shares for their contributions, we expect the 'activation energy' for authorship to be small. Potential authors will not be daunted by the need to commit thousands of hours to complete an entire text. Furthermore, they will be encouraged by the knowledge that even small contributions can receive financial recognition.

Purchasing of Services: A variety of services will need to be purchased, from marketing to network hardware. Sub-contracts will be granted as needed to obtain services not available from personal directly working on the database. In general, most services will be obtained via sub-contract, given the current thrust of American business toward more numerous, smaller, leaner, and quicker companies.

Legal Services: Legal services here will be related to memorializing royalties, shares, and other remunerative issues.

Accounting: Share accounting and other accounting related to financial property is covered here.

Share Assignment: The editorial review board will determine the assignment, reassignment, or retirement of database shares to and for authors.

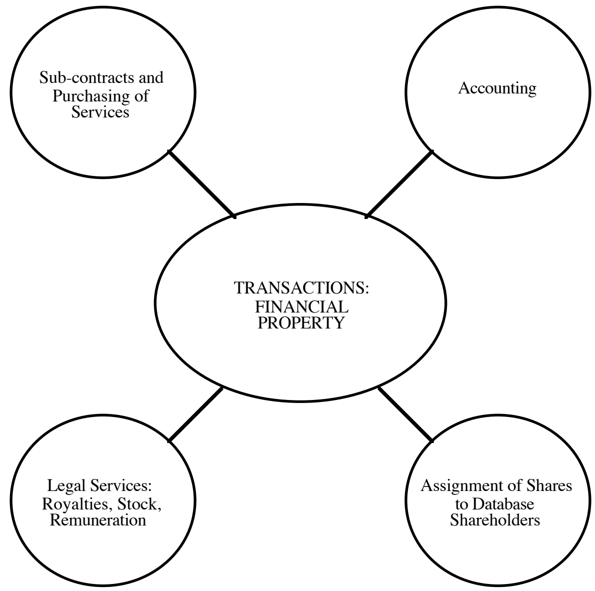

Figure Five: DARTEXT Financial Property Transaction Framework

III. Uniqueness

We believe our concept is unique in important and compelling ways. It mirrors many of the forces and trends in American and world-wide business today: trends toward decentralization, the breakup of conglomerates, 'lean and mean' organizations, down-sized organizations, the spin-off from core competencies of corporate service organizations, just-in-time inventory, and empowering all employees to take greater responsibility for their products. It applies these ideas to the realm of publishing, and creates a new paradigm for publishing in the academic arena. The paradigm is a departure from the idea of a single, or a few, authors as intellectual creators of a text, having complete control over the material. A structural and organizational framework for the textual content of the database takes the place of the textbook, with responsibility for creating material falling to those who will choose to shoulder it, in return for tangible remuneration. In essence, our concept is midway between the rigid form of traditional publishing, and the *hive mind* or *swarm system* conceived by Kelly [Kel94], whose principal attribute is non-controllability, in return for the 'immortality' of the hive or swarm.

Our concept goes beyond recent advances in electronic publishing, which remain at root an exercise of total author control over how the user interacts with an informational database, and even more control over what that database's content may be. Distributed authorship means distributed publication and proofreading costs. It means all users will benefit from a wider variety of viewpoints. Users' feedback on revising and improving the database will be virtually instantaneous compared to conventional textbook publication. The resulting work will not be immutable. Consumers will interact with the product, and have the opportunity to influence its improvement or change.

A. Attributes

Our concept has a number of important attributes. Authorship is distributed. By setting design standards, in the manner that most technical journals these days set layout and design standards, allows authors to create content to these standards, thus minimizing costs of publication. The financial incentives for authorship, even on a small level, promotes active learning by offering incentives for activity, and disincentives to passivity. Students will therefore be more likely to be engaged by the material, through a feeling of authorship beyond mere understanding.

B. Challenges

A number of challenges appear on our horizon. Some must be surmounted before our path can be deemed a success. Most obviously, success will be measured by market acceptance. These challenges are discussed separately in the following paragraphs.

Distributed, Distance, and Interactive Learning: Using communications systems to access information from remote locations has led to the development of systems which facilitate and monitor distributed learning. It is conceivable that tools for distributed learning could also be used to handle copyright management automatically. These tools could monitor use of particular portions of the database, providing the editorial review board with metrics to determine which portions of the database are: unclear and in need of refinement; widely used and appreciated, necessitating perhaps a share readjustment for their authors; or little used, and therefore in need of removal. Interactivity may also be facilitated. In the long run, the database could serve, not only as a source of textual information, but as an evaluative framework for student work. This last extrapolation holds especially for quantitative work with specific answers, such as most present-day homework and exam problems. Open-ended problems, or true design work, will not lend itself to such evaluative services.

Portability: Students have a need for their textbooks to be portable. Studying rarely occurs in a single locale. Lightweight, notebook computers may help extend our concept to address these issues more simply, though even with present technology, the cost of notebooks is usually too great, while they are neither as rugged nor as portable as a conventional textbook.

Bundling Tools: Many courses in mathematics, physics, chemistry, and engineering employ calculation tools such as Matlab, Mathematica, and Maple as key components of instruction. It is possible such tools, and examples based on them, may be bundled with the database. Such use could potentially lower the cost to the students of the software tools. Their incorporation would, however, complicate the legal and accounting pressures on the database owners, however.

Search Engine: The choice of a search engine for the database is important. We have settled on the use of Texis [Mne94]. Its features for content-based searches, or searches based on lexical relationships between words and phrases, is quite strong, and as databases grow will be essential.

Building Coalitions of Authors and Users: It is critical that the need for the database be agreed upon by parties from a number of institutions, academic or otherwise. Whether the common nature of the institutions drives the collaboration, or their common interest, is somewhat immaterial. In either case, a database conceived or formed by a single person or institution will be likely to fail the test of economic success, which is to be profitable. Toward this end, we have established collaborative relationships with Bucknell University.

Choosing Appropriate Databases: To achieve critical mass, get over the initial activation energy, and propel this concept forward, databases with large audiences should be sought first. Introductory calculus, introductory physics, introductory chemistry, and engineering systems appear to be ideal candidates.

Rate of Information Creation and Annihilation (Turnover): We expect databases to focus on two ends of the information 'frequency spectrum'. Here, by 'frequency' we mean the rate at which new information enters the database, especially new knowledge and original content, and not simply re-statements of older presentations. High frequency databases will therefore focus on leading edge technologies, in the early stages of formation. Low frequency databases will focus on introductory material at the undergraduate level. As an example, once formed we would expect a database focused on introductory calculus to change only slowly. However, a database focused on micro-machines and microelectromechanical systems (MEMS) will change rapidly, as new information in this field is being created daily.

Competitive Databases: If our concept proves successful, we expect competitive databases to arise. Since one of our motivations is to lower the cost of instruction materials for the consumer, this eventuality can only improve the cost and performance of each database product. The electronic 'publisher', or consortium responsible for each database, will need to take competitive positions similar to those employed by present-day textbook publishers. For instance, nearly every academic textbook publisher in the sciences carries one or more introductory calculus titles on their list. We expect no different a result with our concept.

IV. CASE STUDY: ENGINEERING SYSTEMS

We present here a brief example derived from the engineering curriculum at Dartmouth College. *Engineering Sciences 22: Systems* is a course founded on the mathematics of ordinary differential equations. Its goals are to instill in students a systems-oriented approach to the analysis and design of systems of any sort, whose state changes over time, and to learn and use the mathematical tools to execute such design and analysis.

The schematic for the thought process which forms the foundation of this Systems course is shown in Figure Six. Students begin with a real-world system of any complexity. The system can be measured using a variety of experimental techniques, which are also taught in the course. The dynamic behavior of the system is then modeled by, first, creating a simplified conceptual model of the system; second, extracting a mathematical model from the conceptual model, using appropriate physical laws; third, solving the mathematical model using appropriate techniques; and finally, comparing the predicted and measured response of the system. If discrepancies are found which are unacceptable, the cycle must be repeated, with adjustments made at any of the points in the circle.

The figure below becomes image mapped, and serves as the point of departure. Students may click on any of the circular points in the process, to determine more detail about specific aspects of the process. Subsequent figures are also image mapped. [In the HTML version of this document, only certain of the image maps are enabled, for purposes of demonstration.]

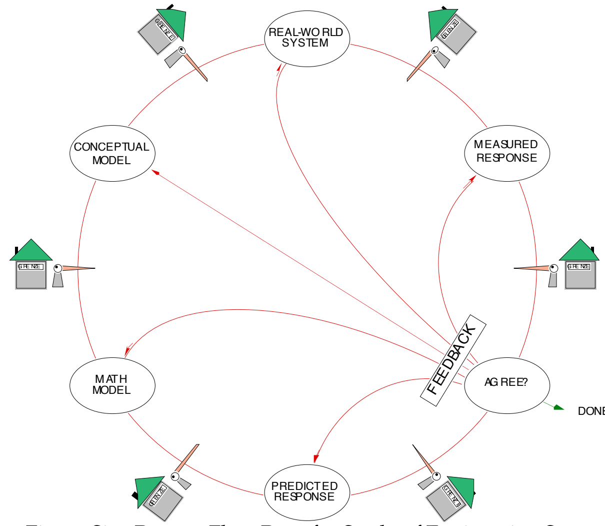

Figure Six: Process Flow Page for Study of Engineering Systems

Let us assume we are a student, given a real pendulum as a system to analyze. Let us also assume the student has already conducted a series of experiments to measure the system's response subject to a delta-function input, has stored the data, and now must analyze the system. The first step is to create a conceptual model. The student turns to the Conceptual Model Page (Figure Seven).

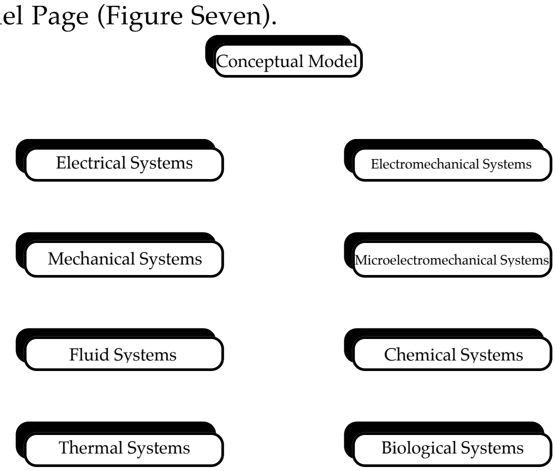

Figure Seven: Conceptual Model Page

Here, there are any number of systems to choose from, but clearly this particular system is a mechanical system. There are a number of avenues away from the 'Mechanical System' hyperlink. Some point toward specific examples, as in Figure Eight, which fit the framework of dynamical systems described by first- and second-order, linear differential equations. Others may point to the physical laws which describe the behavior of mechanical systems (that is: Newton's laws), and more extensive descriptions of creating conceptual models from real systems using these laws.

	MECHANICAL SYSTEM EXAMPLES		
	1st-Order	2nd-Order (undamped)	2nd-Order (damped)
INPUTS: 0	Book Sliding on Table		
INPUTS: $\delta(t)$			Pendulum
INPUTS: $u(t)$			
INPUTS: $u(t)\cos(\omega t)$			
INPUTS: $\cos(\omega t)$			Rotary-Mechanical System

Figure Eight: Examples Matrix Page for Mechanical Systems

On the Examples Matrix Page for mechanical systems, any number of systems may be represented. Given inputs from authors, the matrix can be expanded to handle: higher order systems; other specific mechanical systems examples; videos or simulations of the dynamic behavior of these systems; and responses of these systems to inputs other than those shown.

Once the student chooses the Pendulum example, and has created a conceptual model for the real pendulum based on the physical laws of mechanical systems, it is time to extract the mathematical model, or differential equation, which describes the system's dynamic behavior, and solve for the predicted response of the system. Figure Nine describes this process in detail. Each step, again, becomes a point of departure. There is also opportunity for more descriptive comparison and contrast of the different methods, to achieve a higher degree of sophistication, and assist students in choosing the most appropriate methods for a given set of boundary conditions, for a particular system, or for a specific input forcing function.

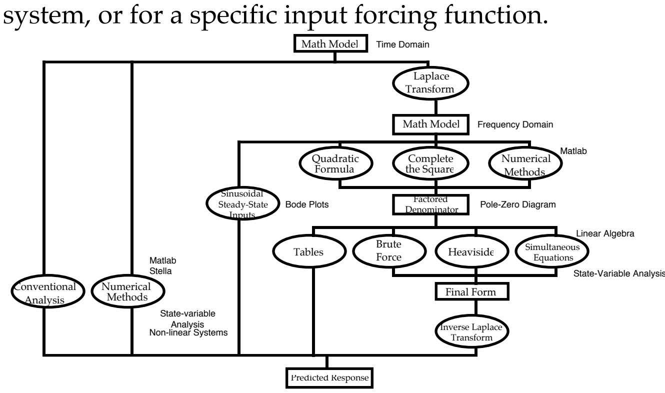

Figure Nine: Mathematical Models and Process Page

The student may choose to remain in the time domain in order to effect a solution of the differential equation. In this case, the student moves to the Time Domain Representation Matrix page (Figure Ten), and can explore the various possible methodologies. Or, the student may choose to utilize Laplace Transform methods, in which case Figure Eleven is the appropriate next step. In both cases, these time and frequency matrices serve as points of departure for finishing off the solution of the problem, and finding the predicted response. Once the predicted response has been achieved -- perhaps by using Matlab or another numerical solution tool -- it can be compared to the data taken previously. If satisfactory agreement is not reached, the student can return to the top level of the process, or any intermediate level, at any time.

	TIME DOMAIN SYSTEM REPRESENTATIONS		
	1st-Order	2nd-Order (undamped)	2nd-Order (damped)
INPUTS: 0	$\frac{dx}{dt} + ax = 0$	$\frac{d^2x}{dt^2} + ax = 0$	$\frac{d^2x}{dt^2} + b\frac{dx}{dt} + ax = 0$
INPUTS: $\delta(t)$	$\frac{dx}{dt} + ax = \delta(t)$	$\frac{d^2x}{dt^2} + ax = \delta(t)$	$\frac{d^2x}{dt^2} + b\frac{dx}{dt} + ax = \delta(t)$
INPUTS: $u(t)$	$\frac{dx}{dt} + ax = u(t)$	$\frac{d^2x}{dt^2} + ax = u(t)$	$\frac{d^2x}{dt^2} + b\frac{dx}{dt} + ax = u(t)$
INPUTS: $u(t)\cos(\omega t)$	$\frac{dx}{dt} + ax = u(t)\cos(\omega t)$	$\frac{d^2x}{dt^2} + ax = u(t)\cos(\omega t)$	$\frac{d^2x}{dt^2} + b\frac{dx}{dt} + ax = u(t)\cos(\omega t)$
INPUTS: $\cos(\omega t)$	$\frac{dx}{dt} + ax = u(t)\cos(\omega t)$ Ignore Boundary Conditions →	$\frac{d^2x}{dt^2} + ax = \cos(\omega t)$	$\frac{d^2x}{dt^2} + b\frac{dx}{dt} + ax = \cos(\omega t)$

Figure Ten: Time Domain Representation Matrix Page

	FREQUENCY DOMAIN SYSTEM REPRESENTATIONS		
	1st-Order	2nd-Order (undamped)	2nd-Order (damped)
INPUTS: 0	$X(s) = \frac{x(0)}{s+a}$	$X(s) = \frac{s\,x(0) + x'(0)}{s^2+a}$	$X(s) = \frac{(s+b)\,x(0) + x'(0)}{s^2+bs+a}$
INPUTS: $\delta(t)$	$X(s) = \frac{1}{s+a} + \frac{x(0)}{s+a}$	$X(s) = \frac{1}{s^2+a} + \frac{s\,x(0) + x'(0)}{s^2+a}$	$X(s) = \frac{1}{s^2+bs+a} + \frac{(s+b)\,x(0) + x'(0)}{s^2+bs+a}$
INPUTS: $u(t)$	$X(s) = \frac{1}{s(s+a)} + \frac{x(0)}{s+a}$	$X(s) = \frac{1}{s(s^2+a)} + \frac{s\,x(0) + x'(0)}{s^2+a}$	$X(s) = \frac{1}{s(s^2+bs+a)} + \frac{(s+b)\,x(0) + x'(0)}{s^2+bs+a}$
INPUTS: $u(t)\cos(\omega t)$			
INPUTS: $\cos(\omega t)$	$Y(s) = \mathcal{L}[\cos(\omega t)]$ $X(s) = G(s)\,Y(s) = \frac{1}{s+a}Y(s)$	$X(s) = \frac{1}{s^2+a}Y(s)$	$X(s) = \frac{1}{s^2+bs+a}Y(s)$
	← $x(t) = \lvert G(j\omega)\rvert \cos[\omega t + \angle G(j\omega)]$ →		

Figure Eleven: Frequency Domain Representation Matrix Page

Clearly, the opportunities for additional contributions to this framework are enormous. Video, sound, still photos, experiments, numerical examples, worked homework problems and exam problems, open-ended analysis or design problems -- all may be incorporated, with full hyperlinks. Such links, of course, may point outside this Systems database, as required or desirable. Historical examples and anecdotes can be incorporated.

This framework for studies of engineering systems focuses on the *process* of solving and analyzing systems, based on the foundations of ordinary differential equations (ODEs). ODEs become the unifying principles for studying systems from every discipline. As a result, the framework is rich and complex, yet has a common and unifying point of departure for the study of all systems. The framework is flexible, in that other systems, other analytical techniques (e.g. numerical methods), other examples, other perspectives (e.g. historical) can all be added with relative ease, by virtually any user or prospective author.

V. Conclusions

We have presented our concept for the authoring and retrieval of textual information which, in the past and even present, would be presented as a bound textbook. Given the power of present and future technology, however, the restrictions of this format have truly become antiquated and obsolete. We envision replacing the traditional means of authoring and publishing, by a new set of frameworks. These frameworks will create dynamic, living databases of information, textual in nature, which address the needs and sophisticated expectations of a large, computer-literate audience.

We have begun the process of developing one such database, using the body of knowledge termed Engineering Systems Analysis and Design as our point of departure from tradition.

Finally, we note that American institutions of higher learning will be under increasing financial pressures in the next decade. The problems faced by government and industry over the last several years cannot be avoided by academe. We believe our concept can facilitate this downsizing trend by decreasing the cost of access to textual information for students and researchers, and by extending the useful life of information rendered into textual form. At the same time, it will maintain high publication standards, and incorporate new and stimulating technology. Productivity will be increased by consolidating repetitive and redundant commercial resources and distributing tasks, such as document preparation and proofreading, to authors, publishers, and users of the textual information.

Acknowledgments

Numerous discussions with colleagues across the country have refined our ideas, first sketched out during the American Society of Engineering Education conference in Edmonton, Alberta in June of 1994. The feedback of John Erickson and Dan O'Connor of the Interactive Media Lab at Dartmouth deserves special recognition.

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