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Digital Libraries as Learning and Teaching Support

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Abstract: For 30 years repeated attempts have been made to use computers to support the teaching and learning process, albeit with only moderate success. Whenever major attempts failed, some seemingly convincing reasons were presented the for less than satisfactory results. In the early days cost or even lack of suitable equipment was blamed; after colour graphics computers started to be widespread, production costs of interactive and graphically appealing material were considered the main culprits; when modern multimedia authoring techniques did not change the situation either, the lack of personalized feed-back, of network support and the difficulty of producing high quality simulations were seen as main obstacles. With networks now offering excellent multimedia presentation and communication facilities the final breakthrough of computers as ultimate teaching and learning tool is (once more) predicted. And once more results will be disappointing if one crucial component is again overlooked: good courseware must give both guidance to students but also provide a rich variety of background material whenever such is needed. It is the main claim of this paper that the advent of sizeable digital libraries provides one of the most significant chances for computer based training ever. We will argue that such libraries not only allow the efficient production of courseware but also provide the extensive background reservoir of material needed in many situations.

Key Words: Digital libraries, electronic libraries, learning support, teaching support, instructional technology, CAI, CBT

Category: H.3, H.4, H.5, K.3

1 Introduction

The saga of trying to use computers for education and training goes back well over thirty years. Rather than repeating all that has been said over and over we refer to one of the last major "presentation type" efforts in computer assisted instruction, COSTOC, and the arguments presented there, see (Makedon et al 1987) and (Huber et al 1989). The essence is, however, that even large scale projects involving fairly high quality animated colour graphics and sophisticated question-answer mechanisms did not succeed as replacement or even support for teaching on a large scale: although some successes due to better production tools ranging from Hyper-Card and Toolbook to Authorware and particularly HM-Card (Maurer et al 1995) have been attained, supported by the integration of advanced media such as digital audio and video segments a decisive change has not occured mainly due to three facts: (a) courseware has been always difficult to customize; (b) students did not have sufficient background material available in electronic form when getting stuck; and (c) no direct feedback from students to teachers has been provided in most cases in the past.

We believe that the proper use of digital libraries imbedded in modern "second generation" hypermedia systems is about to offer the best chance ever to succeed in using computers for educational purposes.

This paper is structured as follows. In Section 2 we explain the need for second generation hypermedia systems and how they relate to digital libraries. In Section 3 we describe how such digital libraries can address the points (a) - (c) mentioned above. And we will argue in Section 4 that the always mentioned problem of copyrights and payments for electronic books can indeed be solved easily using existing techniques. The paper concludes with references in section 5.

For a general look on hypermedia see (Nielsen 1995). For a survey of applications (Lennon et al 1994b).

2 Second generation systems and digital libraries

In this section we explain some of the properties of first generation hypermedia systems, using WWW as the most prominent example. We contrast them with those of Hyper-G, the first second generation model. We confine attention to networked hypermedia systems with a client/server architecture. For completeness' sake we refer to papers describing important attempts such as Gopher (Alberti 1992 et al), WWW (Berners-Lee et al 1992), IRIS (Haan et al 1992), WAIS (Kahle et al 1992). For papers on Hyper-G see (Andrews et al 1995a), (Andrews et al 1995b), (Kappe et al 1994), (Maurer 1994), and the book (Maurer 1996b).

Information in a hypermedia system is usually stored in "chunks". Chunks consist of individual documents which may themselves consist of various types of "media". Typically, a document may be a piece of text containing a picture. Each document may contain links leading to (parts of) other documents in the same or in different chunks. Typical hypertext navigation through the information space is based on these links: the user follows a sequence of links until all relevant information has hopefully been encountered.

In WWW, a chunk consists of a single document. Documents consist of textual information and may include pictures and the (source) anchors of links. Pictures and links are an integral part of the document. Pictures are thus placed in fixed locations within the text ("inline images"). Anchors can be attached to textual information and inline images, but not to parts of images. Links may lead to audio or video clips which can be activated. The textual component of a document is stored in so-called HTML format, a derivative of SGML.

In Hyper-G the setting is considerably more general: chunks, called "clusters" in Hyper-G terminology consist of a number of documents. A typical cluster may, for example, consist of five documents: a piece of text (potentially with inline images), a second piece of text (for example in another language, or a different version of the same text, or an entirely different text), a third piece of text (the same text in a third language perhaps), an image and a film clip. Anchors can be attached to textual information, to parts of images, and even to regions in a film clip. Links are not part of the document but are stored in a separate database. They are both typed and bidirectional: they can be followed forward (as in WWW) but also backwards.

Hyper-G allows multiple pieces of text within a cluster to handle e.g., multiple languages in a natural way. This also elegantly solves the case where a document comes in two versions: a more technical (or advanced) one and one more suitable for the novice reader. As indicated, pictures can be treated as inline images or as separate documents. Often, inline images are convenient, since the "author" can define where the user will find a picture in relation to the text. On the other hand, with screen resolution varying tremendously, the rescaling of inline images may pose a problem: if a picture is treated as separate document, however, it appears in a separate window, can be manipulated (shifted, put in the background, kept on-screen while continuing with other information, etc.) independent of the textual portion (which in itself can be manipulated by for example narrowing or widening its window). Thus, the potential to deal with textual and pictorial information separately provides more flexibility when required. Text can be stored in Hyper-G in a number of formats, clearly important for digital library purposes.

In addition to the "usual" types of documents found in any modern hypermedia system, Hyper-G also supports 3D objects and scenes.

Let us now turn to the discussion of the philosophy of links in WWW versus Hyper-G. The ability to attach links to parts of a picture is clearly desirable, when additional information is to be associated with certain sub-areas of an image. That links are bidirectional and not embedded in the document has a number of very important consequences: first, links relating to a document can be modified without necessarily having access rights to the document itself. Thus, private links and a certain amount of customisation are possible; second, when viewing a document it is possible to find all documents refering to the current one. This is not only a desirable feature as such, but is of crucial importance for being able to maintain the database. After all, when a document is deleted or modified, all documents refering to it may have to be modified to avoid the "dangling link syndrome", or to avoid being directed to completely irrelevant documents. Hyper-G offers the possibilty of automatically notifying the owner of a document that some of the documents that are being refered to have been changed or deleted, an important step towards "automatic link maintainance". Thirdly, the bidirectionality of the links allows the graphic display of a "local map" showing the current document and all documents pointing to it and being pointed at, an arbitrary number of levels deep. Harmony makes full use of this fact and provides local maps as an invaluable navigational aid that cannot be made available for WWW databases (Fenn et al 1994). Finally, the fact that links can have types can be used to show to the user that a link just leads to a footnote, or to a picture, or to a film clip, or is a counter- or supporting argument of some claim at issue: typed links enhance the perception of how things are related and can be used as tool for discussions and collaborative work.

Navigation in WWW is performed solely using the hypertext paradigm of anchors and links. It has become a well accepted fact that structuring large amounts of data using only hyperlinks such that users don't get "lost in hyperspace" is difficult to say the least. WWW databases are large, flat networks of chunks of data and resemble more an impenetrable maze than well-structured information. Indeed every WWW database acknowledges this fact tacitly, by preparing pages that look like menus in a hierarchically structured database: items are listed in an orderly fashion, each with an anchor leading to a subchapter (subdirectory). If links in WWW had types, such links could be distinguished from others. But as it is, all links look the same: whether they are "continue" links, "hierarchical" links, “referential” links, “footnote links”, or whatever else.

In Hyper-G not only can have links a type, links are by no means the only way to access information. Clusters of documents can be grouped into collections, and collections again into collections in a pseudo-hierachical fashion. We use the term “pseudo-hierarchical” since, technically speaking, the collection structure is not a tree, but a DAG. I.e., one collection can have more than one parent: an impressionist picture X may belong to the collection “Impressionist Art”, as well as to the collection “Pictures by Manet”, as well as to the collection “Museum of Modern Art”. The collection “hierarchy” is a powerful way of introducing structure into the database. Indeed many links can be avoided this way (Maurer et al 1994), making the system much more transparent for the user and allowing a more modular approach to systems creation and maintainance. Collections, clusters and documents have titles and attributes. These may be used in Boolean queries to find documents of current interest. Finally, Hyper-G provides sophistacted full-text search facilities. Most importantly, the scope of any of such searches can be defined to be the union of arbitrary collections, even if the collections reside on different servers.

Note that some WWW applications also permit full-text searches. However, no full-text search engine is built into WWW. Thus, the functionality of full text search is bolted “on top” of WWW: adding functionality on top of WWW leads to the “Balkanisation”, the fragmentation of WWW, since different sites will implement missing functionality in different ways. Thus, to stick to the example of the full text search engine, the fuzzy search employed by organisation X may yield entirley different results from the fuzzy search employed by organisation Y, much to the bewilderment of users. Actually, the situation concerning searches in WWW is even more serious: since documents in WWW do not have attributes, no search is possible on such attributes; even if such a search or a full text search is artificially implemented, it is not possible to allow users to define the scope for the search, due to the lack of structure in the WWW database. Hence full-text searches in WWW always work in a fixed, designated part of the WWW database residing on one particular server.

The acceptance of a hypermedia system is certainly not only dependent on deep technical features, but above all on the information content and the ease of use. Due to the fact that large hypermedia systems tend to lead to disorientation, second generation hypermedia systems have to try very hard, both at the server and at the client end, to help users with navigational tools. Some navigational tools, like the structuring and search facilities have already been described; others, such as maps, history lists, specific and personal collections can also be of great help and are available in Hyper-G; a particular speciality of the Harmony client (assuming an OpenGL environment) is a 3D browser: the “information landscape” depicts collections and documents (according to their size) as blocks of varying size spread out across a three-dimensional landscape, over which the user is able to fly.

The architecture of Hyper-G is clearly well suited for handling the material one would want to put into an electronic library. Such material includes traditional journals in electronic form, see e.g., (Calude et al 1994) and (Maurer et al 1994), books in electronic form, see e.g., the Internet guide found under http://iicm.tu-graz.ac.at/Cinternet_guide, courseware such as found under http://iicm.tu-graz.ac.at/Chmcard, diverse pictures, audio- and video-clips, etc. The structuring and search facilities of Hyper-G allow easy access to information, the variety of navigational tools help to prevent the "lost in hyperspace" phenomenon, and the fact that links can be added to documents even if one is not allowed to change the contents of the document allow a high degree of customisation and personalisation. Finally, the multimedia capabilities available supported by the animation and question-answer facilities of HM-Card (Maurer et al 1996a) provide the possibility to prepare modern instructional material and integrate it into the digital library.

3 How to use a digital library

¿From the student's point of view a digital library is used by "activating" certain material as "relevant background material" to define the scope of future searches (in Hyper-G this is done by defining suitable collections) and then by starting an instructional unit. While working through such a unit students can perform all kinds of searches within the background material as it becomes necessary. Indeed they can create their own links, thus being able to personalize and customize as they find it appropriate. Students cannot only read documents, they can prepare their own documents by integrating into passages they have written (using links) sections of books, journals or other works as may be pertinent.

¿From the teacher's point of view the availability of the digital library and the possibility to prepare instructional material by combining existing ressources with those made up by the teachers for a particular purpose is especially important. This reduces the amount of work to prepare courseware and allows to change courseware at will by adding, deleting or changing sections. Note that this is done by using the flexible link concept of Hyper-G to combine components rather than "copying and pasting" components together. Using the link structure for this purpose has two significant advantages: first, link consistency is much easier to maintain; second, copying and pasting results is usually violating copyrights and royalties to be payed for material being used. We will see in the next section that this problem does not occur when proper linking mechanisms are used as already proposed by Ted Nelson's "transclusions" (Nelson 1987). Indeed preparation of courseware can be done "on the fly", i.e., as part of presenting lectures as we have first pointed out in (Lennon et al 1994a). For a more complete description of digital libraries see (Marchionini et al 1995).

4 Commercial aspects of a digital library

When electronic material is sold over networks some charging mechanisms are necessary. Assuming that users identify themselves with some username/password combination, charging mechnisms typically are:
(1) by time,
(2) by volume,
(3) by number of accesses,
(4) by subscription.

Note that in cases (1) – (3) there is some potential danger to the user (if others manage to get access to the username/password – something fairly easy to do on the Internet), and that (4) is dangerous to the publisher: persons may allow friends to use their username/password, resulting in many more readers than paid subscribers. Thus, (1) – (3) requires sophisticated security mechanisms (see e.g., (Posch 1995)) to protect users, (4) requires additional mechanisms to protect publishers.

An alternative is to use pre-paid accounts that e.g. allow a fairly liberal yet limited number of accesses. This is a mix of essentiallly (3) and (4) that offers a number of advantages: Even if the username/password is dedected by others it is only of limited use and can cause only limited damage (by illegally "exhausting" the pre-paid sum). Thus, the consumer is better protected in this mode, hence complicated security measures are not that essential. The publisher is also protected: users who pass on their username/password are welcome to do so. After all, whatever use they or friends make of the material offered has been pre-paid. This latter technique has e.g. been used with the electronic version of the ED-MEDIA'95 proceedings, see http://hyperg.iicm.tu-graz.ac.at/Cedmedia or http://hyperg.iicm.tu-graz.ac.at/Celectronic_library.

All of the above assumes that the information resides on one (or a few) servers in the Internet and users access that server. We consider such assumptions unrealistic for two reasons. First, world-wide access to Internet nodes is often painfully slow; second, if large numbers of users access a server, it and Internet connections leading to it will be overloaded unless complex counter-measures are taken.

For this reason we have been propagating for some time that electronic material should reside in local servers, with Internet used to update the material, but users accessing the local (library) servers. This approach taken in J.UCS (see (Maurer et al 1994), (Calude et al 1994)) improves performance for users and also allows publishers a new way of selling information: they sell for each server a license for "at most n simultaneous users", where n can be arbitrary. Typically, a university library could start with $n=1$ and increase n as necessary (i.e. if the material is popular enough that often more than a single user wants to access it at the same time). Note that "same time" is really a parameter that can be adjusted by publishing companies: it means "an electronic book accessed by a person is blocked for other persons for m minutes" (values of m that we have actually experimented with are between 3 and 10 minutes); observe in passing that connection - less protocols such as http in WWW are not well suited for this approach since persons accessing a book block themselves from accessing it again shortly thereafter; this is one of the many reasons why a connection-oriented protocol is built into Hyper-G. The above charging regime is easy to administer for publishers, and allows to install electronic material on a network for all users of the network at low cost (a single license), yet upgrading is easy. Note that the upgrades can even be system supported: Suppose the license is set to "20 users at a time" and the system monitors that usage is increasing steadily and peaks of 19 simultaneous users become more and more frequent; then the system can alert the librarian to buy additional licenses. Indeed variants are possible: no limit to the number of simultaneous users is fixed, but the charges for some electronic material are made to depend on the "average number of simultaneous users".

We now come to the main point: using second generation systems like Hyper-G and a version of above charging regime it is possible to customize material from various sources without violating copyright restrictions. This is so since customisation in systems such as Hyper-G is done by linking not by copying, very much in the spirit of Nelson's Xanadu proposal.

To be concrete, suppose on a server a number of books from various publishers have been installed, each licensed for some number of simultaneous users.

An instructor wanting to customise information by taking material from various books and combining it (potentially integrating own material) can do so in Hyper-G by not copying the material but by adding links that are only visible to a specific group, e.g. the group of intended students. This is depicted in a small example in Fig.1 .

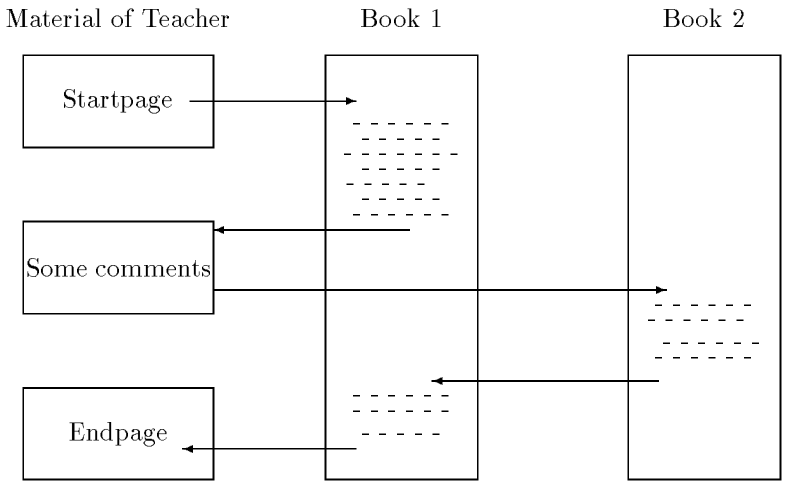

Fig.1

The arrows in Fig. 1 present links created by the teacher and are only visible to the intended usergroup.

Note that the teacher has thus combined the information on the “Startpage” with a section of Book 1, followed by “Some comments”, a section in Book 2, a further section in Book 1 and some material on the “Endpage”. Even if Book 1 and Book 2 are from different publishers no copyright violation accurs: if many students use the material as customised, Book 1 will be accessed more often then Book 2, hence the number of licenses for Book 1 may have to be increased, as should be the case.

Thus, holding electronic material in LAN’s and using systems such as Hyper-G customisation is not only possible but can be done without any infringements on copyrights. In a way what the proposed set-up does is to implement Nelson’s vision of “world-wide publishing using transclusion” (Nelson 1987) in a local environment.

5 References

References

[Alberti et al 1992] Alberti, B., Anklesaria, F., Lindnder, P., McCahill, M., & Torrey, D.(1995). Internet Gopher Protocol: A Distributed Document

Search and Retrieval Protocol; FTP from boombox.micro.umn.edu, directory pub/gopher/gopher_protocol.

[Andrews et al 1995a] Andrews, K., Kappe, F., Maurer, H., & Schmaranz, K. (1995). On Second Generation Hypermedia Systems. *Proc.ED-MEDIA'95*, Graz (June 1995), 75-80. See also J.UCS 0,0 (1994),127-136 at http:///www.iicm.tu-graz.ac.at /Cjucs_root.

[Andrews et al 1995b] Andrews, K., Kappe, F., & Maurer, H. (1995). Serving Information to the Web with Hyper-G; *Computer Networks and ISDN Systems 27 (1995)*, 919-926.

[Berners-Lee et al 1992] Berners-Lee, T., Cailliau, R., Groff, J., & Pollermann, B. (1992) WorldWideWeb: The Information Universe. *Electronic Networking: Research, Applications and Policy 1,2 (1992)*, 52-58.

[Calude et al 1994] Calude, C., Maurer, H., & Salomaa, A. (1994). J.UCS: The Journal of Universal Computer Science. *J.UCS 0,0 (1994)*, 109-117 at http://www.iicm. tu-graz.ac.at/Cjucs_root.

[Fenn et al 1994] Fenn, B.& Maurer, H. (1994). Harmony on an Expanding Net; *ACM Interactions 1,3 (1994)*, 26-38.

[Haan et al 1992] Haan, B.J., Kahn, P., Riley, V.A., Coombs, J.H. & Meyrowitz, N.K. (1992). IRIS Hypermedia Services; *Communications of the ACM 35,1 (1992)*, 36-51.

[Huber et al 1989] Huber, F., Makedon, F., & Maurer, H. (1989). HyperCOSTOC: a Comprehensive Computer-Based Teaching Support System. *J.MCA 12 (1989)*, 293-317.

[Kahle et al 1992] Kahle, B., Morris, H., Davis, F., Tiene, K., Hart, C., & Palmer, R. (1992). Wide Area Information Servers: An Executive Information System for Unstructured Files; *Electronic Networking: Research, Applications and Policy 1,2 (1992)*, 59-68.

[Kappe et al 1994] Kappe, F., Andrews, K., Faschingbauer, J., Gaisbauer, M., Maurer, H., Pichler, M., & Schipflinger, J. (1994). Hyper-G: A New Tool for Distributed Multimedia; *Proc.Conf.on Open Hypermedia Systems, Honolulu (1994)*, 209-214.

[Lennon et al 1994a] Lennon, J., & Maurer, H. (1994). Lecturing Technology: A Future With Hypermedia; *Educational Technology 34,4 (1994)*,5-14.

[Lennon et al 1994b] Lennon, & Maurer, H. (1994). Applications and Impact of Hypermedia Systems: An Overview. *J.UCS 0,0 (1994)*, 54-108 at http://www.iicm.tu-graz.ac.at/Cjucs_root.

[Makedon et al 1987] Makedon, F., Maurer, H., & Ottmann, Th. (1987). Presentation Type CAI in Computer Science Education at University Level. *J.MCA 10 (1987)*, 283-295.

[Marchionini et al 1995] Marchionini, G. & Maurer, H. (1995). The Role of Digital Libraries in Teaching and Learning. *Communications of the ACM 38,4 (1995)*, 67-75.

[Maurer 1994] Maurer, H. (1994). Advancing the ideas of WorldWideWeb. *Proc. Conf. on Open Hypermedia Systems, Honolulu (1994)*, 201-203.

[Maurer et al 1994] Maurer, H. & Schmaranz, K.(1994). J.UCS – The Next Generation in Electronic Journal Publishing. Proc. Electronic Publ. Conference, London (November 1994) in: *Computer Networks for Research in Europe 26, Supplement 2-3 (1994)*, 63-69.

[Maurer et al 1995] Maurer, H., Schneider A., & Scherbakov, N. (1995). HM-Care: A New Hypermedia Authoring System. To appear in: *Multimedia Tools and Applications*.

[Maurer et al 1996a] Maurer, H., & Scherbakov, N. (1996). *HM-Card*. Addison Wesley Pub.Co. Germany (1996).

[Maurer et al 1996b] Maurer, H. (1996). *Power to the Web! The Official Guide to Hyper-G*. Addison Wesley Pub.Co., UK (1996).

[Nelson 1987] Nelson, T.H. (1987). *Literary machines.* Edition 87.1, 702 South Michigan, South Bend,IN 46618, USA (1987)
[Nielsen 1995] Nielsen, J. (1995). Hypertext and Hypermedia; Academic Press (1995)
[Posch 1995] Posch, R. (1995). Information Security in Educational Networks. *Proc.ED-MEDIA'95,* Graz (June 1995), 45-50.