Hypermedia and the Teaching of Computer Science: Evaluating an Open System.

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ABSTRACT: The authors have been involved in a project to build an open hypermedia system known as Microcosm. This paper examines the reasons why hypermedia has made so little impact on teaching in higher education. The open hypermedia system, Microcosm is introduced, and an experiment to use the system to support the teaching of SML as a first language is described.

1 The Development of the Use of Hypermedia in Education

Hypermedia has for some time been proposed as an adjunct to printed material within the educational process. However, large scale implementation of such material in any educational setting has yet to materialise, which implies that there are still barriers to the extensive use of hypermedia in education. These may be summarised as follows:

1.1 Authoring is non-trivial

Typically academic staff are already heavily burdened with administrative duties, and although many may initially be enthusiastic about using hypermedia, it is only realistic to recognise that they may be deterred by the extra time involved in learning how such packages are constructed. Much of the hypermedia material that has been produced for education to date, though often very professionally produced, is relatively small in scale; typically HyperCard, or HyperCard-like, stacks with at most a few hundred cards. We have very little experience of authoring large hypermedia systems, of the order of say 10,000 items and 100,000 links, which many believe will demonstrate the real potential for hypermedia. Given this scale of operation, it is clear that the process of linking pieces of information to other related or associated pieces of information cannot be undertaken as a purely manual task. Tools must be provided for automatically creating at least a subset of all the links to be included.

1.2 What is educationally effective hypermedia ?

The most widely reported research study is the Intermedia project at Brown University in the USA [Yankelovich87]. Other studies include the ILAB project at the

University of Southampton [Hall90], the StrathTutor Project at the University of StrathClyde [Mayes88] and the Perseus project at Harvard [Crane87].

Creating an amorphous network of nodes and links through which the learner is left to sink or swim may be even less effective for learning than a strait-jacket of programmed learning [Nielsen90].

There is growing evidence of other problems associated with learning from the more basic forms of hypermedia: getting lost; failing to see the wood for the trees; failing to find material; unmotivated rambling; problems with the interface [Hammond] [Hutchings92a].

1.3 Innovation is not rewarded

The mere availability of hypermedia products is an insufficient condition for their uptake into universities. Experience with CAL over the past fifteen years suggests that university culture is a major obstacle to the improvement of teaching and learning methods. Lecturers who devote extra time to the preparation of teaching materials rarely receive recognition and are unlikely to be rewarded for producing fewer research publications than colleagues. Few institutions provide significant staff training and faculty support for lecturers interested in teaching and using, modifying or producing hypermedia materials [Hutchings92b].

2 The Microcosm Model

Microcosm [Fountain90] is an open Hypermedia system that is the result of research at the University of Southampton. Using Microcosm it is possible to generate large hypertexts very quickly from text, pictures and video materials that are already available. It is then possible to use "mimics" (guided tours) and links for teaching purposes, or it is possible to use the tools provided to browse over a large corpus of information. Microcosm is currently in use in a number of areas of teaching and research.

The range of tools which Microcosm provides place it at a higher level than most currently available hypermedia systems, and make it a particularly suitable environment for integrating data and processes.

Microcosm consists of a number of autonomous processes which communicate with each other by a message passing system. No information about links is held in the document data files in the form of mark-up. All data files remain in the native format of the application that created them. Instead, all link information is held in link databases, which hold details of the source anchor (if there is one), the destination anchor and any other attributes such as the link description. This model has the advantage that it is possible for processes to examine the complete link database as a separate item, and also it is possible to make link anchors in documents that are held on read only media such as CD-ROM and video disk.

In Microcosm the user selects the item of interest (e.g. a piece of text) and then chooses an action to take. We may see this as selecting an object then sending it a message. A button in Microcosm is simply a binding of a specific selection and a particular action. A particular feature of Microcosm is the ability to generalise source anchors. In most hypertext systems the source anchor for any link is fixed at a particular point in the text. In Microcosm it is possible for the author to specify three levels of generality of link sources.

The generic link . The user will be able to follow the link after selecting the given anchor at *any* point in *any* document.

The local link. The user will be able to follow the link after selecting the given anchor at *any* point in the *current* document.

The specific link. The user will be able to follow the link only after selecting the anchor at a *specific* location in the *current* document. Specific links may be made into buttons.

Generic links are of considerable benefit to the author in that a new document may be created and immediately have access to all the generic links that have been defined for the system. This feature enables authors to extend hypertexts very quickly.

The basic Microcosm processes are viewers and filters.

2.1 Viewers

Viewers are programs which allow the user to view a document in its native format. Included with Microcosm are viewers for ten data formats, such as text, bitmaps, video, audio, animations and micons (moving icons). The viewer is responsible for binding the information into a message, which is sent on to the filter chain where it will look for one or more processes that can satisfy this request. Any Windows application might be used as a viewer, with the proviso that it is possible to select objects, and, at the least, copy them to the clipboard. Microcosm is capable of taking actions upon objects on the clipboard. In cases (such as Word for Windows and Toolbook) where the application has some level of programmability, it is sometimes possible to add a menu to the application so that the application is a viewer in its own right. Thus Microcosm may be considered an umbrella environment, allowing the user to make links from documents in one application package to documents in another application package.

2.2 Filters

The actions that filters take will be of the nature of changing the message, or adding or removing messages.

The filters provided with Microcosm are

Link Databases. Link Databases hold all the information referring to links. More than one database may be installed at a time. It is possible to have a concept of public and private databases.

Show Links. When the user selects a chunk of text and uses the Show Links action this filter will organise the display of *all* available links, including those links which are not buttons, such as generic links.

Compute Links. Sometimes no links have been defined for a particular subject, but by selecting some text and choosing the Compute Links action, the system will very rapidly return a number of other documents within the system that have a similar vocabulary to the selected block. This action relies upon a document index which the system maintains.

Navigational Filters. There is a history mechanism that keeps a list of all documents that have been visited, and allows the user to return to a particular document and a *Mimic* filter allows the user to follow a pre-defined tour through the documents.

3 Description of The SML Project

This application of Microcosm was designed to support the teaching of the SML [Wikstrom87] language to first year undergraduates. There were three components in the material available to the students, through Microcosm: a set of comprehensive lecture notes on SML; a series of supporting documents on specific Computer Science topics and a guided tour, a Mimic, illustrating an SML topic through animations and text.

These students were studying the SML functional language as their first programming language on the Computer Science course. It was the first time that SML had been taught this early and it was expected that some students might find difficulty with the approach. So to support the planned lectures and laboratory classes, it was decided that students would have a session exploring SML through Microcosm. The use of the system was encouraged by setting an assignment half way through the course, after about 3 weeks. Subsequently two machines were left in place and available for general use until the end of the course.

Students were first given a brief description of how to use Microcosm. The opening document of the system offered a choice between self exploration and a guided tour. The material available for investigation came from two sources. Firstly there was the set of lecture notes already given to the students. This included a comprehensive contents table which was chosen as the student's entry point to the stored notes. Most of the items in the contents list were made into buttons, linked to the corresponding section of the notes. But within the notes there were passing references to some topics, such as other programming languages, without any supporting detail. These references were made into generic links to additional descriptive documents written especially for this system. Thus with the Microcosm system students had access to a wider range of information than was available solely from their notes. For example they could read about Pascal, Miranda and Prolog.

The guided tour covered a single topic chosen for its importance when getting to grips with SML: recursion and lists. The mimic started from a simple *length_of_list* function defined in the notes, emphasising its polymorphic nature. This was illustrated by an animation of the successive recursive calls during an evaluation. The animation consisted of a series of bitmaps each of which represented a stage of the evaluation. A semi-abstract diagrammatic notation was chosen for the lists, with list elements as coloured geometric shapes. This was done to emphasize the notion of polymorphism.

The standard animation facilities in Microcosm were well suited to this particular application. Students could run the animation either continuously, to gain an understanding of the process of reduction, or stepwise to study individual steps. An animation sequence can be run both forward and backward (conceivably of help in this application), and the speed of sequencing can be varied between slow/medium/fast.

After the introduction to the *length_of_list* function through text and animation the tour went on to develop its subject. It showed the use of the function with more complex lists, and as a component of a *count_all_elements* function i.e. one counting all elements in a list at every level. It finished by demonstrating the use of the map function to write the same function. Each stage consisted of text and supporting animations. Students were asked to answer a variety of questions as they progressed.

Students were also encouraged to use the History mechanism. With this one may view again either the last viewed document, or a document selected from a list of all those viewed earlier. This navigation device was suggested as a way of "retracing one's steps" and most students used it for this purpose.

Some students were intrigued enough by the system to use it for more than one session. After finishing the exercise they were asked to complete a short questionnaire.

4 Analysis of Logging Data

A new filter was introduced into Microcosm that produced the log files for each user of the system. Each log had the same standard header information which contained session details, such as the student name and the time. Each entry in the log represented a message to view a new document, and contained a time stamp in seconds from the time that the first document was read, details of how the document was launched, the name and type of the document and where appropriate, the text that the link was made from.

Using data from previous similar experiments, a number of spectra were devised based on easily obtainable measurements which would allow the visualisation in 3 dimensions of different interactions with the hypermedia system.

- *Spirit:* a measure of activity in terms of the number of different nodes accessed.

  `Spirit = Number of nodes accessed / Total number of Nodes`

- *Style:* a measure of the way in which information is accessed.

  `Style= Number of Hypertext Actions / Total Number of Actions`

- *Medium:* a measure of the type of information accessed.

  `Medium = Number of Text Nodes Accessed / Total Number of Nodes`

For the task given to students during the SML study, values for *style*, *medium* and *spirit* were calculated for each individual. These values are all objective, quantifiable measures of the manner of an individual's interaction with the system, and as such are applicable to any interactive multi-media information system - not just the one described here on the subject of SML.

5 Results and Conclusions

45 students used the SML application, but only 36 complete log files and questionnaires were collected. The questionnaire contained 25 questions, eight of which are reproduced here. The average session lasted around 30 minutes which corresponds to the booking slots that were available on the two delivery machines, but one quarter of the students returned for more than one session. In these cases it was clear from the logs that some were searching for specific information, which they found and then left, whereas others were exploring the system out of interest.

Correlating values for *style*, *spirit* and *medium* as defined above, it became clear that second time users made greater use of hypertext links, and that the explorers had lower medium, indicating that they found a greater number of non-textual documents than on their first visit.

Question	**Strongly Agree**	**Agree**	**No Comment**	**Disagree**	**Strongly Disagree**
It is easy to become disoriented within the system	10	31	35	24	0
Microcosm Access to lecture notes improved understanding of SML	0	21	48	31	0
The animations clarified recursion	4	48	31	14	3
The History mechanism was helpful	21	52	17	10	0
The Material on subjects other than SML was helpful	0	41	59	0	0
It was easy to find and follow links	10	31	28	24	7
This form of instruction was enjoyable	7	45	34	14	0
The Program is an effective learning resource	14	48	24	14	0

Figure 2: Percentage Responses to Selected Questions.

A question of particular interest to us was to find out whether the students would use the many generic links available to them. An attempt was made to correlate *style* (a measure of the use of hypertext links) with the answer to the question “It was easy to find and follow links”. The results were inconclusive, and indicate that many students thought that buttons in the text were the only links available. Future work will involve an extension to the logging software so that it is possible to identify what sort of link was followed.

A further discovery from the logs was that when searching for a specific piece of information, the students were as likely to use the file box and select a file by its name as they were to use the contents page to move to the correct information. This leads us to believe that file browsing is still a significant method of searching, particularly for the computer literate, and for this reason we are extending the system to allow files to be stored with attributes, particularly a short description, which may be used for this purpose.

In general the results of this work are inconclusive, but this study represents the first attempt to use Microcosm in a full scale trial with students. We have a lot to learn about explaining the concept of generic links. The students were generally very enthusiastic and would have liked the system to have been available on a more convenient basis. The effectiveness of the system as a learning environment has still to be established but there is little doubt that the availability of this material was a useful extra source of support for first year students attempting to grasp a large number of new concepts.

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