Applications and Impact of Hypermedia Systems: An Overview

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Abstract:
"Hypermedia" is a term that is widely misunderstood and misused, often loosely associated with hype about new applications of computers to multimedia. The term "multimedia" is also frequently used with too narrow a meaning. Few people appreciate the likely consequences of the new technology in all its ramifications. This paper is an attempt to show what impact the new technology will have on many aspects of life. One thing is certain: the impact will be tremendous and irresistible. Before long, organisations won't be able to afford *not* to use hypermedia.

We believe that the definition of "multimedia" must be generalised from the usual one (a mix of text, pictures, graphics, animations, video and sound) to include 3D objects, 3D models of scenes of arbitrary complexity, interactive movies, diagrams, maps, CAD drawings and much more. A hypermedia system can be defined as multimedia, with links, embedded in a network, i.e. a networked system supporting the storage and retrieval of linked multimedia and the real-time transfer of this data among the terminals in the network.

It can be argued that hypermedia systems can revolutionise work, leisure, and lifelong learning.

Applications of hypermedia discussed in this paper include:

- Administration: A fully integrated system such as the one proposed will mean efficient data processing and valuable statistical data.
- Electronic orientation and information displays: Electronic guided tours, public information kiosks and publicity dissemination with archive facilities.
- Electronic Personal Assistants: Hypermedia systems will turn into powerful personal digital assistants as they make information and communication available when needed.
- General Information and Communication Systems: Distributed information systems for purposes such as businesses, schools and universities, museums, libraries, health systems....
- Lecturing: A system going beyond the traditional to empower both teachers and learners.
- Libraries: A further step towards fully electronic library systems.
- Directories of all kinds: Staff, telephone and all sorts of generic directories.
- Research: Material can now be accessed from databases all around the world. The effects of networking and computer supported collaborative work are discussed and examples of new scientific visualisation programs are quoted.

The paper concludes with a section entitled "Future Directions".

Key Words: multimedia, hypermedia, Internet, Hyper-G, hyperlinks, collections, converging technology, e-mail, libraries, electronic publishing, kiosks, CSCW, conferencing, life-long learning, electronic lecture room, CAI, electronic personal assistant.

1 Introduction

Film, television, video and computer technologies have converged dramatically. We now see competing thrusts from interactive T.V., videotex, both orthodox and unorthodox [Maurer and Sebestyen 1982], video-on-demand and CD-ROM technology that, coupled with the force of increased user interaction, will drive the convergence even closer. We already have computers that can store television movies for later play back. As we shall explain shortly, all this is only a one facet of

multimedia. Now add to multimedia the facility to link computers (network) and data (hyperlink) and you obtain hypermedia.

It is obvious that the drawing together of these technologies will change the way we:

- live (see Section 5),
- work (see Section 6),
- and learn (see Section 7).

The boundaries of these rather arbitrary categories, already blurred, will overlap increasingly as hypermedia systems expand:

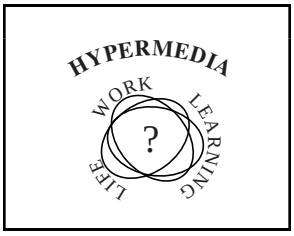

Figure 1

It cannot possibly be predicted what the final outcome of all this will be. One thing is certain: it makes for interesting speculation! Even those things that can be forecast (i.e. the "lower bounds" described in the paper "Forecasting - an Impossible Necessity" [Maurer and Lennon 1994] are very remarkable indeed.

This paper, although by no means a complete survey, will demonstrate in more depth than has been attempted before the impact that multimedia and hypermedia systems can have on various aspects of life as we now know it. For further reading on hypermedia and hypermedia systems we refer the reader to the surveys by Conklin [Conklin 1987]and Tomek et al. [Tomek, Khan, Muldner, Nassar, Novak and Proszynski 1991] as well as the texts "Hypertext and Hypermedia" [Nielsen 1990] and "Multimedia Systems" [Koegel-Buford 1994]. We use the term "multimedia system" in its widest sense to mean a computer system linking text, graphics (two, three or more dimensional), CAD drawings, animations, video clips and sound, as well as "interactive" and "annotated" movies [Jayasinha,

Lennon and Maurer 1994]. A "hypermedia system" (HM) is assumed to be a large networked system incorporating multimedia. For the reader not yet familiar with the notion of a hypermedia system we briefly review some of its salient features before exploring some of its main applications.

Hypermedia systems

Networked multimedia systems

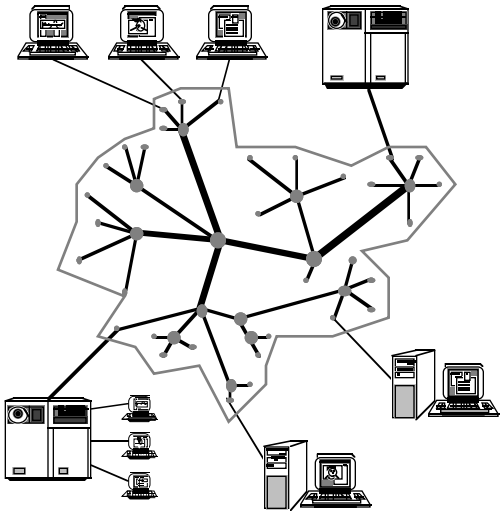

Figure 2

Modern computers can store huge amounts of information in the form of text documents, graphs and diagrams, as well as the digitised information of photos, paintings, music, video clips, etc. Electronic information systems range from single documents to large multi-volume encyclopedia sets to distributed databases. The information can be accessed, updated, and used for many purposes: the dissemination of information (e.g. advertising and public relations efforts), desktop publishing, presentations, video conferencing, research, computer-aided instruction and a whole new virtual world of simulations. Multimedia systems incorporating new sophisticated search techniques can help users gain control of the information explosion in more efficient, productive, and yet interesting and stimulating ways. We believe that as extensively

networked hypermedia systems are used increasingly for communication and collaboration, their impact will not only tie information together but, even more significantly, "tie people together" [Maurer 1993a].

2 Internet

Internet has (as of July 1994) a total of two million host sites world-wide (up from about 800,000 in January 1992) and an estimated 25 million users. It offers access to a tremendous variety of information stored in databases all over the world – much of the information up-to-date to the minute.

2.1 Internet Systems

Of course, this information is only as good as the functionality of the data-retrieval system that accesses it, and unfortunately much of the currently available infrastructure is less than satisfactory. E-mail on its own does not allow structured discussions or systematic collaboration (particularly between more than two persons), and most information systems still provide information only in text form. When switching from one database to another, both user interface and functionalities tend to change dramatically – multimedia segments rely on different hardware and software platforms, and customisation of information-access is rarely supported. Cross-referencing between chunks of information is usually impossible across database boundaries. Thus efforts tend to be fragmented. It is our contention that these limitations and barriers will be overcome by systems now emerging.

There have been significant advances in the science of information retrieval as applied to very large databases [Maurer, Kappe and Scherbakov 1994]. One of the first innovative systems was "Intermedia: The Concept and the Construction of a Seamless Information Environment" [Yankelovich, Haan, Meyrowitz and Drucker 1988], and its successor "IRIS Hypermedia Services" [Haan, Kahn, Riley, Coombs and Meyrowitz 1992]. Hyper-G [Kappe, Maurer and Sherbakov 1993], [Kappe et al. 1994], is one of four other major systems that can be said to have similar philosophical goals in that they aim to provide an easily used, professionally polished environment for general information retrieval.

The other three systems are Gopher [Alberti, Anklesaria, Lindner, McCahill and Torrey 1992], which lacks the link structure of Hyper-G, WWW [Berners-Lee, Cailliau, Groff and Pollermann 1992], which lacks the collection mechanism and many other features of Hyper-G, and WAIS [Stein 1991], which has a fulltext engine but no link or collection structures. In this sense we argue in another paper [Lennon and Maurer 1994a] that Gopher, WAIS and WWW should be seen as typical instances of "first generation" hypermedia systems, while in Hyper-G we are already seeing the advent of "second generation" systems.

Hyper-G is designed to manage not only megabytes of data but mega-quantities of documents. It incorporates a highly sophisticated structured browsing system [Maurer, Kappe, Scherbakov and Srinivasan 1993]. The system links users who may well use alternative hardware, and in contrast to standard networks such as Telnet, where every keystroke is sent to the host computer, Hyper-G makes as much use of the viewer's machine as possible. Complete packages of data are transmitted to a variety of client machines (Unix, IBM, Macintosh and, involving a loss of functionality, even text-based terminals such as the VT100s). Each client is supported by a "viewer". The data may then be viewed with as much sophistication as the local hardware and software supports.

Thus, Hyper-G aims to combine the best of the other existing systems while remaining compatible with them. Hyper-G itself can be electronically file-transferred (FTP) [Hyper-G 1994], along with half a page of installation instructions, and installed without much ado.

2.2 System Security

Obviously, any large system must have a monitoring program built in. First and foremost in any system containing confidential data there must be certain tight levels of security – integrated with flexible access and update facilities. Several levels of anonymity have been recognised [Maurer and Flinn 1994], and the four available in Hyper-G [Kappe and Maurer 1993b] are as follows:

1. Identified mode where, subject to strict password control, the user has read and write access to data.

2. Semi-identified mode, which differs from 1. in that the users' names are known to the system but they may log on with a pseudonym and password. This allows a certain level of anonymity on mail items, etc.
3. Anonymously identified mode, giving read access but restricting write access to the user's private files.
4. Anonymous mode, giving read-only access.

Where documents require such a high level of security, all records and passwords will be encrypted, of course, using public key protocols such as the RSA system [Salomaa 1990].

2.3 System Maintenance

Systems must monitor all four types of access, and the importance of the statistics obtained is difficult to overstate. Housekeeping programs maintain an efficiently running system and control vital processes such as backups. Book-keeping programs keep track of just what was done, when, and how often. This information can provide valuable feedback to database authors. If an author has little feedback on just how much their work is being referred to they will not be motivated to either contribute more to the system or to keep the existing work up to date. Feedback statistics are also important for helping maintain an error-free database. If, for example, statistics show that only the first fifteen pages of a sixteen page report are ever read then something is wrong!

2.4 Charging

Inevitably electronic charging systems have to be implemented – at least in some systems. As discussed in Section 6.2 electronic transaction processing is increasing. Most of us are all too familiar with credit cards and the value-coded swipe-cards widely used in places such as museums and copying centres.

Obviously security issues are paramount and validation techniques must be included, techniques such as those currently being applied in many European countries where "telebanking" has become routine due to the spread of Videotex [Maurer and Sebestyen 1982]. PIN and transaction

numbers must be used together with cryptographic protocols [Salomaa 1990].

Copyright issues, particularly with respect to electronic publishing, are complex (see Section 4.5) and far from being solved. However, systems such as Hyper-G do support several types of billing.

3 Converging Technology

As we have mentioned in the Introduction, technology is converging at a tremendous rate and what the long term result will be when it all comes under a network umbrella we cannot predict.

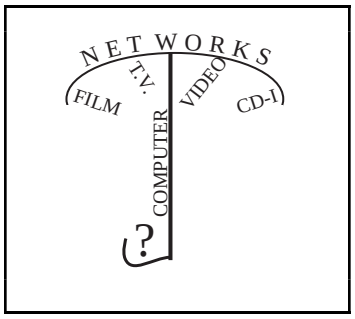

Figure 3

For example, CD-I technology is currently a cheaper option than CD-ROM technology, but we believe that the latter may well be the better option since it supports more diversity. Much important material is already available today only in CD-ROM form. Currently, one CD-ROM disk can contain about 600 million bytes of data – as much as 300,000 pages of text. Drawings and colour photos can of course also be included, and all this information can then be accessed in a wide variety of ways. We note with interest that IBM has demonstrated optical disk technology that could produce disks with about 6.5 billion bytes of data by storing up to ten layers on a single disk. And if this is coupled with new "blue laser" technology it will be theoretically possible to put several thousand 200-page books on one CD.

4 Communication Systems

Communication is really what Hypermedia is all about, communication ranging from simple e-mail communication to virtual-reality experiences, and using as many senses as are appropriate.

4.1 E-mail

An increasing amount of communication is being conducted by electronic mail systems, sometimes right across the world but just as often between people who work in offices right next door to each other. This is indeed an invaluable service, but most users have experienced the problems associated with receiving large quantities of unsorted and frequently unsolicited mail [Denning 1982]. We are seeing more and more managers who used to be enthusiastic e-mail correspondents turning over all their e-mail communication to secretaries for sorting, forwarding, printing out, and of course discarding.

In a well structured electronic mail system the mail can be categorised by author, subject, date, etc., as well as by key words. A graphical interface can be provided along with a good classification system. This will enable messages to be saved in an orderly manner and provide semi-automated retrieval and purging systems. Messages stored with recall dates will be automatically displayed at appropriate times. Out-of-date messages such as seminar notices can be automatically deleted (with safeguards) once the date for the event has passed. The user can provide a default date for purges - which of course can still be overwritten.

4.2 Help Lines

Whole virtual communities on Internet have evolved from PC, Macintosh, and other user groups. We now are seeing valuable support networks for people with health risks such as cancer or AIDS. Once groups such as these are integrated with existing medical systems we foresee a radical breakthrough in all areas of community health care. For example, pacemaker signals will trigger direct connections from patient to emergency centre.

Once a significant proportion of personal computers have microphones, or better still video input, we shall see further improvements. Help calls can be sorted, evaluated, and routed directly to police, fire, civil defence, or medical departments. Since all time and place details will be automatically included, the problem of human error in emergency situations will be greatly reduced. In addition, with video connections a human may not even need to initiate the call!

Once we start thinking globally about "help" information systems we look forward to their support in all areas of life, from critical repair work on space or atomic power stations to helping a new user discover a useful shortcut in a word-processing package.

The effectiveness, and use, of all types of help systems will undoubtedly be greatly enhanced once they are integrated with electronic personal assistants such as those we describe in Section 8.

4.3 Accessing Library Information

We discuss the accessing of library information under two headings:
1. Making the information stored in existing libraries – in the treasure troves of paper books – more accessible.
2. Developing electronic publishing.

The updating of traditional libraries is discussed in considerable detail in this section, and then generalised to electronic publishing in Section 4.4.

We believe that the next few years will see dramatic changes in library systems. As more members of the public have access to networked computers more browsing of catalogues will be done away from the library than ever before. Physical library space is a particularly expensive commodity when you take into account such factors as security and construction problems (e.g. floors having to be designed to withstand the weight of books). Many libraries in educational institutes allocate this space to students as study areas. However, it is our observation that students often simply work on assignments, making no use of the library's resources except for the convenient sitting spaces. A better and more cost-effective solution is to provide students with alternative study

areas where they can not only work but sip coffee and get involved in important group collaborative exercises.

In the foreseeable future it will become standard practice, on cataloguing a new book or journal, to scan (i.e. fax) the table of contents into a HM system so that borrowers can rapidly access the new information. This much at least can be done without infringing copyright laws (see Section 4.5). Some Internet servers such as Hyper-G [Kappe, Maurer and Sherbakov 1993], support library systems, integrating services, and fast efficient searches of titles, tables of contents, etc. Users can also define the scope of their searches by defining "active collections" within the information database [Kappe and Maurer 1993].

An important technicality involved in text searching is worth looking at in some detail since it comes up in many connections. Since scanning documents produces only a simple bit map, an Optical Character Recognition program must be used to convert the bit map into text. This is required so that the text can be (1) compressed and (2) searched. The question of efficient searches is such a complex one that we shall only touch the surface. It is unfortunate that even the best OCR programs introduce errors into the scanned text. However, the use of "fuzzy" searches not only solves this problem for all practical purposes but helps in other ways as well.

A fuzzy search will have a good hit rate with:

- Search keys with spelling errors and typos in them [Baeza-Yates and Gonnet 1992], [Wu and Manber 1992]
- Abbreviations and inflected forms of words
- Synonyms
- Phonetic searches

Fuzzy searches can incorporate whole semantic nets instead of just lists of synonyms. These are of particular importance in areas such as Computer Aided Instruction (CAI) where we wish to avoid categoric true/false answers and instead give graded responses. For example, if the answer to a question is "Oxygen", then answers like "gas" or "air" do not warrant an unqualified "no" response. The response could be "Yes, but what type of gas" or "Please be more specific".

When the new book or journal has been electronically catalogued, information in e-mail form can be sent to all members of a library according to their personal "information profile". Such an action can be almost entirely automated using suitable systems.

Once people have found a paper relevant to their work, e.g. by using the electronic table of contents described above, they will no longer have to go to the library to read or copy the papers. Rather, just by clicking at the paper selected in the electronic table of contents, the enquirer can send a message directly to the library. Library staff now copy the paper and send it to the person concerned; the copy may even be sent in electronic form, again using a scanner exactly like a photo-copying machine.

Although this approach does place an additional burden on library staff, looking at it from a global point of view it is much more efficient than all the present legwork put in by physical users, and time spent searching for journals that would be found by library staff much more quickly. Other aspects of the library may be automated by:

- Subscribing to electronic publications rather than paper publications (see Section 4.4)
- Introducing automatic recall where the user, wanting to use a book and finding it is out on loan, can by a single click initiate an e-mail message to be sent to the borrower
- Electronic record keeping

All of this will free library staff from other work so that the proposed much more efficient library might not need a substantial increase in staffing.

4.4 Electronic Publishing

There is no doubt that journals such as J.UCS [Calude, Maurer and Salomaa (1994)], [Maurer and Schmaranz 1994], have many significant advantages over traditional journals. One of the most comprehensive reports to date is published in J.UCS, under the title "Tragic Loss or Good Riddance? The Impending Demise of Traditional Scholarly Journals" [Odlyzko 1994].

Most publishing houses see some form of electronic publishing as inevitable. Compelling arguments can be advanced in support of information systems that:

- Support fast text searches (as described in Section 4.3)
- Support graphics, hyperlinks and annotations
- Save time, money, and library space
- Save tonnes and tonnes of woodpulp

J.UCS has the following additional advantages:

- Papers, refereed by an editorial board consisting of over one hundred computer scientists, will be as prestigious as those in any other reputable journal.
- Since it is based on Hyper-G [Kappe et al. 1994], it will be easy to access, over a variety of platforms, from all Internet access points (see Section 2).
- Since it is fully supported by Springer-Verlag, printed versions of the journal will be available (as well as CD versions).

News can be flashed around Internet before it appears on conventional news channels. Electronic newspapers are being trialed. Many publishing houses are already accepting manuscripts in electronic form for in-house editing, or for inserting directly into edited volumes such as conference proceedings.

Material can be accessed directly either from the Net or from CD. Electronic books distributed on CD-ROM include such titles as "The Oxford Textbook of Medicine on CD-ROM", "The Complete Works of Shakespeare" and several encyclopedias [Barker, Giller, Richards and King 1993].

The application "PC-Bibliothek" (PC-Library) is a recent development from Graz University of Technology for PCs running Windows. It offers a powerful generic user interface for electronic multimedia reference works. At any time, the user can choose a set of reference books from the system's virtual bookshelf in order to look up information using headword and fulltext search. Features available for searching include logical operations for query definition, spelling error tolerance in queries, creation of a personal alphabetical keyword list. The system

allows personal annotations to be made. Access from other Windows applications is available, together with data export and import routines.

"PC-Bibliothek" [Maurer, Muelner and Schneider 1994] is a commercial product that comes on floppy disks or CDs with an extended manual. The material of the "PC-Bibliothek" will also be integrated into Hyper-G [Kappe, Maurer and Sherbakov 1993] in the near future.

4.5 Copyright and Intellectual Property Issues

The issues involved in copyright and intellectual property are undoubtedly far from clear. Many issues pertaining to electronic copying have still not been defined, laws can vary from country to country, and important decisions are still tied up in law courts. Certainly they can protect the software developer [Fernandez, Fenwick and West 1994].

Tables of contents of magazines, journals etc. can be stored and publishers can make arrangements for certain selected pages to be copied, or notably, abstracts or the first few pages of a novel.

In universities there are additional problems because it is difficult to predict how far a document will actually be distributed - to a single user (or dustbin) or campus-wide.

It is a very sad fact that in many countries there has been extensive electronic sellout of national treasures due to insufficient governmental legislation [Maurer, Rajasingham and Tiffin 1994]. Because many art museums were unaware of the ramifications, they have sold the exclusive rights to the digital copies of great art works (or practically given them away) to the first applicant.

4.6 Comparing Documents

Much research, by its very nature, involves extensive comparative work. In English Literature, for example, it can be highly desirable to have two documents on the screen at the same time: if one document is a validated Chaucer text then the other can be compared to determine whether it was likely also to have been written by Chaucer - and whether it was written

by Chaucer some ten years later. In Law, many cases have to be carefully compared to see whether an existing case is a precedent. Tools must do some of the comparing (see Section 8).

4.7 Cross-referencing and Checking

This is an area where a supervisory program, like the Personal Assistant (PA for short) discussed in Section 8 of this paper, will have a big impact. A PA program will provide intelligent cross-links enabling better use to be made of today's huge databases. Not only will the PA make continuous searches for cross references on what we are reading but it will also make cross checks on what we are writing. One such system, "Ways 2", produced by the Swiss wizard Keller, has been marketed in Germany with considerable success. Having such checking done automatically, in whole or in part, is the only way to ensure that the increasing amount of stored work taken to be authoritative is at least relatively free of errors.

5 The Changing World Around Us

Like it or not, the entertainment industry is the driving force behind many of the changes we are describing, and the impact of commercial interactive movie technology should not be underestimated – it will invade work, leisure and learning. In the paper "Interactive and Annotated Movies" [Jayasinha, Lennon and Maurer 1994] we describe techniques that significantly extend the usual definition of "interactive", and to illustrate the wide applicability of the new technology we outline examples for the ballet and orchestra enthusiast, the reader of great literature, the surgeon, and students of medicine, geography, and history.

5.1 Public Information Systems

Although we still occasionally see public information systems of the shake-the-fist-and-walk-away type we are also seeing many more highly successful ones. Information displays, widely used at airports and on street corners, can give users touch screen options for locating a wide variety of services such as hotels, taxis, and rental car firms. Perhaps

even more interesting to use are the wall-sized maps of train connections that let the traveller, using touch screen options, build up and print out their own itineraries - complete with connection times and costs.

As airline flight information becomes more widely accessible via the Net we shall undoubtably see a similar move towards more interactively defined travel itineraries. For example, decisions such as how early is "too early" and how much risk to take in shortening connection times are personal questions of sometimes high emotional status that are much better determined by the individual traveller. And of course we look to the day when we shall be able to not only make the necessary bookings directly but bypass much red tape with a simple swipe of a general purpose chip-controlled credit card.

Interactive maps based on Global Positioning Systems data are being developed by major car companies. Once a significant proportion of cars have such displays, information from traffic control vehicles can be directly integrated into traffic flow diagrams and drivers can have alternative routes automatically displayed.

Information bureaux may act as servers for whole networks of kiosks. Besides supplying a wealth of publicity, information bureaux will be able to provide specialist information such as sports therapy programs.

As a final example, consider the benefits of having an integrated hypermedia system in a civil emergency. Army, airforce, police, fire, and civil defence may all be involved, and for coordinated efforts they need interactive access to all relevant and up-to-date data. Cell phones have proved to be a valuable aid in traffic control - perhaps, at the least, there should also be special cell phone call numbers for civil emergency information.

5.2 Access to Background Information

The "quiet revolution" in desktop publishing has been paralleled by an increasing amount of readily accessible background information:

- Dictionaries
- Encyclopedias

- Price lists
- Salary scales
- Detailed specifications
- Scientific glossaries for Computer Science, Biology, Engineering
- All types of manual – computer, car, cookery....

Interactive hypermedia programs can access information of this sort from CD or from databases via a network, making details very much more widely accessible.

5.3 Disseminating Topical Information

Pages and pages of figures or just a few well chosen graphical representations? Static pictures or dynamic graphs that reflect changes? Two dimensional or three dimensional? The choices are many. Sales catalogues, schedules, and timetables, all can be distributed, checked, and annotated electronically.

As described in the article "Conferencing – Do it the Hypermedia Way!" [Maurer and Schneider 1994a], conferences of all types can be supported in many ways: issuing invitations, submission of contributions, registration procedures, administration details etc. etc.

Audio clips of new tape and CD releases are already available on Internet. Once previews of films, shows and concerts are widely available in the form of multimedia clips, people will look back on the ways we currently choose our entertainment as buying a pig in a poke.

5.4 Managing Telephone Directories

Corporate telephone listings are typical instances of directories that are notoriously difficult to keep up to date in printed form. Staff come and go or are promoted, they change their offices - and change their names. Current lists are usually out of date by the time they are published. We have seen more than one directory where corresponding entries in two sorted lists do not agree. In an integrated database system these problems can be overcome. Subscribers will have their own record in the database, that will include their telephone number, room number and perhaps

additional personal information. The data will occur only once in the database but it will be accessed by other sub-systems such as the telephone directory. The updating of the information will, of course, be controlled by authorisation level. To maintain the integrity of the system there will be certain data to which only system supervisors will have read/write or read/write/update privileges. But to avoid the "Big Brother Syndrome" it is important that all members of staff should be given at least read-only access to their own data. On the other hand, phone numbers are probably best updated by the person directly concerned, or their secretary. By using this approach the inconsistencies found in most directories will be avoided.

5.5 Orientation and Information Displays

Orientation and information displays can be made available at public kiosks, in entrance halls, and information centres such as those provided by any large institution, for example a National Tourist Board. The Images of Austria project is a noteworthy example [Maurer, Sammer and Schneider 1994].

The University of Auckland, New Zealand, is engaged in an ambitious program to install a University Transaction, Information and Communication System: UTICS [Maurer and Schneider 1994b]. The university is also making use of a multimedia system called "Unimedia", [Unimedia 1994], to provide information about the campus in a form easily understood by all visitors to the campus.

For the benefit of overseas users, a world map picturing New Zealand can be "opened up" to show Auckland and the location of the University. When users select the University icon they are presented with a large-scale map of the campus that they can "walk through" or "fly through" and zoom into any part of. Here they can orient themselves and then locate any facility, whether a car-park, a lecture theatre or an individual office. As explained below, selecting any feature will bring up more detail. Experienced users may not only bypass any of the above steps but, using the powerful query options available, directly access specific information such as lecture times, room numbers and telephone numbers.

5.5.1 Virtual Tours of Buildings

At any stage of a tour a user may select a building and choose to follow predetermined paths. For example:

- Selecting a particular building will not only show a photo of the actual block together with a description of its function but give the option of following any one of several different paths. To take the university setting again, if the building selected is Mathematical and Physical Sciences the following path might be selected: School of Mathematical and Information Sciences / Department of Computer Science / Hypermedia Unit / Room 248. A more detailed description of such paths is given in the next section.
- The user may search for a particular member of staff, or a lecture room, or a library, and in each case they can always be directed to the appropriate building and location.

5.5.2 Navigation Through the Hierarchies

One of the primary goals of systems such as Hyper-G [Kappe et al. 1994] is to help users find what they need to know as efficiently as possible, while ensuring they are comfortable in the search environment [Kappe, Maurer and Sherbakov 1993]. Hyper-G documents are defined as follows: "Every Hyper-G document is a member of one of more collections, which are in turn members of one or more collections (except for the root collections)" [Kappe et al. 1994]. This definition gives us collections of overlapping hierarchies as shown in Figure 4.

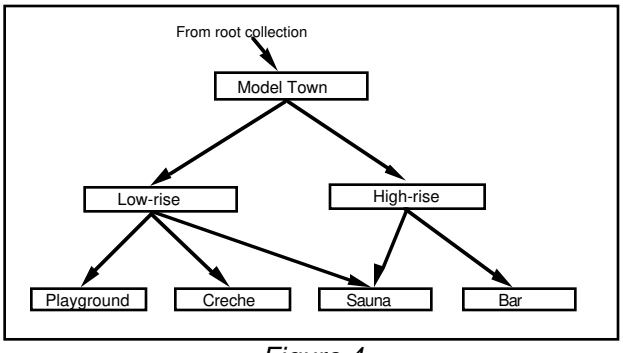

Figure 4.

At each node appropriate information is available on request:

- General information, including historical references and notes on any future planning.

- Specific items of interest such as sports facilities.

- Personnel details. These will include pictures of members, their telephone numbers and e-mail addresses, their interests both present and past, and any biographical or general information the person is happy to put into the system.

Users have guided tours, both two and three dimensional, as well as paths to aid them.

5.6 Repercussions in the World of Advertising

Can we really look forward to the disappearance of unsolicited, one-size-fits-all advertisements? If the current exponential growth of trading on the Net is anything to go by, the answer may certainly be "yes". As consumers, we shall be able to search for what we want when we want it.

Users will have much more intelligent access to publicity material. We shall see interests ranging from sports fitness centres to adult education courses being targeted to reach specific audiences. Printed advertisements may become as obsolete as town criers.

Where licence agreements are involved it is frequently necessary to pass charges down to the users. This can be achieved either by the introduction of a yearly subscription fee or a charge per page. For example, readers of electronic magazines and journals may have to pay a licence fee for access, just as is required for certain software now, and an organisation may need more than one licence for a popular publication. However new forms of sponsoring are emerging. Sponsors can provide the organisation with its licence fees in return for special advertising privileges.

6 The Impact of Hypermedia on the Way We Work

Hypermedia systems are already changing the workplace (however we define it) as people from home care-givers to politicians discover what it means to have a world of information literally at their fingertips.

6.1 Electronic Purchasing

Once small businesses evolve past the "word processing" stage into the world of hypermedia we predict another radical change. As suppliers, we shall be able to finely target small markets. As consumers, we shall discover a new definition of "personal assistance". Consumers, by simply sending their own electronic agents through the Net, will command and receive personalised service – probably to the level of receiving individualised products such as designer jeans with the wearer's own emblem emblazoned on them!

6.2 Automatic Data Transfer

Over the past 25 years, electronic transaction processing has become steadily more robust and correspondingly better trusted by businesses large and small. As networks connect more homes and businesses we shall inevitably see still more distribution of data entry points. For example, electronic "armchair shopping" may directly generate bank debits – although again there is obviously concern over security issues (see Section 2.4). In large educational institutions systems will manage all transaction processing from enrolment data and academic transcripts to crediting and debiting of all sorts of fees - possibly without the students having to set foot on the campus, let alone wait in lines.

6.2.1 Telemetry

Bob and Penny Gascoigne have long been out of work. Now even the meter reader must find other work as meters are read from a distance and the charge debited from the consumer's bank account (see Section 2.4). Not only can gas, electricity and water consumption be electronically dealt

with. Licensing of TV services can also be dealt with – and made fairer. The whole system could shift to a finely tuned user-pays basis.

Consumer surveys can be carried out with minimal interruption to anyone's life. Automatic monitors can run program rating surveys.

6.3 Publicity

Good publicity, both local and international, is obviously critical for the success of any business. It is particularly significant in the recruitment of personnel. It is important to advertise as widely as possible, not only in the interest of fairness, but to ensure that the calibre of the recipients is as high as possible. Even restricting ourselves to Internet, general information and lists of vacant positions can be widely distributed.

Since staff may be attracted from all over the world it is most important that information reaching these people is as accurate and relevant as possible. Ideally applicants (whether local or foreign) should be able to link directly into companies' information servers and take part in guided tours that provide pertinent information on working conditions, salary scales, benefits and such thorny issues as visa requirements. People considering coming from another country will appreciate having access to publicity material on surrounding country and towns - all of which lends itself to great hypermedia presentations as has been dramatically demonstrated by the "Images of Austria" project [Maurer, Sammer and Schneider 1994].

6.4 Computer Supported Collaborative Work (CSCW)

CSCW comes under the heading of Groupware. It ranges from simple e-mail communication (as described in Section 4.1) to the joint preparation of hypermedia documents [McQueen 1993], [Dewan 1993], [Derycke, Croisy and Vilers 1993] and [Ellis, Gibbs and Rein 1991].

It may be divided into two categories:

(1) Asynchronous: An asynchronous CSCW system has the advantage of enabling users to collaborate when they are separated not only by

distance but also by time constraints. This is obviously an advantage when workers are in countries separated by, for example, a twelve-hour time difference.

(2) Synchronous: In a synchronous system the participants are logged on to the computer system at the same time even though they are not necessarily all in the same room together, as in teleconferencing. Recently there have been significant improvements in the quality of large-scale projected images [Berends 1993].

6.5 Electronic Group Discussions

Whether the discussion is formally supervised by a complete computer conferencing system (see Section 6.9), or is just an informal exchange of ideas between two colleagues, the impact of computers on communication is already being felt across the world. The traffic in e-mail is voluminous and increasing all the time (see Section 4.1). There is certainly a tremendous need for much of this interactive correspondence to be coordinated by a supervisory program such as we shall describe in Section 8.

6.6 Version Control

When two or more people work on the same document it is even more important than usual to be conscientious about keeping track of changes to the document. Much research remains to be done on systems that are automatically version-controlled. These will automatically keep track of versions for backup and archival purposes (future historians will have a difficult time tracing document life cycles if valuable annotations are lost) and enable two or more users to see and keep track of each other's changes [Halasz 1988], [Neuwirth et al. 1992].

6.7 Meeting support

When calendar functions are integrated into good e-mail systems meetings can be electronically timetabled. Although we feel that some scheduling systems intrude too much on users' privacy, other systems,

not exposing personal calendars, can be just as effective. One user will suggest a time for a meeting, and the system after browsing at appropriate calendars can report back with the number of clashes if any. Since the attendance of certain members may be critical, a weighting may have to be placed on certain entries.

A CSCW system may support computer screens providing a shared workspace, so that all participants can literally work on the same document at the same time and all simultaneously see the result [Elrod et al. 1992].

To help communication further and to engender a feeling of camaraderie (to help offset feelings of computer-generated alienation) the screen may also show video images of the participants, although space considerations strictly limit the number of users.

When two or more users work on the same document at the same time there has to be a carefully constructed means of ensuring that the document always reflects its true state. Successful work is already in place ensuring proper lockout.

6.8 Contract Preparation

In all the above discussion we have assumed that the various collaborators have had the same basic aims. But there is one application of CSCW in which the participants may have quite different objectives: contract preparation. The different parties to the document are both – or all – working on it. But in this case each has to obtain a version that is best for their own interests, and there can be a tendency for each to slip in changes it is hoped the other party will overlook. In this case the computer system's supervisory role is to ensure fairness.

6.9 Computer Conferencing

A computer conference provides a highly structured discussion. First a topic or proposal is presented and the system forces contributions of the required type: extended topic or generalisation, supporting argument, supporting example, counter argument, counter example.... Varying

levels of anonymity can be supported - from complete anonymity to every contribution being identified by the sender's real name. Often pen-names are used. There are also times when documents require such a high level of security that all communication is not only anonymous but encrypted using public key protocols, as for example in the RSA system [Salomaa 1990].

6.10 Supporting Decision Making

A special case of asynchronous conferencing or CSCW is seen in electronic decision support centres [Nunamaker, Dennis, Valacich, Vogel and George 1991], [Sheffield 1993]. All participants are physically in one room, usually with a facilitator, and may communicate normally at any particular time. However everyone is also linked to a computer system and discussion usually takes place anonymously with immediate feedback. Unstructured "Bulletin Board" discussions have worked where there are only a few participants, but they quickly get out of control with more than a few. In a "Card Passing" system messages are passed to members chosen at random and each successively adds to the "card" until either the facilitator or a member calls a halt at a point where a vote on the issue might be taken.

In the paper "The Impact of Electronic Meeting Systems On New Zealand Organisations" [Sheffield 1993] the author states: "Participants using simultaneous computer input may work throughout the meeting without being 'blocked' by other participants. Because there is no competition for air time, task focus is increased. Persuasion and advocacy are less necessary in achieving consensus. The combination of high task focus, high participation and expert facilitation appears to produce a more informed consensus." The ability of participants to access and organise information is enhanced and surveys show that participants claim a time saving of sixty or more percent - a factor of great importance to administrators. Although the electronic meeting rooms do not themselves generate decisions (these may need very human interactions including eye contact), the decisions reached are proving very workable and highly satisfying, as detailed follow-up surveys [Sheffield and Gallupe 1993] show.

6.11 International Business

As businesses amalgamate, nationally and internationally, networks are being used increasingly to coordinate operations. For example the International Maritime Satellite Organisation is a cooperative involving about seventy nations. Their satellites, built by an international consortium, will be launched by U.S. and French companies using Russian rockets.

Electronic Document Interchange (EDI) is being used for a growing number of international business transactions. Although it is really just formalised e-mail, legally binding electronic documents can be created by using digital signatures [Salomaa 1990], [Lennon 1993].

6.12 Administration

Many operations are characteristic of any large corporation: maintenance of personnel files, payroll systems, stock control and forecasting. A well designed database system with a good human interface can today be regarded as essential.

Traditionally offices have tended to simply computerise existing processes. However there is a broader view of workflow as more than mere process automation [McQueen 1993]. New workflow tools are being developed that include such important aspects of administration as negotiation techniques and levels of satisfaction [Medina-Mora, Winograd, Flores and Flores 1992]. Since students can be regarded as customers, universities should benefit from these new programs as much as businesses will.

6.12.1 University Administration

Certain problems are unique to educational settings. Universities, for example, are often proud of their historical roots and many have evolved such complex degree regulations that it is sometimes said that prospective students need to have a degree already to understand the Calendar!

We envisage that when students are able to log on to educational networks they will be guided through mazes of regulations from the safety of an armchair. They will be able to explore various options, and the system will indicate what the effects of these choices will be in both the short and long term. It is a sad fact that all too many of today's students fail to look very far ahead to see what papers they should be taking as prerequisites for their desired major.

Within a few years students should be able to use voice-mail to enter their chosen courses into the university database. Any clashes and inconsistencies will be immediately relayed back to the student, who can modify the course appropriately.

Early in the enrolment process students will be issued a Pin number so that necessary levels of security can be maintained.

6.13 Supporting the "Culture" of an Organisation

In this vital area of an organisation's life the problem is not so much how to distribute notices but how to keep control over them. All too often expired notices are littered amongst the current ones. In our system all electronic notices will be time-stamped when the notice is first entered. The system will generate a default expiry date, from the date of the event, but this may be over-ridden by the user. In addition to this the user will be asked to say what is to be done with the notice once the date has expired: delete the notice, or place it in a Past Events list to be maintained by the system. This list will be invaluable for compiling not only end-of-year reports but histories. Decisions must be made on how to maintain the Past Events list. We propose that, after two years in the list, certain items should be archived - for fifteen years, or one hundred years?

The notices will be arranged by certain criteria and keywords: training programs, conferences, public lectures, open days, and block bookings for theatrical events (both music and drama), to name but a few.

Company esprit de corps will be enhanced when "virtual common rooms" contain information such as bulletin boards, photos, best performance awards, and names of past innovators.

In university and school settings graduation events will take on a new dimension when photos taken at functions of the graduands in their regalia are archived along with statistical information. They can be presented to each graduate immediately after the ceremony as a memento!

Employees will run all types of bulletin boards, displaying club information, accommodation listings, sporting calendars, virtual "flea markets" of second-hand goods including books (both paper and electronic). In all these areas there will be the question of whether or not outside commercial interests should be allowed to place paid advertisements, and if so what control there should be to prevent abuse.

As to interpersonal life, workers will be able to keep in contact with friends across the world. Networking may be the next best thing to telepathy!

7 Life-Long Learning

The greatest revolution of all must surely come in the areas of teaching and training as we move towards "on-the-job training", "life-long learning", and "just-in-time learning". We have divided this immense topic into two sections:

1. Section 7.1 – Short term applications of hypermedia to teaching.
2. Section 7.2 – Longer term projections.

7.1 Teaching and Training

Hypermedia: art or science? As foreseen by the visionary Ted Nelson [Nelson 1987] the melding of what were traditionally thought of as being two opposites is already occurring. In fields ranging from high tech CAI to movie making, artists are collaborating with computer scientists. It is a trend that we hope will extend right across campuses (closed or open), and hypermedia networks can provide the links. Although at school students interact with friends of varied interests, later in life many specialise early and lose contact with other disciplines - to the detriment of more than just the students' interests. Staff and students need to hear other problems being discussed to realise that their own work may hold

solutions. Fundamental theory, advanced technology, wider perspectives, ethical, social, legal considerations - any can unexpectedly revolutionise the way an undertaking is viewed. Hypermedia networks can provide the needed communication channels. Also, as it becomes more and more difficult to separate education and entertainment, we shall see students controlling their own education in new and probably unpredictable ways. Ideas will buzz across the networks.

The classical "chalk and talk" lecture has certainly stood the test of time. It is cheap, and coupled with a good duster it allows the teacher a great deal of flexibility. The last few years have seen the increased use of overhead projection slides. These allow the lecturer to prepare beautiful, detailed colour diagrams in advance. However in an OHP presentation spontaneity and audience participation may both be sacrificed: both pose risks, because they may suddenly demand a change in either the content or the order of the prepared slides. The whole effect may be spoilt if a teacher has to illustrate points by trying to draw, with an inadequate pen, in corners of the transparencies - which now become cluttered. There is a problem too with making references back to points on previous slides: it can be difficult to find a particular slide among a whole pile of used ones. However since both chalk and OHPs are so widely used, any serious alternative must combine the flexibility of the classical blackboard method with the ability to show prepared material. The use of electronic media with projector or multiple screens can provide this combination, and much more besides.

In 1989 Dartmouth College was the first university to require every student to either purchase a computer or arrange the loan of one. It is becoming such a widespread practice it seems likely that before long all staff and students at universities will find the possession of a personal computer as essential as a slide rule was for engineers back in the 1950s. This will have far-reaching consequences, as we shall outline in Section 7.1.3 and Section 7.2.

7.1.1 Traditional Computer Support

Since tools such as word processors, spreadsheet packages, database management systems and CAD packages became widely used we have seen a revolution in the quality of the documents produced by teachers. Graphs

can be printed directly from spreadsheets. Output from computer simulations can be captured in pictorial form and included in reports. As mentioned in Section 4.4 many publishing houses accept electronic versions of papers and books for in-house editing or as final copy for directly incorporating into edited books.

7.1.2 Multimedia Presentations

Several different metaphors are available for presenting material in a coherent form, but the one teachers will probably feel most at home with is surely the "Book" or "Library" metaphor. A good multimedia implementation will support moving both forwards and backwards through the pages of presentation material, have an index into the pages, incorporate a bookmarking system and have the facility to iconize any particular page needing to be referred to more than once. Students may well appreciate seeing a graphical icon indicating both the number of pages already viewed and the number of pages yet to be shown. The system must support multiple windows and perhaps incorporate the interesting possibilities associated with zooming into parts of diagrams. Maps of all sorts lend themselves particularly well to this sort of treatment: geological and oceanographic maps, and particularly maps produced by special methods such as infra-red photography. Any area can be re-scaled and points of interest visited by displaying new windows of information. Information in the biological sciences can be more clearly shown by displaying uncluttered diagrams where additional details are not shown until required. Lectures in medicine can benefit by incorporating photographic quality images and by studying the body not only in various ways (e.g. by looking at bone structure or blood or lymph systems) but by viewing each system under increasing (and decreasing) degrees of magnification. Students of engineering and architecture receive extensive training in the use of computer-aided design (CAD) tools. CAD is not only being used in the initial design phases of projects but, coupled with good HM systems, it is being incorporated into training sessions for new staff, retraining for current staff, building and maintenance specifications, and high tech troubleshooting.

It is important that the teacher be able to annotate the material as freely as in any traditional environment. The annotation system should provide suitable drawing support in perhaps a variety of forms. The software

used to produce the presentation should be on line so that real time additions or deletions can be made. There should be an option to determine which changes are to be permanent and which are just temporary.

At any stage in a presentation the teacher should be able to capture any page or pages of information and have the option of either distributing them electronically to the students (or to any other interested group, e.g. a disabled or home schooling group) or having the pages printed out as hard copy for the students to take away. This helps to minimise mindless note-taking.

Information invisible to the students can be displayed for the teacher to use at will. If the presentation system is networked then even more valuable possibilities exist. The teacher can access backup encyclopedias to enhance the lecture as well as answer questions. Art teachers have a particular problem in that they currently rely heavily on slide carousels for illustrating their talks. It is difficult to move backwards and forwards through the slides to find any particular one they need to refer to, and they cannot display slides from previous lectures in response to students' questions. Furthermore they often need to show two slides at the same time to compare and contrast them. Electronic libraries of pictures, and CDs such as Microsoft's "Art Gallery" will provide an Aladdin's trove for users such as these.

7.1.3 The Electronic Lecture Room

As personal computers become smaller, cheaper and consequently more widely used, we envisage students bringing their own laptops to class and connecting to the teacher's computer via a network. This opens many interesting possibilities (see Section 7.2), just a few of which we list here:

- Students will be able to electronically read in the teacher's notes and then individually annotate them from the teacher's explanations.

- Electronic question and answer sessions will open the possibility of having lecture forums with the teacher simply acting as chairman.

- Instead of bringing just a tape recorder into lectures, students will have the choice of voice recorders, electronic cameras and even video recorders, and they will be able to store the data directly into their own computers for perusal at their leisure.

It is well established that people experience a significant mental barrier to asking questions in large class situations where they feel self-conscious. In future it may be desirable to provide each student with some sort of electronic signalling device. This could enable students to anonymously indicate to the teacher that they did not understand a point or that the pace was too fast or too slow. In large classes this might mean that the teachers would need some computer support to analyse the incoming data without impinging too much on their concentration.

7.1.4 Tutorials

Fully networked tutorial laboratories provide a wide range of learning environments:

- Teacher-directed learning. Students new to the computerised environment can be guided step by step until they are proficient.
- Teacher-guided learning. Students can be given increasing control over what and how they learn. They can be encouraged to explore at their own pace with the teacher acting as guide.
- Student-directed learning. Mature students can benefit by being given control over their environment. The teacher's role will be that of a mentor or supervisor.
- Working in groups. Many students prefer to do computer work in groups rather than alone. This preference is seen in many minority groups and particularly amongst women.

It can also be argued that all students benefit by a certain amount of group activity since there is so much team work in the workplace. Work can be divided up among the group members, results compared and combined, and the final version prepared in professional form.

Wide-area networks can provide an immeasurable resource base for tutorial work. Many groups will benefit from having brainstorming

sessions with various degrees of anonymity - again it is seen that many minority students would appreciate this.

7.1.5 Computer Aided Instruction (CAI)

Amalgamation, corporatisation, expansion! As big gets bigger, and distances between offices increase, many companies are urgently looking for more efficient training and retraining programs. It is worth noting that in the United States large companies like Bell Labs and AT&T have multi-million dollar budgets for computerised training of network maintenance workers. It is not our contention that CAI will ever completely replace the human teacher, and certainly not in universities, but it can complement a teacher's activities and in certain areas, particularly where students need to build confidence, it has a unique part to play in education.

An outstanding example of using computing in higher education is the Athena project at the Massachusetts Institute of Technology [Balkovich, Lerman and Parmelee 1985], [Murray and Malone 1992].

7.1.6 Presentation Type CAI Lessons

A large number of applications have been written in this field. Early on, Apple Macintosh encouraged its educational users to produce lessons written in Hypercard by giving the application away free. Much good software has been produced, often in the long hours of busy teachers' nights. This is certainly an area which needs more coordinating and cataloguing so that excellent work doesn't get lost in proverbial "bottom drawers".

University faculties should investigate ways of ensuring that members involved in the preparation of CAI material get academic recognition for their work on a parallel with time expended on writing textbooks. It should be possible to publish CAI packages just as books are published.

Once students have access to a hypermedia system supporting CAI they can access information as and when they need it. We expect students to be better motivated not only to make intelligent use of basic information but

to probe more deeply into areas they find particularly interesting. However a note of caution is needed here. Experience has shown that students need encouragement and even gentle discipline to form the new study habits required for mastering the new learning environment.

The Hyper-G system, for example, already supports over 500 lessons covering topics ranging from medicine, ecology, and natural sciences to computer science. These lessons make full use of the power of hypermedia [Kappe, Maurer and Sherbakov 1993].

In the article "Why Hypermedia Systems Are Important" [Maurer 1992] the author states:

"It is to be understood that the visual component of a computer supported multimedia system is not limited to ordinary digitised photos and movies: such photos and movies of real-life situations are valuable in some cases but lack the necessary level of abstraction in others. At least as important are other techniques for visualisation, among them:
(i) diagrams, maps, and abstract pictures;
(ii) process visualisation tools;
(iii) data visualisation tools;
(iv) 3D modelling, animation, and abstract movies."

These techniques, discussed further in Section 7.1.15 and Section 7.1.16, enable teachers to create exciting and effective learning environments. However, even coupled with modern authorware packages most lessons incorporating graphics inevitably need an immense investment of time to produce. Fortunately, as mentioned in Section 4.3, new data access methods that use modern searching algorithms are providing gateways to a wealth of database material.

One interesting observation should be noted here. Our second most important sensory organ, the ear, has a counterpart - the mouth. But our eyes have no such counterpart. We cannot project mental images for other people to capture. In the paper "The Missing Organ" [Maurer and Carlson 1992] the authors suggest that multimedia systems may develop to a stage where they will provide us with a prosthesis to make up for this deficiency. We may be able to produce concrete and abstract projections of our mental images, by computer, so easily and naturally

that they will provide us with a new dimension in communication and transform our lives even more than books have done.

CAI programs that make full use of multimedia can certainly provide captivating and effective learning experiences. However, to create high quality courseware an author needs to combine the skills of educator, graphical designer and computer specialist [Augenstein, Ottmann and Schoning 1993]. Unfortunately many CAI packages break even the most fundamental rules of good design:

- Too much text cluttering the windows (at worst page after page copied straight from books)
- Cluttered diagrams
- Flagrant abuse of colour combinations
- Too little or too much flexibility in navigation paths through the material
- Inappropriate or patronising computer generated responses

In the paper "Multimedia: We Have the Technology but do we have a Methodology?" [Alty 1993] the author describes a study indicating that peripheral or parallel streams of information containing redundant information can be of importance in helping students understand complex ideas. He also argues that the users of multimedia systems should be given flexibility to determine which particular medium suits their purpose best, and concludes that a great deal more work needs to be done in this area.

7.1.7 Intelligent Tutoring Systems (ITS)

Currently much research is being directed into the development of general tutoring systems involving artificial intelligence. Systems, coupled with discourse languages, have been developed to interactively set up knowledge bases (lessons, examples, tests, etc.) in more than one field (ranging from biology to physics). The Exploring System Earth Consortium is a group of universities and industries in the United States currently developing intelligent science tutors. The group is addressing the problems associated with choosing appropriate teaching strategies based on students' backgrounds and tutorial experiences [Woolf 1992].

Because a significant investment of time is still needed to create an ITS or to tailor any general program to a specific domain, a system is urgently required that will enable staff to find out readily what existing work has already been done in any area of interest. Using networked multimedia systems such as Hyper-G [Kappe, Maurer and Sherbakov 1993], lists of available software are becoming accessible.

7.1.8 Exploratory Learning

There is still an immense amount of work to be done in this field to determine just how students learn best when confronted with a large information system. There may be as many different answers as there are students. However there has been some good work done in providing students with tours and maps [Davies, Maurer and Preece 1991].

Programs enabling students to experiment by directly manipulating graphical objects can provide fascinating learning experiences. In his paper "Direct Manipulation: A Step Beyond Programming Languages" [Shneiderman 1993a] the author asks, "Why not teach students about polynomial equations by letting them bend the curves and watch how the coefficients change, where the x-axis intersects, and how the derivative equation reacts?"

Many virtual instrument systems exist supporting the real-time plotting of data in forms that can be manipulated on the computer as required. They can, for example, generate plots reflecting conduction in nerves or forces in muscles.

7.1.9 Student Study Aid Programs

It is often the very students who would benefit most from assistance programs who are the least likely to hear about them. An attractive, non-threatening multimedia environment is likely to have such wide appeal that many more students will learn how to obtain help before it is too late.

7.1.10 Resource Centres

Here again well designed hypermedia systems can guide users to the various campus facilities to find out what is available. It is a fact that most students today have no idea of the many resources available to them: audio and video tapes held in other departments, computing services, teaching resources, sports equipment, and of course HM programs of many kinds.

7.1.11 Self Testing

CAI can provide unique ways for students to assess themselves in a relaxed and non-threatening environment:

- Incoming students can determine whether they are well enough prepared to embark on their selected courses of study.
- Students who attain a required standard by sitting self-administered preparatory tests will be able to sit formal examinations with considerably less stress.
- Masters students can use tests to determine what background reading they must do before embarking on their graduate projects.

More advanced programs can help students assess their level of understanding on key topics and direct them to appropriate material.

It may not be necessary to build into the CAI packages electronic marking of the students' answers. In fact it may be best for the answers to be written or drawn on paper. Since the self-assessment results do not influence the students' final results, it is in the students' own interests to get as accurate an assessment as possible. Thus the tests can provide model answers and let the students determine the correctness of their responses. Alternatively two students may work on a quiz together and mark each other's work using the computer's answers as a guide.

Several types of self tests exist. Perhaps most easily adapted from standard tests are multi-choice tests. More interesting are tests asking the user to draw their answers or indicate them on diagrams. Tests involving interactive animation can frequently test students' understanding of processes more reliably than standard testing methods. For example, in the assembling of complex pieces of apparatus the

various parts can be dragged across the computer screen to test correct assembly order. In an interactive medical simulation, complete with awe-inspiring hospital sound effects, medical students are tested on their knowledge of operating room procedures using computer-controlled time constraints and lifelike animations.

Attempts have been made to design systems in which the questions themselves are computer generated. However the results to date have not been encouraging. In the paper "Question/Answer Specification in CAL Tutorials (Automatic Problem Generation Does Not Work)" [Maurer, Stone, Stubenrauch and Gillard 1991] the authors describe two programs: one to generate functions to give students practice in differentiation, and the other to provide sets of linear equations for solution practice. The authors found that it was difficult to control the generation of undesirable functions and sets of equations, and they conclude that "with present methods, the use of such procedures is neither cost-effective nor desirable. Better results, with less effort, seem to come from random selection of 'fixed' problems from a (possibly large) database of such problems."

Since it is often desirable to let a student re-sit a test, groups of questions need to be defined so that the program can randomly select from each group during any particular run.

7.1.12 Examinations

It is the hope of many educators that traditional examinations will gradually be replaced by much more effective Mastery Learning programs where students continue studying, with either a teacher or CAI, until they are able to show by a practical demonstration that they have mastered the subject.

As in the case of Self Administered Tests there are several different types of testing programs available:

- Multi-choice tests that can accept answers in words, numbers, or diagrams.
- Simple graphic tests where, for example, the students can graph points or indicate the correct answer on a graph.

- Tests designed so that the student indicates the required answer by circling a region.

It is an interesting problem to design tests that can be electronically marked and yet test the order in which activities are performed. For example, if students are tested on their knowledge of the assembly of chemical apparatus they may have to assemble the pieces in a predefined order. In order for the CAI program to assess their answers a system is needed whereby the students' responses can indicate order - without resorting to script numbers, which are difficult to analyse.

There is a problem with administering computerised tests to large classes: where there are not enough computers for each student to use one simultaneously, multiple tests have to be devised and this too is time-consuming. The sharing of work among colleagues from different campuses can alleviate the problem a little, but alternative methods of marking may have to be used. For example, if questions are answered on well designed paper forms they can be scanned and marked electronically.

7.1.13 Research

Computer networks link my office to the office next door, to facilities across the campus, to databases in other universities, to the American Library of Congress catalogue.... Most academics see the computer as a way to improve teaching, research, management and general university life, even in days of financial retrenchment. Scientists are developing visualisation tools that provide effective student training without expensive laboratory equipment and chemicals. Biological scientists, who are now very aware of the environmental impact that their students make on nature, are experimenting with computer simulations in "dry laboratories".

Heavy use is being made of Internet in many disciplines: chemists (particularly inorganic chemists who cannot work without up-to-date information on the thousands of new compounds), the medical profession (keeping up to date with the daily emergence of new, life-saving drugs) and lawyers (with endless cases to look up for precedents). In addition to all this, today's networks contain databases of patent registers as well as collections of abstracts and much more.

There is no question that having material available in electronic form is as important as having it available in print, or more important. The statement "more important" is justified since the perusal of electronic information, at least for "entry point" research, is much more efficient than the use of printed volumes (and much of the material available on CD-ROM is of the "entry-point" type: collections of reviews, abstracts of papers, dictionaries, etc). A wealth of bibliographic data and several complete encyclopedias of information now exist in electronic form and are available via networks.

7.1.14 Simulation

This very promising resource unfortunately demands a great investment of time to implement, and staff need more support to help them find out what software is already available. One outstanding project is worth mentioning again here: the Athena project developed at Massachusetts Institute of Technology [Murray and Malone 1992]. This includes, for example, a total immersion learning environment for teaching French - a virtual reality. Students can walk through the streets and buildings of Paris with full-scale video on one screen while they interact with the plot via a computer display of maps and dialogue boxes. They have the options of dictionary searches, replay phrase by phrase, and even clean sterile Language Lab French if they must.

In the business world new techniques are being developed to enable complex interrelations to be comprehended. One successful application produces a simulation of the state of the stock market. In a virtual reality setting the viewer can navigate through landscapes reflecting the state of stock by using geometrical representations. While the user is investigating areas of personal interest the system will note other relevant changes.

7.1.15 Data Visualisation Tools

Physical scientists and mathematicians have traditionally made considerable use of graphs and diagrams, but now with computer support the field can be further extended [Domik 1993]. Programs are now

available enabling scientists to visualise: the "greenhouse effect", quantum tunnelling, and brain tumours [Computer 1989], the dynamics of the atmosphere, bio-electric fields, stresses and strains, 3-D fluid flow fields and robotic surgery [IEEE 1993] - to name just a few. A great deal of work has already been done to enable hyper-dimensional problems to be visualised [Maurer 1992], [Hanson and Heng 1992].

The Human-Computer Interaction Laboratory at the University of Maryland has developed many innovative projects involving data visualisation - projects ranging from the visualisation of nested directories [Johnson and Shneiderman 1993] to interactive programs that enable users to select their own ideal piece of real estate [Williamson and Shneiderman 1993]. In the introduction to "Information Visualisation: Dynamic Queries, Treemaps, and the Filter/flow metaphor" [Shneiderman 1993b], the author states: "Our eyes can carry a hundred times more information to the brain than our ears. Adding user-controlled animation can further increase comprehension. The world of the future will be more like driving or flying a plane through colourful three (or four) dimensional information spaces. Users will rapidly select, combine, eliminate and construct new displays."

Dynamic queries enable a user to control animated displays and filter the data by using graphical sliders as well as menu options, graphical buttons, text, etc. Programs such as these provide a powerful medium for showing trends - as exemplified by the dramatic animation of an influenza virus spreading across Europe. Of particular note is the project "Dynamic Queries on a Health Statistics Atlas" or "Dynamaps". Pages and pages of indigestible numeric medical data form the database for the program, which displays the information graphically by:

- Geographic region
- Year
- Sex
- Education Level
- Smoker / non-smoker

Startling correlations can be demonstrated, such as between education levels and deaths by cervical cancer. The authors conclude that exploring data interactively lets researchers see correlations by looking at

patterns, and find scientific insights that can be demonstrated in a convincing manner.

7.1.16 Process Visualisation Tools

Animated diagrams provide a most effective way of showing many processes, whether in commerce, medicine or the physical sciences. New authoring tools can be used to good effect.

In the field of computer algorithm visualisation, there are systems such as Tango [Stasko 1990] and XTango [Badre, Beranek, Morris and Stasko 1992] that use graphical facilities to show how a program works. There has been doubt cast on just how much these aids really do enhance a student's understanding of any particular process, but it is certain that the tools can be of considerable help in debugging and optimising programs.

7.2 Lecturing: A Future With Hypermedia

In the paper "Lecturing Technology: A Future with Hypermedia" [Lennon and Maurer 1994b] we discuss ideas that will take future lecturing techniques far beyond the use of computers for simply giving presentations. There have been many highly innovative ideas on how to use computer-based teaching theatres [Norman 1993], [Shneiderman 1993c], [Gilbert 1993] and [Fisher 1993], and we propose a system, based on these ideas, that will:

- Allow students and teachers to interact electronically.
- Generate high quality CAI in the form of refined lecture material that is coupled with question and answer material electronically captured from students' interactions with teacher or tutor. This material may be multi-authored.
- Enable students to plug their own personal computers into the university network, and to play and replay lectures at their own convenience.
- Allow the lecture itself to develop into an anonymous group discussion similar to that which takes place in a decision room.
- Support computer-supported collaborative work.

- Support computer conferencing.
- Support distance teaching [Hewitt 1993], [Rajasingham 1988]. In difficult economic climates more students have to be handled with smaller financial resources. Distance teaching and CAI are two solutions to what is at first glance an impossible situation.

The consequences of any one of the above points will be considerable. What the net effect will be no one can predict.

It is a truism that only through education will any real progress be made. An estimated 80% of U.S. college students now have access to networks. For everyone from kindergarten children through to university administrators the new worldwide network links provide educational possibilities undreamt of.

7.2.1 "Just in Time" Learning in the Virtual Classroom

The electronic lecturing system described above should now be put into a wider educational context. It has been argued that, for a successful future, education must shift from being teacher centred to being student centred [Petruk 1992]. To survive in the information age students will need to be proficient in navigating various information pathways, and they must be provided with the necessary skills. Once they have these skills they will be able to take control of their learning to a much greater degree than ever before. Many large firms such as Boeing and AT&T have "need to know" training programs already in place. Where projects are as large as these no trouble-shooter can expect to know everything. "Just in time" learning has taken on new dimensions with the introduction of multimedia programs to help technicians diagnose faults literally on the fly!

In the area of medical research new knowledge about treatments is becoming available at such a rate that no general practitioner has a hope of keeping up to date. With electronic help members of the public will be able to query the world's medical databases and bring the most up-to-date information to their own doctor's attention so that the best treatments available may be chosen.

7.2.2 Total Immersion Learning Environments

The computer is also becoming the ultimate media machine. This in itself will profoundly affect the way students learn and the way we teach. Interactive movies already exist where the viewer can modify the plot or help solve a mystery. We are very close to being able to model complete interactive environments. As we saw in Section 7.1.15 we already have two and three dimensional animated data-modelling programs. Virtual reality enables investigators to interactively explore three dimensional models. Whether we model a human heart, a museum, a city or a planet (either actual or imaginary), it involves basic virtual reality research. The real thrust of virtual reality research is not in the gimmicks like space helmets and data gloves (exciting as they may be to use) - it is in the modelling. Some of the most challenging research in this area is undoubtedly the work on modelling human figures [Paouri, Magnenat-Thalmann and Thalmann 1991], [Magnenat-Thalmann and Thalmann 1991a], [Magnenat-Thalmann and Thalmann 1991b]. The human eye is certainly amazing at noting even minuscule imperfections in human anatomy! But we are close to succeeding even here.

8 The Role of the Personal Assistant

The idea of having an electronic personal assistant is not new. Computer scientists have long dreamt of having an electronic assistant (i.e. a supervisory program) to help them manage everything from electronic mail to research and teaching commitments. And of course science fiction writers have taken the idea of a personal assistant still further by suggesting that it will assist with all our personal problems!

An extensive survey of "Intelligent Agents" is given in a special issue of "Communications of the ACM" [Communications 1994]. The paper "From Personal Computer to Personal Assistant" [Lennon and Maurer 1994c] also gives an overview of the subject, and we summarise just a few of the more important points here:

As software systems are used by more and more people the problems associated with training have multiplied. Users simply do not have the time, or motivation, to browse extensively through printed manuals or on-line help files, so they are frequently unaware of useful features. The

need for electronic assistance was already recognised back in 1985 when a "computer coach" that "unobtrusively monitors interaction with a system and offers individualised advice" was developed to help users in a word-processing environment [Zissos and Witten 1985]. In 1992 a system was developed to help users avoid repetitive formatting tasks [Mo and Witten 1992]. A more generalised personal assistant has been proposed by the second author of this report [Maurer 1993b].

Many of the major computer companies are committed to the development of what they are now terming an electronic agent. Prototype versions of systems exist in which agents are capable of learning from repetitive actions. In such a system the agent first of all indicates that the user's actions are being shadowed by highlighting selections, menu choices, etc., in a specific colour. Then if the user decides that all actions have been shadowed correctly, there is the option of letting the electronic agent help from then on. Computers carrying out a whole range of voice commands are also no longer fiction: form letters can be entirely written using only voice-activated commands.

We hope that the electronic agent will develop from this rather primitive beginning into a fully fledged electronic personal assistant; i.e., develop into a general background processor to help users stay in control of their environment. The widespread problem of information overload will be eased if an electronic personal assistant sets up filters so that all searches can be tailored to the user's requirements. As we have already discussed in Section 7 a supervisory program will also be an invaluable aid, a watchdog, for helping researchers cross-reference and check their work. This is becoming critically important as daily so much highly questionable data is being quoted as fact.

9 Future Directions

In the paper "Forecasting - an Impossible Necessity" [Maurer and Lennon 1994] we state: "In the area of information technology we are going to witness tremendous jumps in quantity. Not just a few more computers. In ten or fifteen years from now everyone will carry small but powerful Notebook computers around with them. The much heralded Newton is certainly a first step in this direction! You will be able to talk into your notebook and have more commands, programs, and facilities available

than we can imagine. For example, if you go to a foreign country and talk into your notebook in English out will come Greek or French. A global positioning system will display maps for you and show you at any time exactly where you are located on the surface of the earth. And of course a mobile telephone will be integrated into your notebook, giving access to all the databases of the world - so you can look up theatre programmes and bus and train connections. It will be your digital photo camera, and it will replace your wallet and credit cards. It will be indispensable. Thus, we are going to witness a jump in quantity from many computers to omnipresent computers." We argue that while we can, and must, make short-term predictions, we cannot make long-term predictions because of the unpredictable effects such things as new inventions and global economics have. No one can predict where this jump in technology will take us!

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