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ABSTRACT

With the explosion in information resources being developed by computer scientists, subject specialists, librarians, and commercial companies, the challenge for the information professional is to keep abreast of the most significant developments and to distill the information for a wide range of users. This paper looks at some of the developments in electronic libraries on both sides of the Atlantic and the impact on the information professional. New projects involve multimedia, hypermedia, user interfaces, and other aspects of the integration of diverse libraries, and show that methods of research are also changing. Information professionals must continually keep aware of new techniques and sources if they are to contribute to their usefulness. Intelligent agents are beginning to replicate some of the tasks which are familiar to librarians, such as current awareness, but intelligent agents can also act as a tool for the librarian. The challenge for the researcher and developer, and also for the librarian, is to make an efficient transport system for the information superhighway. Knowledge robots and 3D visualization are tools to simplify the increasingly complex and diverse information world. However, pooling skills and resources between information professionals will become ever more essential. (Contains 41 references.) (Author/SWC)

Information Professionals as Intelligent Agents – or When is a Knowbot Only a Robot?

By:

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Information professionals as intelligent agents — or when is a knowbot only a robot?

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Abstract: *During the 1980s we saw the role of the information specialist develop with the gradual introduction of end-user searching. The number of online databases was increasing but they were structured and conducive to controlled searching. We now see an explosion in the resources becoming available and being developed by computer scientists, subject specialists, librarians and commercial companies or often by all four together. The challenge for the information professional will be to keep abreast of the most significant developments and to distil the information for a wide range of users. It will be increasingly necessary to pool knowledge with both professional colleagues and clients. The parallel efforts of academics and librarians to develop subject guides to the Web illustrate this well. The computer scientists are currently making dramatic use of computer techniques and computer power to make information more accessible and navigable. Librarians can assist by sharing their knowledge about the efficient organisation of information.*

This paper looks at some of the exciting developments in electronic libraries on both sides of the Atlantic and the impact on the information professional. These projects are tackling multimedia, hypermedia, user interfaces and other aspects of the integration of diverse libraries, and showing that methods of research are changing as a result. Information professionals need to see these as an increasingly rich set of resources with a greater variety of techniques for accessing. However, they must continually keep aware of new techniques and sources themselves if they are to contribute to their usefulness. Intelligent agents are beginning to replicate some of the tasks such as current awareness which are familiar to librarians but these can also act as a tool for the librarian (just as driving an automatic simplifies driving a car). The challenge for the researcher and developer and also for the librarian is to make an efficient transport system for the information superhighway: to make it easier to drive different cars and to provide an complementary (and often complimentary) taxi service. Knowledge robots and 3D visualisation are tools to simplify the increasingly complex and diverse information world but pooling skills and resources will become ever more essential.

Keywords: Information professionals, librarian skills, intelligent agents, software agents, knowbots, digital libraries, electronic libraries

1. Introduction

We are now celebrating 30 years of using computers in libraries and information services and are using them as tools in ways we barely dreamed of in the sixties. We expect a library's catalogue to be online and probably accessible from the other side of the world — if we can find the correct route in, around and hopefully out again. We are beginning to use electronic journals and other full-text databases more frequently. We are exploring the potential of databanks and a variety of media. An acoustics journal issue may come with examples of sounds on a CD. Now an encyclopaedia, on CD-ROM, has a video clip showing a space shuttle launch. Personal computers are more powerful than many mainframes used to be and the world is our oyster if we have access to the Internet. The World Wide Web on the Internet has accustomed us all to using hyperlinks as one of the commonest methods for finding our way around this vast distributed multimedia information system. The new seven storey New York Science, Industry and Business library will enable visitors to search more than 125 business and science databases, browse the Web on 100 workstations or bring in their own laptop and use one of 500 seats wired for their machine. During the 1980s we saw the role of the information specialist develop with the gradual introduction of end-user searching. The number of online databases was increasing but they were structured and conducive to controlled searching. The new 'cybrary' in Manhattan symbolises the explosion of resources becoming available and the library profession's initiatives for dealing with it. The new or enhanced information banks are being developed by computer scientists, subject specialists, librarians and commercial companies or often by all four together. They are increasingly incorporating intelligent agents to help users fulfil their information

needs more effectively. The challenge for the information professional will be to keep abreast of the most significant developments and distil the information for a wide range of users. 'To participate more fully, librarians will need the help of technologists to understand the possibilities being created by digital technologies, and technologists will need the help of librarians to appreciate the richness of traditional librarianship and to identify the aspects of it that are most relevant to the continued evolution of libraries' (Ref 1). I will look first at one example of an electronic archive that is changing the way in which research is communicated.

2. Digital library techniques transform scholarly communication

In the high energy physics community, mainframe computers used to be used by librarians (using punched cards and batch processes) to create regular lists of reports (called preprints) to distribute physically around the world. These days the reports themselves are sent electronically by their authors to an entirely automated central depository at Los Alamos National Laboratory in the US (Ref 2). Started by Paul Ginsparg in 1991 to serve a small community of less than 200 physicists, these archives now contain numerous other physics databases and serve over 40,000 users worldwide. The established researcher will go straight to this archive by the most efficient route while a librarian will provide pointers for the student or researcher from another discipline, perhaps by providing links from a subject guide on the library's Web pages. Putting scholarly papers onto the Web will dramatically increase the speed of research communication (although alternative economic models may be needed to sustain the related electronic journal publishing) (Ref 3).

The phenomenal success of the physics e-print archive has motivated Stevan Harnad at the University of Southampton to start an international archive for the cognitive sciences modelled on the American pioneer. It is indicative of the variety of skills that are frequently needed now in the digital information world that the electronic document specialist who will set this up needs a good understanding of a complex set of text processing formats, document conversion, hypertext linking and information retrieval as well as Unix programming tools. This archive will soon join the increasing set of distributed resources to which libraries and their customers will have 24 hour access and which can enhance the productivity of research.

3. Evolving information services and the demand for types of information skills

Discovery tools are important in a distributed environment, although to some extent their significance is decreasing owing to the growth of digital libraries. Digital libraries such as those above are usually established by individuals or bodies that care enough about their contents to build, maintain and in some cases describe them. An example of a body developing a library with an associated 'electronic community' is the Interest Group on Pure and Applied Logic, an international association of almost 1000 logicians from almost all the countries of the world (Ref 4).Thus, for many users, one option for reducing the task of network discovery is to find the best digital library and then search within it.

Paul Ginsparg suggests that the electronic medium naturally facilitates large scale disintermediation (although his own community uses what to some people might seem quite a high level of information handling skills to transmit and retrieve their reports) but he admits that there remains a need for organisation of *intellectual* value-added services. Current concerns for his archive include not only the continued development of a robust global mirroring system but also a better means of handling meta-level indexing information. In helping tackle indexing problems such as these, the library and information science communities could surely provide a constructive contribution. 'It would be remarkable if centuries of ostensibly relevant experience will find little applicability in the network context'(Ref 5). The skills of the archivist may also be crucial for addressing the issues of the long term preservation of electronic resources. There is indeed optimism that the demand for information professionals, in the broadest sense, will continue to expand in our information intensive society. Michael Hill, Chair of the Aslib conference on the Future Information Professional in May this year, stressed in the invitation to participate in the meeting that 'The information society by definition opens up enormous numbers of opportunities for the information professional. What he/she needs is foresight, imagination and the courage to go for them.' Nick Moore (Ref 6) suggests that three complementary groups will emerge: creators, communicators and consolidators. We may need to reflect more carefully in which area our skills lie or more consciously add new ones like design skills as part of our career development. We will certainly need to master the fast changing jargon of Internet and multimedia database retrieval in order to teach some of our customers these information skills. Digital literacy means being at home in an expanding but shifting mixture of words, images and sounds (Ref 7).

In a related approach to looking at the role of the intermediary, Brewer *et al.* (Ref 8) look at the value-added services that need to be provided in the emerging digital library. They then divide them up into search services, classification, information filtering, translation services (for formats as well as languages) and publishing. While the digital world will blur distinctions between publishers and libraries they argue that digital libraries will bring many new forms of intermediaries, some rooted in the services that libraries and publishers have always provided and others which respond to entirely new intermediation needs. Future libraries will in any case incorporate both digital and traditional resources. The proactive nature of today's library services will need to be continued even

if some of the intermediary's role may also be to develop software agents to simplify 'robot librarian' tasks in the digital environment.

The working party of the American Coalition for Networked Information (CNI) on networked information discovery and retrieval has endorsed the view that the active, continual involvement of a human will be still be necessary to control the process and to make complex decisions involving relatively unstructured information (Ref 9). Therefore, although much research effort in electronic libraries is being expended in automatic and semiautomatic semantic indexing there will still also be an active role for the librarian or subject specialist. Abstracting and indexing in particular will entail some human input until the day all data is highly structured and complies with clear data interchange standards, and the tools become truly intelligent. In the UK pilot projects in the Electronic Libraries Programme (Ref 10) such as EEVL in Engineering and OMNI in medicine, librarians are developing specialised resources which provide the metadata (the information about information) currently rarely available for resources on the Web. At the same time they are adding value by sifting for quality sources with a UK relevance which are also harder to find in a world with an initially American bias. These subject based services will provide effective pointers for librarians who are teaching students or researchers new to a given field how to use the Internet most profitably in their research projects.

4. Wide ranging progress is taking place in electronic libraries

In the UK, the ELVIRA series of conferences on Electronic Library and Visual Information Research, which has now reached its third year, samples the progression of research in the many interdisciplinary fields of digital library research. These range from fundamental infrastructure issues such as turning the World Wide Web into a library (Ref 11) to the state of the art of automatic image content retrieval (Ref 12), and practical examples such as creating a digital medieval manuscript (Ref 13) or publishing a scholarly journal on the Web (Ref 14). We are now at the stage of having some experience of setting up (Ref 15) and using tailored electronic libraries. Evaluation of how effective they are is beginning to take place, for example, in the Elinor library (Ref 16) at De Montfort University and this is an aspect of digital library work which will profit from more research. The information specialist is well placed to help look at the real needs of the user while the computer scientist creates new methods (Ref 17) of helping the librarian visualise where the end-user is having difficulty.

5. Visualisation in digital databases

Visualisation is increasingly a key area of emphasis in research with interesting experiments in 2D and 3D mapping. Some examples will serve to illustrate this. The Hyper-G hypermedia information system for the Web (Ref 18), initiated at Graz University of Technology in Austria, is developing a 3D information landscape (which can be viewed on a powerful Unix machine) to supplement its 2D local maps as an aid to navigation in hyperspace. At Delft University of Technology in the Netherlands, researchers are using techniques at the confluence of geographical information systems and multimedia to develop a prototype of the hypermap concept of georeferenced multimedia for their campus information system (Ref 19). On the East coast of the US a digital library, also based on a spatial metaphor, is being developed in the State of Florida — metadata on collections is divided into information zones on a map of Florida (Ref 20). On the West coast the Alexandria Digital Library (Ref 21), which is co-ordinated by the University of California, Santa Barbara, will provide online public access to maps, photos and other information referenced in geographical terms. It will help make available data currently found only at major research libraries. The user interface includes a map browser and the search is done by zooming and panning a base map. The spatial indexing will play an increasingly important role as the catalogue grows.

Another interesting experimental interface is being developed for a very different set of spatial sequenced digital data — the National Library of Medicine's Visible Human Project which is in the process of creating a large digital library of anatomical images of the human body. In the Visible Human Explorer user interface (available from *http://www.nlm.nih.gov/*) the library contents are indexed by metadata consisting of automatically generated miniature visuals. By dragging a slider over an overview of the body users select the visual previews from which they can straightaway download the desired images. Human factors research will be needed to determine usability measures of differences between 2D representations such as this Visible Human Explorer interface (Ref 22) and potential 3D representations. However, as computer hardware increases its power, 3D representation techniques are becoming more practical and attractive.

6. Large scale test-beds forge ahead in US digital libraries

In the US the government has made digital libraries the flagship research effort for the National Information Infrastructure. The Digital Library Initiative (DLI) (Ref 23), sponsored by the National Science Foundation, the Advanced Research Projects Agency (ARPA) and NASA aims dramatically to advance the means to collect, store and organise information in digital forms, and make it available for searching, retrieval and processing via communications networks. The DLI projects, such as the Alexandria Project cited above, give a good indication of the current research into large-scale digital libraries. Six projects run by university-led consortia are funded

from September 1994 to August 1998 and all are building testbeds with large collections to relate their fundamental research questions into building large-scale electronic libraries.

7. An established digital library begins to mould research techniques

In the humanities we already have a digital library which has been developing for long enough to give us some findings on the impact of putting a critical mass of materials in digital form. The Perseus Project (Ref 24) is an ongoing digital library on ancient Greek culture that has been under development since 1987. Experience has shown that it is almost impossible to predict with accuracy what electronic tools will and will not prove valuable. Services that initially seemed promising have at times been less useful while functions which had attracted little or no thought have emerged as dynamic new tools and even catalysts for the transformation of practice. Does this then indicate that evaluation of new tools, such as Web searching tools (Ref 25) and intelligent agents, is thus a constructive area of research for information professionals to be involved in? What is striking in the Perseus Project is that translating from print into electronic form has undercut the distinction between student and research tool. Analysis, although still at an early stage, is tending to show that students looking up the meaning of a word use the research lexicon and only 20% of the time choose to switch to the briefer entry in the student lexicon. In their paper forms the research lexicon was too dense and complex for use by any but professionals while the student lexicon had previously languished untended for more than a century. With the possibility of incorporating thousands of images cheaply text is also beginning to share centre stage with other electronic documents in this particularly visual subject and, with the development of languages like Virtual Reality Modelling Language (VRML), 3D walk-throughs could become a natural area of development for this database.

8. Virtual reality provides visions of future information worlds

There are in fact many images of the cybrary and the cybrarian of the future which help us envisage some of the potential of the emerging technologies for electronic libraries and distributed multimedia information systems. The DigiCom company's virtual reality databank in the film of Michael Crichton's bestselling thriller *Disclosure* (Ref 26) is vividly portrayed by modern film techniques as a 3D library. In a multimedia version of my paper I would like to be able to link the reader directly to the appropriate video sequence but it is perhaps indicative that the DigiCom library becomes a black and white world when there is too much data to move around. Current research into the real-time display of continuous media data such as video and audio (Video-On-Demand or VOD) is focusing on such issues as improving the transmission of media traffic over high-speed networks (Ref 27) but the technologies and also the copyright mechanisms are not yet quite mature enough to satisfy all our wants. Neal Stephenson's science fiction novel *Snow Crash* (Ref 28) introduces a wonderful piece of software — the Librarian daemon, who looks like a pleasant, fiftyish, silver-haired, bearded man with bright blue eyes. He does all the investigative work of a robot librarian: the only thing he can't do is think. The virtual world, called the Metaverse, is also populated with avatars — the surrogate graphic characters which have become familiar in online chat systems such as CompuServe's Worlds Away. Dedicated Worlds Away users can even upload their own images to be used as their avatar's head.

Another visionary scenario is Martin Halbert's *Knowbot Explorations in Similarity Space: Library Conversations in the 21st Century* (Ref 29). These knowbots, like the Librarian daemon above, are programs which collect information from network databases and organise it for their owners. Textures are used to convey information about the database regions in the 3D datascape. Barren fields, for example, represent very new records in the database that have not been analysed for content, type of publication etc. They have only been scanned and indexed for basic similarity measures to place them in the database. Mountainous regions represent clusters of relevant documents. Buildings represent hypertext links so that a heavily cited journal in an electronic journal database looks like a metropolis. The knowbots are based in a 'knowbot corral' and are represented by animated holographic icons. In the corral are clusters of knowbots, sub-knowbots and metabots. The metabots are knowbots that can be programmed with customers' preferences. They can automatically suggest and manage the creation of new knowbots when they spot a relevant new topic. They can also optimise the current stable of robots. This futuristic technology portrayed here is still in its infancy but it is now beginning to be possible for lay people to build their own knowbots or software agents. Books (Refs 30, 31) can now provide you with enough information about bots and the software (such as Tcl, Java or Telescript) necessary to create them, to customise your very own personal digital assistant or research assistant.

9. Knowbots and software agents

Intelligent software agents are often popularly referred to as knowbots but there are numerous more specialised definitions around, like the sinister sounding:

knowbot: an independent, self-acting computer program that seeks for information on behalf of a user, possibly

replicating itself on other hosts on the network. As the knowbot performs its task, it sends reports back to the user, and self-destructs when it completes its task (Bryan Pfaffenberger — *Internet in Plain English*).

The power of knowbots on the Net is increasing but the early examples on the Web frequently look like basic information retrieval techniques translated into a world that was previously lacking them. When programmed to repeat their searches they may be an upgrade of the familiar Selective Dissemination of Information (SDI) of traditional online databases — updated with a more friendly interface and often more sophisticated searching techniques. The computer scientists have reinvented current awareness profiles for the masses and called it information filtering. An interesting example is the Mercury Center's Newshound (*http://www.sjmercury.com/hound/*) which automatically searches articles from a wide range of newspapers and wire services, as well as classified ads from the *San Jose Mercury News*, using a profile created by you and sends any relevant documents directly to your electronic mailbox. Knowbots on the Net are knowledge acquisition robots — autonomous programs that can search for and act upon information found on the Internet. Knowbots can sit on a single node and probe the Net, or can wander from server to server (as a worm). Examples of currently existing knowbots are Archie servers, some directory servers, the Web meta-indexes and the World Wide Web wanderer. One can now draw a distinction between first generation and second generation knowbots. A first generation knowbot is a tool that traverses the Web and retrieves raw data with no post-processing. A second generation knowbot is a more complex tool that uses some kind of knowledge analysis system, like an expert system, to refine the information extracted from the Internet. While the Newshound shows minimal intelligence, other systems such as NewsWeeder (Ref 32) contain agents which exhibit more intelligence by learning users' interests. WiseWire, the commercial version of NewsWeeder, will be a Web-based service that uses neural net filtering technology to learn a user's interests automatically. As you rate information, WiseWire learns your responses. At the same time all new content is filtered by users with similar information preferences. This collaborative filtering is added to provide a more efficient personalised online information service which they call a Personal Surfing Assistant.

Knowbots, softbots, taskbots, interface agents, personal agents and network agents are just some of the new terms used by various researchers to describe their agents. The idea of employing agents in the interface to delegate certain computer-based tasks was introduced by visionaries such as Nicholas Negroponte and Alan Kay and over the past few decades numerous researchers such as Marvin Minsky and Patti Maes have studied problems that demonstrate some type of agent behaviour. Agent research draws on the results from several disciplines and there is continuing debate within the community on ways of classifying and defining agents (Ref 33). At a simple level, agents can be considered personal software assistants with authority delegated from their users. Patti Maes at MIT's Media Lab, for example, has been working to create agents which reduce both work and information overload for computer users (Ref 34).

There had been a long tradition of investigation into the use of agent intermediaries in the information world before the advent of ubiquitous and powerful PCs with easy access to the Internet which has helped fuel the current enthusiasm. For example, twenty years ago the Rand Intelligent Terminal Agent (RITA) (Ref 35) provided a network advisory system which proved a good testbed for the demonstration and evaluation of intelligent agent capabilities. Software intermediaries were developed within the field of expert systems — computer-based systems that use knowledge and reasoning techniques to solve problems that would normally require human expertise, usually within a relatively narrow domain. That inexperienced users could operate retrieval systems at all was demonstrated by experiments with the CONIT system from MIT. But whereas CONIT taught users a command language and suggested search techniques so that the users then had to decide for themselves how to apply these techniques, their next experimental intermediary system EXPERT (Ref 36) aimed to help inexperienced users search bibliographic retrieval systems using a menu-selection/ fill-in-the-blanks mode to aid search strategy formulation and reformulation. In the UK, Pollitt was one of the first to use artificial intelligence techniques for a database access system. His menu-based system CANSEARCH (Ref 37), using a touch sensitive screen, provided access for doctors to cancer therapy literature in the Medline database using Medical Subject Headings (MeSH) to guide the search process. Another system, TOME.SEARCHER (Ref 38), commercially available from Tome Associates, which was first used to search INSPEC's scientific databases has been extended to provide an intelligent front end to a wide range of databases.

More recent work is often pictured in a more modular way with an emphasis on multi-agent systems composed of a set of intelligent entities called agents. These agents have their own capabilities and then they communicate with each other and cooperate in order to achieve a global goal.

10. Intelligent agents in practice

One useful framework for understanding current work on agents divides them into three types of agent which perform a variety of specialised tasks:

- interface agents
- task or mediator agents
- information agents

Interface agents interact with the user, receiving user specifications and delivering results. *Task agents* have knowledge of the task domain and support decision making by formulating problem solving plans. They carry out

these plans by querying and exchanging information with other software agents. *Information agents* provide intelligent access to heterogeneous collections of information sources.

The University of Michigan Digital Library project (Ref 39) is building its infrastructure in this way with three separate groups of agents. It also provides a subclass of mediator agents, called facilitators, expressly to team up with other agents to accomplish more ambitious tasks. The 'robot corral' is beginning to be populated. In this case, a shoal might be a more appropriate metaphor since the remora agent is an example of one of the mediator agents in the Michigan library. The remora is a kind of fish which attaches itself to sharks and the remora agents attach themselves to information agents for the purpose of detecting events. Users specify events of interest and receive notification when such events, like new items appearing in the collection, occur. This current awareness service is just one of the value-added services that the library can provide. The agent architecture lets them develop specialised capabilities and add them as needed. For example, through new interface agents they can customise interfaces to new user classes such as high school students.

The ability to perform reasoning is one of the key aspects of intelligence that distinguishes intelligent agents from more robot-like agents. Reasoning, in turn, is dependent on the ability to demonstrate human like traits like emotions, beliefs and intentions. In order for us to feel more confident about the actions and level of abilities of our assistants, some agents are represented by agent icons not unlike the fictional examples previously referred to. One of the first agents with wide recognition, both in the press and with a large number of users, was the BargainFinder Agent (*http://bf.cstar.ac.com/bf/*) from Andersen Consulting, which assists with comparison shopping on the Internet. It uses a miner with his lamp to show progress on a query. MIT has produced icons in which the faces are deliberately simplified to avoid presenting an impression of more intelligence than the agent actually possesses. A 'smart' image could lead one to expect all the services of a real human professional advisor. However, many more information aware organisations are now in a position to evaluate their use of prototype agents and GlaxoWellcome (Ref 40), for example, have found that their 'dumb' agents have proved extremely useful in helping their knowledge workers navigate their heterogeneous information systems. They therefore endorse the view that the first innovations will be in simple time saving but will pave the way for more sophisticated agents and more profound benefits. In the meantime they will pursue parallel initiatives on improving the consistency of their information infrastructure to simplify the problems. Coming back full circle to the very first example in this paper of the Physics community, there is also another successful database project in Germany — a Network Publication System for the European Physical Society (Ref 41) which will allow remote users to order a document from several document databases for local printing-on-demand. Early indications here also show that agent technology can be useful in serving the needs of specific user groups.

11. Conclusion

No one individual or profession has all the skills now needed to create an information infrastructure for a community of users. We have seen many variants in the electronic library and other distributed multimedia information systems projects with partnerships between computer scientists, librarians, teaching faculty, trainers, publishers and media designers. The advent of electronic publishing and particularly the Web has given everyone the potential to be a publisher. However, the opportunities for using multimedia give options for sophisticated presentation that will increasingly put a premium on artistic and design skills as part of the portfolio of skills desired. Hopefully the end result will be resources that the user will require fewer skills to negotiate and manipulate, even given the increasing richness and variety of the material. Knowbots and other agent technologies, whether of the smart or dumb kind, look set to ease but not take over all of the tasks of the end-user. Agent research, in fact, gives a real opportunity to put research results directly into the hands of the end-user. After over 20 years of using online databases the skills and knowledge base needed by both the user and the intermediary in this increasingly distributed multimedia environment will continue to change and keep us on our toes.

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