Integrated Public-Access Computer Systems: The Heart of the Electronic University

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Introduction

Computing technology, by which I mean a fusion of computer and data communication technologies, is transforming publishers, academic libraries, and universities. Increased use of computing technology in these organizations is creating complex, intersecting patterns of change.

Publishers initially used computing technology to streamline their internal publication procedures, which led to supplying electronic information to online vendors. Online retrieval systems, in turn, spawned other electronic information services, such as gateway vendors. Increasingly, publishers are supplying electronic information to libraries and end-users for local use, and publishers are expanding the availability of non-citation databases (e.g., full-text and numeric databases).

Academic libraries have begun to shift their computing emphasis from the long process of automating internal library functions, such as circulation, to providing systems for direct use by library patrons, such as reference CD-ROM databases. These "public-access computer systems" will provide users with an increasing diversity of information materials and services. As these systems multiply, there will be a growing need to integrate them to provide effective user access.

Universities are creating a distributed computing environment founded on user workstations, networks, and large-scale computer servers. This networked environment does not stop at the boundaries of the campus; rather, interconnected networks link the scholar to systems around the country and the world.

It has often been said that the library is the heart of the university. As the central repository of recorded knowledge on campus, the library is an essential resource for scholarly activity, and one measure of the greatness of a university is its library's collections. As electronic publishing expands and universities become computer-intensive organizations, what will the academic library's role be in this dynamic, technology-driven environment? Will it still be the heart of the university? This paper examines the medium-term future (10-15 years) of electronic publishing, the emerging "electronic university," and integrated public-access computer systems. Its central theme is that the academic library can synergetically combine traditional collections and services with new computer-based information resources and services to create a unified information system. By employing this strategy, it can continue to be the heart of the evolving electronic university.

Josh Billings once said: "Don't never prophesy, for if you prophesy wrong, nobody will forget it, and if you prophesy right, nobody will remember it." Like all technological forecasts, this one will have its limitations. Yet, technological forecasts, although imperfect, often serve two useful functions: stimulating critical thought about the future and inspiring the actions that shape the future. It is hoped that this paper will serve these purposes.

Electronic Publishing

The future of academic libraries, universities, and the publishing industry are inextricably intertwined. Consequently, publishers' increasing use of computing technology and other information technologies to produce "electronic" materials has been of great interest to academic librarians and scholars.

A plethora of issues surround electronic publishing: user acceptance and demand, cost of production and distribution, access fees and subsidized access, ability to effectively mimic the printed page (e.g., typography and illustrations), redefinition of the structure of books and journals (e.g., what constitutes an issue?), re-examination of conventional editorial procedures (e.g., will electronic journals be refereed?), acceptability of electronic publications to academic tenure committees, mutability of electronic information, ease of reproduction and copyright enforcement, ownership and preservation of electronic information, overall impact on libraries' collections and services, and other issues.[1-6] Opinions are clearly divided about the inevitability and imminence of electronic publishing. Lancaster predicts the dominance of electronic information over print by the turn of the century.[7] In such a "paperless society," scholarly research, publication, and communication would be dramatically changed:

> The scientist would use a terminal to maintain electronic notebooks, compose reports for subsequent electronic publication, access sources of information in the form of databases, index and store information, and communicate with a geographically dispersed network of professional colleagues. Publications would be electronic. For example, a scientific report would be accepted into a database rather than printed in a journal, and all communications among authors, editors, and referees would be through electronic mail.[8]

The fate of the library in an information environment dominated by electronic publishing is in question. Libraries could increasingly become obsolete print archives.[9] In this scenario, the ultimate fate of the library could be "the spectacularly sudden extinction of the dinosaur."[10]

Understandably, many information professionals and scholars, while not denying the emerging importance of electronic publishing, remain skeptical of such assertions.

Drawing a lesson from the history of an earlier technological breakthrough, Dougherty and Lougee state:

> As is so often the case with innovations, the early forecasts for their acceptance are far overrated. In recent history, there have been predictions that microformats would sweep libraries by storm, becoming the medium of choice for publications in addition to serving as an archival record. . . . A decade ago one forecaster, Klaus Otten, suggested that acceptance could not be achieved until the industry developed good microform systems which were human engineered, standards which were agreed upon, librarians were educated in microform technology, and copyright and just payment procedures developed to protect and encourage publishers and authors to publish in microform. As one examines the issues associated with electronic publication, Otten's litany begins to have a familiar ring.[11]

Providing a publisher's view of the contemporary marketplace, Hunter states: "At the present time, with the possible exception of some bibliographic databases, there are virtually no traditional scholarly publications which can be acceptably and economically created and distributed exclusively in electronic form."[12] Summit and Lee point to high costs to users as an inhibiting factor for all types of electronic journals:

> Cost remains the major reason online journals have not threatened their print counterparts. An online database is simply not a cost-effective mechanism for delivering a periodical subscription. The cost of downloading (at 1200 baud) one issue of *Business Week*, for example, would be about seventy-five dollars; the newsstand price for one issue is two dollars. Cost will be a major obstacle until advertising is incorporated into online files.[13]

Projecting forward to the year 2000, Butler says:

> The 20 percent of journals that represent 80 percent of the journals currently and cumulatively in use will continue to be received by the library in printed form, for two reasons. First, these journals will be the *last* to abandon print for online, optical disk, or other electronic distribution media. Second, their level of use will require that they initially be distributed and available for use in their original form. . . .
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> The most scholarly journals will not abandon the printed journal either, but for two different reasons. First their generally non-profit, professional charter will require them to maintain a printed publication so long as any subscriber group--especially international libraries and scholars--cannot receive electronic service as readily as a printed journal. Second, their limited levels of distribution and use will require them to employ the subscription and page-charge funding system for a longer period than their commercial trade magazine counterparts.[14]

In a detailed 1985 survey of 224 librarians, library science professors, publishers, scientists, and law school deans, it was found that 33.2% of respondents strongly agreed and 56.5% of respondents agreed that book publication will "continue to increase in the future despite the increase of publication of information in computerized and multi-media formats"; 60.4% of the respondents thought this would be true past the year 2000.[15] Asked to what degree optical disks would replace hardcopy materials by the year 2000, 49.8% said that it would be under 25% and 39.7% said 26% to 50%.[16]

Examining the future need for libraries, Briscoe et al focus on the critical need to preserve recorded knowledge:

> Society's need to collect, preserve, and maintain the integrity and availability of records in all media is permanent, which is why it makes perfect sense for a public institution to be given the responsibility. Businesses can go bankrupt, merge, and be swayed by political and economic factors. And a business, no matter what it does, must ultimately be profitable. When the profit margin for a product or service declines, either a solution is found to stabilize or reverse the trend or the product is withdrawn. . . . Any permanent collection/archive/database of records can only exist in the not-for-profit sector.[17]

For libraries to provide access to information in all forms in the future, ownership is required:

> Lately it has become fashionable to say that access to information, not ownership, is what is important. This is a dangerous oversimplification. Access always presupposes or depends on ownership---by some party. At present, libraries can more or less guarantee unrestricted, continuing, affordable, and integral access to records because they collectively own them.[18]

Libraries are also needed to protect the integrity of electronic information: "To put it mildly, databases are extremely vulnerable to improper additions, deletions, and revisions. Security measures notwithstanding, they are inherently revisable, and thus conducive to plagiarism, forgery, fraud, censorship, and propaganda attempts."[19] Addressing the broader question of the survival of the library, De Gennaro states:

> Is information technology in the hands of commercial vendors making libraries obsolete? I conclude that libraries are and will continue to be a critical link in the chain that produces, preserves, and disseminates the knowledge that has created and sustains our information society. The information industry is not making libraries obsolete. Rather, it is revitalizing them with new technology and services. Libraries, in turn, nourish that industry with the knowledge resources it needs while providing a vital and ready initial market and distribution system for its new services and products. Libraries are becoming more, not less, important in our information society even though their relative share of the total information market is declining.[20]

The electronic publishing debate is a vigorous and complex one. It has been healthy for the library profession because it has forced us to re-examine the rationale for our institutions as well as ponder the significant potentials for expanded information access that electronic publishing offers. My own view is that electronic information systems will grow considerably in importance; however, they will displace neither the library nor conventional publishing in the next 10 to 15 years, which represents the outside limit of technological prophesy. During this period, academic libraries can provide effective distributed access to both print and electronic materials by employing computing technology to implement integrated public-access computer systems.

The Electronic University

The same forces of technological change that affect the library have an impact on the university as well. During the 1980s, universities have become more computer-intensive environments with the diffusion of microcomputers throughout the campus, the expansion of the use of high-end workstations and minicomputers, and the widespread development of institution-wide and departmental local area networks. This trend, combined with changes in publishing and libraries mentioned previously, suggests a possible technology-driven metamorphosis of the university, and this future university is sometimes called, among other terms, the "electronic university."[21]

Given its central role as the university's primary information provider, the library is an important element in the emerging electronic university, and it could potentially play a major role in its creation. Lewis indicates that a fundamental shift has occurred from the early 1980's to the present in how some academic librarians perceive their mission: "Then the goal was to reinvent the library; today it is to reinvent the university. A dramatic shift, the issue is no longer library automation: it is remaking the structure of scholarly communication."[22] Battin states that the library and the computer center, merged as a Scholarly Information Center, will not be the heart of the future university, but its DNA:

> The new process will be a helix--we provide a basic set of services and technical capabilities, users interact and experiment with the new technical dimensions and develop new requirements, which then influence the evolution of a new shape for the infra-structure. As the genetic code of the University, the character and quality of the Scholarly Information Center will determine the character and quality of the institution.[23]

Focusing on the next 10 to 15 years, we will examine how quickly universities will be changed by computing technology, what roles librarians can play in the change process, and what the nature of the electronic university will be.

At present, universities are moving towards becoming computer-intensive environments; however, except at a few avant-garde institutions, this process is slowed by the need to build substantial support infrastructures, both human and technological, to support advanced computing use. Since fiscal resources are finite, hard decisions must be made about their allocation for this purpose, and not all members of the university community have unbridled enthusiasm for large-scale computing projects. As Moran et al note in their analysis of the ambitious Scholar's Workstation Project at Brown University:

> The interviews made it clear that Brown administrators, faculty, and librarians on all levels were divided in their opinions about the Scholar's Workstation project. They were split in their expectations, their knowledge, and their acceptance of the project. With one major exception though, all the individuals interviewed were in favor of the concept, although the degree of acceptance varied.
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> Where disagreements arose, it almost always centered on the overall cost of the project. . . . The costs have greatly escalated from the original estimates, and the fact that the expenses of the project will soon have to be covered as a part of the regular operating budget has caused many early proponents to worry that Brown may have undertaken more than it can afford. As in all universities, especially private universities, there are many competing demands on the budget, including demands for increased faculty salaries and more generous student aid.[24]

At a time when academic libraries are in a deepening financial crisis due to escalating materials costs and broadened collection goals related to electronic information, other key support units needed to create the electronic university are also under considerable stress. As Lewis notes:

> Computer centers are also in a difficult situation. With the introduction of small powerful computers, many individuals and departments are purchasing their own machines. As a result they no longer use central time-shared equipment; they no longer buy CPUs, and computer center income declines. At the same time, the individuals and departments need and expect the computer center to supply advice and consulting services; of course, they are expected to be supplied at no charge. Communication networks have

> increased in importance, and computer centers are usually asked to supply the technical and consulting support to install and maintain them. Unfortunately, rarely do substantial budget increases accompany the new responsibilities, nor are the full costs of networks billable.[25]

Although the emergence of online catalogs and other public systems may have altered the university community's perception of academic librarians' technological skills, it should not be assumed that faculty and others view librarians as the natural leaders of computing technology efforts on their campus. It is likely that many academic librarians will need to alter their image on campus before they play a major part in university computing efforts. Given their role as key information providers and their generalizable information management skills, academic librarians are well positioned to make a significant contribution to the development of the electronic university; however, they must have determination and perseverance to succeed at this task. Librarians should carefully examine what legitimate roles they can play in this process given local conditions, determine which of these roles they want to play, transform their image as needed, form strategic partnerships with other key players, and act as change agents within their institutions.

In spite of the impediments to the development of an "electronic" university, we can expect that, during the next 10 to 15 years, universities will be changed considerably by computing technology. Compared to other information technologies (television, film, etc.), computing technology has been generally well received by the academic community, especially since the advent of the microcomputer. In contrast to other technologies, computing technology provides general-purpose tools that can be readily employed for scholarly work, administrative purposes, and instruction. Continuing price/performance improvements will encourage the inextricable weaving of computing technology deeply into the fabric of the university. On most campuses, the electronic university is likely to emerge in an incremental fashion, with the implementation of the unifying force of the electronic university--its primary internal network--being followed by the linkage and gradual functional integration of increasingly powerful distributed computer systems within academic units. In this environment, there will be a dramatic shift in the user's perception of library and computer center services from a "Ptolemaic" service-provider-centered orientation to a "Copernican" user-centered orientation.[26]

Yet, we should not assume that the university will be so transfigured as to be unrecognizable to us today. The modus operandi may change, but the basic nature of scholarship and instruction is likely to remain the same.

For over 25 years, England's Open University has demonstrated that non-residential, media-based education is feasible for large-scale, degree-oriented programs.[27] Yet, the opportunities for this kind of study in our country are still rather limited, confined mainly to traditional correspondence courses. The technological tools to support non-traditional teaching efforts have existed for some time, but university faculty have been fairly conservative in their use of them. To make any profound changes in the instructional process of the university, faculty must be significantly rewarded for teaching and, by extension, for creating computer-based instructional materials and procedures. Powerful new instructional tools, such as hypermedia and intelligent computer-assisted instruction systems, are likely to be employed by a growing number of faculty; however, unless reward structures are changed, financial assistance is provided, and appropriate support services (e.g., instructional development centers oriented to advanced computing systems) are put in place, faculty-produced instructional systems will probably continue to account for a small percentage of instructional activity in the university.

More likely to occur is a significant increase in the use of computing technology for information retrieval, analysis, and management; production of scholarly documents; and communication of messages, files, and electronic conference submissions. In the foreseeable future, the "electronic university" will be a recognizable physical institution, which will be empowered by computing technology not subsumed by it.

The Technological Infrastructure of the Electronic University

Van Houweling points to several key factors that drive contemporary computing in higher education:

> 1. Because all forms of information can be represented in a digital form, computing technology is increasingly being used to manipulate all forms of information. The very word "computer" is increasingly becoming a misnomer, and computers are now just one key element in the array of technologies called "information technology."
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> 2. The equipment, or "hardware" elements of information technology are becoming more cost-effective at an unprecedented rate. Capability that cost a million dollars in 1950 will be available in the year 2000 for less than ten dollars.
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> 3. Computing power is now considerably less expensive to purchase in the form of a number of small computers than in the form of a large computer of similar total power.
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> 4. Computers become useful only as they are connected to information storage devices, interconnected via communications facilities, and supported by elaborate computer programs, or "software."[28]

This concise analysis provides a conceptual framework for thinking about the technological infrastructure of the electronic university. The campus computing environment will be characterized by increasingly high-powered workstations and larger server computers linked to campus-wide networks, which in turn will be linked to external networks. The continuing trend towards improved computing price/performance is illustrated by recent predictions of well-known computer expert James Martin, who forecasts:

> Early in the decade of 2000, the use of highly parallel processors will permit computer systems to operate in the following range of speeds: low-priced personal computers, 20 million instructions per second (mips); medium-priced personal computers, 200 mips; high-priced personal workstations, 1 billion instructions per second (bips); top-of-the-line mainframes, 10 bips; top-of-the-line supercomputers, 2 trillion flops; large A.I. inference engines, 500 million logical inferences per second (mlips).[29] The pivotal element of the technological infrastructure of the electronic university is its network:
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> The institutional information network will be the focal point of tomorrow's higher education computing environment. The network will not only provide communication services among thousands of workstations, servers, and other networks but will provide the central information resource for the

> institution. The network will enable knowledge sharing among students and faculty, will unify disciplines across institutional boundaries, will support the integration of textual, graphical, pictorial, audio, and algorithmic information, will facilitate interactions between personal workstations and specialized server facilities, and will provide the foundation for software coherence across the institution.[30]

The network will be as essential to the electronic university as roads and traffic signals are to our ground transportation system. Carrying this analogy further, a city road system is made up of different kinds of roads: residential streets, intra-city highways, and interstate highways. Although responsibility for maintaining the roads falls under different jurisdictions, the roads are, for all practical purposes, one unified system. The city's residents use the roads to travel from their homes to offices and stores to engage in commerce and other pursuits. Likewise, a university network system can be seen as being composed of low- to medium-speed departmental local area networks, high-speed institution-wide "backbone" local area networks, and external networks (e.g., metropolitan-area, wide-area, and value-added networks). Administrative and fiscal responsibility for these networks may fall under different academic units or be outside the university altogether, but the networks can be viewed as one system. Users, employing workstations, electronically "travel" over the network to specialized computer systems called "servers" to perform specialized computing tasks: data analysis, information retrieval, etc. Networks will become increasingly important as more types of media are digitized and transmitted. Image and video transmission will require high-speed channels. Hypermedia information will combine these and other types of media materials into new information packages, increasing transmission capacity needs further. Providing some perspective on the relative speed of transmission of digital images over different data communication channels, Lynch estimates that, not considering time lost due to protocol overhead, the transmission of a single digitized page image would require 14 minutes on a 9.6 kilobits-per-second leased line, but only 1 second on a 4 megabits-per-second Token-Ring local area network.[31]

Networking is a very complex topic. In practice, networking is fraught with difficulty, especially in the area of interconnecting heterogeneous networks. Consequently, the seamless network scenario previously described was an idealized one, which was intended to convey a sense of an important long-range goal of the electronic university. Given the recent outbreak of computer viruses, the age of innocence is over for academic networking and internetworking efforts. Now, there must be an attempt to balance security concerns against the desirable open access policies that have characterized these networking efforts in the past. Networking is a foundational technology of great significance to academic libraries and their parent institutions. Learn has written a commendable summary of networking technology.[32]

Electronic University Prototype Systems

In more concrete terms, what will the electronic university look like? Perhaps the best preview of the emerging electronic university environment is found in the efforts of selected academic medical centers, fueled by seed money from the National Library of Medicine, to unify their diverse administrative, clinical, information, and research systems: The IAIMS initiative of the National Library of Medicine (NLM) was designed to offer a planning framework, support, and encouragement to institutions that were ready to undertake an institution-wide plan for the development of integrated information systems. Inherent in such a challenge is acknowledgement that wise management and problems of university-wide intellectual interaction loom as large as the technical and scientific obstacles to achieving an optimal system. Likewise implicit in the IAIMS initiative was the presumption that more than one arrangement and configuration might be the correct answer to such a problem, depending upon the mission and strengths of the institutions that would take up the challenge. In any event, NLM's goal presumed that a number of model systems would be created by those institutions that completed the IAIMS process, and that experience with such models would be available to other academic institutions in the future as they took interest in the problem of integrated academic information systems.[33]

Since IAIMS (Integrated Academic Information Management System) projects deal with the information needs of disciplines that are all concerned with one general area of knowledge (i.e., medicine), their scope is more limited than a university-wide project with similar ambitions, which must deal with a wide range of disciplines from the humanities to the hard sciences. Nonetheless, IAIMS projects are suggestive of the types of information systems that might be found in the electronic university. Three projects, which are all at least in the prototype development stage, will be examined here: the Virtual Notebook system at Baylor College of Medicine; the HELP, ILIAD, ODYSSEY, and STRATO systems at the University of Utah; and the Knowledge Workstation at the Johns Hopkins Medical Institutions.

The Baylor College of Medicine has created a "prototype of the Virtual Notebook with a hypertext system for information management, a manager for group communications, and a semi-structured message facility for information acquisition and dissemination."[34] The system's latest version, which is being created on high-powered, networked SUN workstations utilizing the UNIX operating system, has a number of interesting features.[35] It has a window-based, icon-driven interface, and it allows users to create and modify original or downloaded hypertext frames of textual and graphic information. Information management is further enhanced by the use of a relational database management system and a full-text information retrieval package. Specialized software, known as the Gatekeeper, provides users with message templates, which they will fill out to request information from online databases, bulletin boards, computer conferences, administrative databases, and other information resources. The message system goes beyond conventional electronic mail by categorizing messages according to their intent (e.g., information request), establishing dates for follow-up action, and by tracking user compliance with those dates. The system will monitor network information resources to identify and download new information that matches the user's interest profile.

The IAIMS project at the University of Utah has developed four systems: (1) HELP, a mainframe-based clinical information system that contains a wide range of patient information and an expert system used in conjunction with this patient data to reach medical decisions; (2) STRATO, an information retrieval program that assists users in extracting and formatting clinical information from HELP; (3) ILIAD, a Macintosh program that gives users access to a quality-filtered database of citations dealing with internal medicine and allows users to create their own citation files from this database and other sources, such as the library's OPAC; and (4) ODYSSEY, a Macintosh program that provides access to both the ILIAD and HELP software.[36]

Since it is under the direction of the William H. Welch Medical Library's Laboratory for Applied Research in Academic Information, The Knowledge Workstation project at the Johns Hopkins Medical Institutions is particularly interesting.[37] The library plays a very proactive role in the information management activities of its institution, and it provides a model for academic libraries interested in this approach:

> The library has articulated the rationale for developing the information infrastructure needed to support an advanced knowledge-based institution, and is an active participant in shaping and extending the communications network, acquiring and managing databases of high utility to the clinical and research community, developing sophisticated user interface tools for information transfer and knowledge management, and introducing new technologies in ways that advance science and health through increased professional productivity.[38]

The long-term goal of the project is very ambitious, and it both clearly articulates the IAIMS vision and prefigures what major features of the electronic university could look like:

> Within the next decade, it is planned that the JHMI [Johns Hopkins Medical Institutions] workers will be able to meet the majority of their biomedical literature and clinical information needs through a hierarchical network of local and remote electronic databases. They will regularly use local desktop workstations existing on a communications network that is part of a larger internet connected to national and international networks. High-usage literature databases and operational clinical systems will be mounted on local computers, with transparent links to less frequently accessed databases on remote computers. Workers will be able to move easily between clinically oriented and literature databases to retrieve facts, refresh memory, record relevant data as part of a patient's management record, access authoritative information from online texts and reference works, review the literature, prepare and administer an examination, compose a book chapter, develop and maintain a knowledge base, and communicate with colleagues. Improved software for literature searches, full-text retrieval, and support of the authorial process will reflect everyday working environments. For maximum effectiveness, the interface between the system and worker will simulate a desktop and contain a set of online user tools as simple and natural to use as a pencil, with only one set of commands and procedures for interaction with all local and remote databases. Initially text-oriented, the environment will eventually support voice and image processing.[39]

The Knowledge Workstation will utilize Macintosh II microcomputers operating under A/UX, Apple's version of UNIX. A hypermedia system, which will be enhanced to support a wider range of information management functions, will be used to construct the user interface of the Knowledge Workstation. The Knowledge Workstation will be linked to database and communications servers using an institutional Ethernet local area network. Initially, bibliographic and full-text reference work databases will be mounted for use, with full-text journal databases being added later. Computer conferencing software will be available for scholarly communication purposes.[40]

Public-Access Computer Systems in the Electronic University

It is clear that access to computerized information is an important element of the electronic university. A diversity of local and remote databases--citation, full-text reference, full-text journal, numeric, image, etc.--will provide access to recorded knowledge. Quality-filtered knowledge bases, created by experts in the area of study, will provide evaluative and synthesized knowledge. Public electronic communication in the form of computer conferences and bulletin boards will enlarge the realm of knowledge, putting on public record what typically were private exchanges among members of "invisible colleges" of scholars. Administrative information, both confidential (personnel records) and public (class schedules), will be made accessible to authorized individuals in electronic form.

The university library can be the focal point for much of this activity, exercising its traditional functions of information selection, acquisition, organization, retrieval, instruction, and preservation in a broader context. To accomplish this, the library will increase its use of public-access computer systems, which give users direct access to systems that provide holdings information, reference and source information, guidance and instruction, and services. These systems, which are summarized here, have been described in detail in another paper.[41] The contemporary library's major public-access computer systems--catalog information systems (e.g., online catalogs) and electronic information systems (e.g., citation databases)--will be diversified and expanded. The library's role as a guide to and teacher for information resources will grow in response to the availability of an increasing variety of information systems and a burgeoning number of remote users of these systems. This will result in more intensive efforts to automate this function through (1) information presentation systems, which provide users with a fixed series of screens in a hierarchical or network arrangement; (2) instructional systems, which present educational material, evaluate user responses, and provide new or remedial material based on user responses; and (3) consultation systems, which provide knowledge-based advice to users. Since printed materials will continue to play a major role in scholarly communication, the library must integrate access to its print collections with these electronic offerings, giving rise to information service and delivery systems that allow users to request library services (e.g., reference assistance) and document delivery of local and remote materials (e.g., interlibrary loan). To facilitate and preserve informal scholarly communication, the library may offer computer conferencing systems. Access to these different library systems and to other university information systems will be provided through end-user computing facilities in the library, which will house workstations that can also be used for general-purpose computing.

Integration of Public-Access Computer Systems

System integration is critical to the successful provision of these diverse public-access computer systems. As the number of public-access systems grows, the library is faced with a proliferation of system-specific workstations, which makes it difficult for users to identify appropriate workstations to meet their information needs, consumes an increasing amount of scarce library space, and requires maintenance of diverse equipment. Remote use of these systems will be increasingly important, but the user may need to employ a variety of access methods (e.g., dial-access numbers, LAN server codes, etc.) to connect to public-access computer systems. While the library can develop uniform interfaces for the systems that it creates, vendor systems are characterized by user interface and other differences that could baffle the user, resulting in what Toliver calls "online Babel."[42] Integration can help overcome these problems.

There are three major strategies of integration: (1) single-vendor integrated systems, (2) hybrid systems, and (3) interconnected systems. While the first two strategies are relatively straightforward, the last is complex and will be dealt with in some detail later. McQueen and Boss identify another approach--linking terminals to multiple systems--that, in my judgement, has limited long-term utility.[43]

In the single-vendor approach, new functions are incrementally added to the integrated system as they are needed, and they can be designed to be consistent with the system as a whole, simplifying access and use. An example of this approach is the Colorado Alliance of Research Libraries' system, which provides access to citation, full-text, and tabular information through the system's OPAC.[44]

In the hybrid system approach, the library purchases a system from a single vendor and, if the vendor cannot deliver new modules to meet the time or functionality requirements of the library, extends the system itself by programming new modules.[45] The Smith Library of Brigham Young University's Hawaii campus illustrates this approach through their modification of their Dynix system to include a variety of locally-developed modules, such as a media booking capability.[46]

In the interconnected systems approach, the library assembles systems from multiple vendors or develops local systems and links them. The Los Alamos National Laboratory took this approach by linking its Geac system to a front-end minicomputer processor that added end-user check-out and purchase request capabilities to Geac.[47]

What are the pros and cons of these approaches to integration?

The single-vendor integrated system approach offers a number of advantages: (1) provision of multiple functions though a single user interface; (2) simplified system selection and connection procedures for users; (3) minimum requirements for local technical specialists, such as programmers, in the library; (4) one vendor or, in the case of software-only systems, a small number of vendors to provide software and hardware maintenance for the system; and (5) a single source for major software enhancements. Potter has summarized the disadvantages of integrated systems:

> Integrated systems, however, have three main deficiencies. The first disadvantage is that a library is tied to a single source for all functions. In the case of a turnkey vendor, this means waiting for the vendor to provide or upgrade functions according to the priorities that he has set. The second disadvantage is that one function may not be as good as another in an integrated system. . . . The third disadvantage is that the functional sub-systems of an integrated library system are so interrelated that the operation of one may degrade the operation of another.[48]Since an integrated system typically runs on one computer, another disadvantage is that, when that computer is down, all system modules are unavailable.

The hybrid approach shares many of the advantages and disadvantages of the integrated system approach with the following differences. On the positive side, the library can develop new modules to meet its own requirements and time frames without being dependent on the vendor. The library could also replace existing vendor modules with its own modules; however, given the costly nature of software development, this is unlikely to happen frequently. On the negative side, the library must employ expensive technical specialists to develop software, involve other library staff in system analysis activities, enhance and maintain new modules itself, and face the possibility that its software modifications may be incompatible with a future software release by the vendor. Of course, the library must have the vendor's source code, have the right to use it, and be able to decipher it in order to engage in this activity.

The pros and cons of the interconnected systems approach are the inverse of those of the integrated system approach. The interconnected systems approach has many significant advantages; however, as we shall see, use of heterogenous computer systems presents many problems. Several key problems, such as user-apparent differences between systems, may be amenable to solution in the long term. In discussing systems that are interconnected using the popular OSI model (open systems), Webb identifies an intransigent problem:

> Another flaw in the open system argument involves vendor-client relations. At present an automated-library manager may monitor a number of hardware and software vendors or contractors. To control them and coordinate their relations is difficult even when the system is running well. In times of trouble, locating the responsible vendor can be extremely difficult. Getting that vendor to admit responsibility is often even more frustrating; finger-pointing and buck-passing are epidemic. The open system will only compound this difficulty, because it increases the number of vendors a library must deal with.[49]

Just as there is no one way of constructing an IAIMS system, there is no universal solution to the problem of integrating public-access computer systems. Each library will need to assess these integration options in light of local needs and identify the best candidate for its sole or predominant integration strategy. Since all needed information cannot be available locally, libraries using either the integrated or hybrid systems approach are likely to supplement it with the interconnected systems approach to interface with remote systems.

Interconnected Heterogenous Systems

If the library chooses to rely heavily on use of a variety of public-access computer systems from different vendors, there is a danger that, as these systems multiply, users will flounder in their efforts to employ them due to the complexity of dealing with the idiosyncratic features of each system. Examining this problem in the context of information retrieval systems, Williams has said:

> Searchers, faced with a wealth of resources and a wide variety of service centers for accessing the databases, must confront a perplexing plethora of access protocols, system designations on different telecommunications networks, passwords, command languages, file-loading techniques, system features, system responses, system messages, data-element designators, vocabularies, print formats, terminal specifications, and shortcuts for commands such as function keys and control characters.[50]

Williams has presented a detailed taxonomy of system functions that can be automated to simplify access to retrieval systems and make system differences "transparent" to the user.[51] The analysis that follows will draw on Williams' work, but it will focus on a smaller number of key areas in the context of public-access computer systems: (1) approaches to system interconnection; (2) assistance in selecting, accessing, and learning how to use systems; (3) uniform user interfaces; (4) overcoming vocabulary differences; and (5) integration with workstation software.

Approaches to System Interconnection

Earlier, it was indicated that networks are the pivotal element in the technological infrastructure of the electronic university. Increasingly, networks will provide the primary physical mechanism for interconnecting public-access computer systems both local and remote; however, it should be understood that other methods of data communication will also be employed well into the future.

There are four main approaches to system interconnection: (1) independent systems, (2) specific-link systems, (3) open systems, and (4) intermediate system.

With the independent systems approach, systems are attached to the network and the user connects to the server that he or she wishes to use. The systems do not communicate with each other; however, from the user's perspective, a basic kind of integration has occurred since all systems are easily accessible from the user's network workstation. From the library's point of view, a major problem with heterogenous systems--separate workstations for different systems--has been solved.
With the specific-link approach, systems communicate with each other via messages that reflect the idiosyncratic commands of each system and exchange data that may or may not be in standardized formats. In a turnkey system situation, this approach requires that vendors participating in the interconnection process be conversant with the particulars of each other's software and be willing to work with the other vendors to create linkages. An example of the specific-link approach is the Online Catalogue at the University of Illinois, where the online catalog (WLN software) is connected to the circulation system (Library Circulation System software) in order to display circulation status information in the online catalog.[52]

With the emerging open systems approach, systems communicate with each other using standard messages and exchange data in standard formats. Since the requesting system does not need to know what internal mechanisms the sending system is using to perform the service, the open systems approach permits easy data exchange between systems. In essence, the other system is a black box. To add new types of data interchange, each system vendor must modify its software to accommodate new standardized messages and data formats; however, each vendor is insulated from needing to know anything about any other vendor's software. With appropriate standardization of transaction messages, systems could update each other's files as well.

The data exchange process occurs in the context of the Open Systems Interconnection model:

> The OSI reference model is a conceptual framework developed by the International Standards Organization (ISO) for considering the various elements involved when two computers communicate with each other. These elements range from the electrical interface used to connect wires to the application programs that are specific to the particular task at hand. . . . This conceptual model divides these activities into seven layers; roughly speaking, layers one through four are concerned with networking and telecommunications, and layers five through seven with computing and computer applications. . . .The OSI reference model is itself a standard but is useful mainly as an intellectual tool that provides standardized terminology and concepts for discussing protocol definitions and actual systems.[53]

Protocol standards do the actual work of linking systems. Of particular concern to the library community are protocol standards at the top layer of the OSI model, the application layer. Application level standards, such as the ANSI Z39.50 Information Retrieval standard, will play a central role in making the open-systems approach a reality, and, if they are utilized by vendors, they "will significantly reduce the costs currently associated with computer-to-computer linkages of automated library systems."[54] Equally important will be data format standards, such as the MARC format, which will ensure that systems share a common definition of how exchanged data is structured.[55] For the open systems approach to bear fruit, the library community must develop a variety of top-level protocol (e.g., interlibrary loan) and data format (e.g., index and abstract record structure) standards, utilize existing lower-level standards and wait for additional ones to be developed and approved, and require vendors to comply with all appropriate standards when they are in place.

An example of a system development effort that utilizes the open systems approach is the Linked Systems Project. The immediate goal of the Linked Systems Project is to support the transfer of authority records between selected systems; however, future goals include bibliographic record transfer, linkage of local systems to bibliographic utilities, and interlibrary loan capabilities.[56] Although it is based on the OSI strategy, the Linked Systems Project is not in perfect accord with it; however, the LSP does plan to fully migrate to OSI once this becomes technologically feasible.[57]
With the intermediate system approach, either the user's workstation itself or a larger system connected to the user's workstation links the user to multiple systems, translating its own commands into the idiosyncratic command language of the target system and, potentially, masking other differences among those systems. An example system is the experimental CONIT system at the Massachusetts Institute of Technology, which uses software mounted on a larger system to connect the user's workstation to a selected database vendor system and translates its uniform command language into the chosen system's command language.[58]

Assistance in Selecting, Accessing, and Learning How to Use Systems

As the number of public-access computer systems proliferates, users will find it increasingly difficult to identify appropriate local and remote systems to meet their information needs, to connect to these systems, and to learn how to use them. The first wave of end-user searching was largely confined to remote database systems and local online catalogs. Some indication of the potential complexity of the former activity is given by considering the U.S. online marketplace in the fourth quarter of 1986, where 14 major vendors offered 517 text-oriented databases that were created by 270 producers.[59] Increasingly, academic libraries are making more local searching options available as they provide CD-ROM databases (both stand-alone and networked) and minicomputer/mainframe databases. Other kinds of systems, outlined previously, will be added in the future. As the number of databases grows, the types of computerized information increase, and the number of retrieval and other systems multiply, the availability of computerized information and services is increased, but the already complex problem of effective user access to these resources is exacerbated.

In the area of end-user searching of commercial database systems, progress has certainly been made with the development of microcomputer-based searching software (e.g., Pro-Search), simplified versions of online retrieval systems (e.g., BRS After Dark), and gateway systems (e.g., EasyNet); however, the academic user of the future will desire a unified, network-based information environment that provides easy access to both local and remote systems.

The following potential software tools, selected and summarized from a more comprehensive list by Williams, may help overcome selection and access problems:

(1) Automated selectors to choose host systems, telecommunications networks, classes of databases and individual databases, and application software to process retrieved information.

(2) Automated routers to connect the user to appropriate networks, systems, and databases; pass searches from directories of databases to one or more appropriate databases; and invoke application software for processing output.

(3) Automated evaluators and analyzers to evaluate user characteristics; match user characteristics to database characteristics; and determine the quality of retrieved information.[60]

The implementation of tools in the automated selectors and evaluators categories would be significantly enhanced by use of artificial intelligence techniques, especially expert system technology. What I term "consultation systems," intelligent systems incorporating expert knowledge, will perform many of these functions for the user of integrated public-access computer systems.

Until such a time as public-access computer systems' use is so intuitive that naive users can employ them effectively with no assistance, instructional systems can be utilized to provide introductions to and assistance with the features of these public-access computer systems at the point and time of need as well as to reduce the ongoing training burden for librarians. The Individualized Instruction for Data Access system, developed at Drexel University, shows some of the potentials of this approach.[61] IIDA offers two kinds of services to the online searcher: a series of graduated training exercises about searching and online assistance. In the latter mode, IIDA monitors actual system-user interaction, evaluates this interaction, describes the user's significant searching problems with short messages, and provides basic suggestions about strategies to remedy these problems.

Building more sophisticated instructional systems, such as IIDA, will become easier as more powerful tools become available, such as Intelligent Computer-Assisted Instruction. Dede and Swigger describe the key differences between ICAI and its familiar predecessor, CAI, as follows:

> A useful general distinction is that AI-based instructional programs contain dynamic models of the task, the student, and the teaching discourse. Operations are then defined that manipulate these models as the learning situation evolves. . . . learning objectives are not expressed as behaviors constructed through elementary stimulus/response associations, but as mental procedures and knowledge structures that are developed and used by the learner.[62]

The prototype REFSIM system at the University of Waterloo employs Intelligent Computer-Assisted Instruction Techniques.[63] This system has three modes: (1) consultant mode, which suggests appropriate reference sources to meet users needs; (2) simulation-based coach mode, which allows librarians to participate in simulated reference interviews and evaluates their performance; and (3) Socratic tutor mode, which teaches users about information search strategies and reference sources through a dialogue with the user.

Uniform User Interfaces

The user interfaces of heterogenous systems can vary in several key ways: (1) command language used, (2) "direct manipulation" techniques used (e.g., pull-down menus, icons, etc.),[64] (3) data format, and (4) system messages. In both methods of communicating instructions to the system (command language and direct manipulation), what actions can be accomplished can vary from system to system as well as the ways in which those actions are invoked. Likewise, the data format differences reflect not only the arrangement of data elements but also the kinds of data included or excluded by the system. Deeper system differences, such as indexing procedures, may not be apparent in the user interface, but they help determine overall system functionality.

For the problem of providing uniform ways of instructing the system what to do, standards are the key to achieving this goal. It is certainly possible to build a system that maps its own unique set of system instructions to those of multiple external systems, masking the instruction differences of those systems; however, this is a labor-intensive process that requires ongoing maintenance. By contrast, if every vendor were to implement an optional user interface that complied with standard command and/or direct manipulation system instructions, this effort would not be required. For command-driven interfaces, the emerging Common Command Language standard holds promise.[65] Similar efforts to define standards for direct manipulation interfaces should be undertaken. We should not be sanguine about the prospects of vendors embracing these standards, but rather we should require in our RFPs and contracts that they do so within reasonable periods of time after such standards are completed.

In the area of uniform system instructions, the goal is to mask system-specific differences without trading off transparency for power and precision in user-system interactions. This balance is difficult to find. Masking too much results in loss of functionality, and masking too little results in overwhelming the user with options. Multi-level interfaces, which have hierarchical subsets of features based on user sophistication (e.g., novice or expert) are an immediate solution to this dilemma. In the long term, user interfaces that construct models of individual users, which reflect their unique characteristics, will provide more fine-tuned adjustment of user-system interactions.[66]

Display format differences are less critical than system interaction procedures, and either special interfaces that mask system differences can be developed or standard display formats can be defined. As we shall see, display formats have implications for the usability of downloaded information as well as for user comprehension. Standard display formats for bibliographic information in the MARC format, supplemented by fields for status information, could be defined to reduce the problem of record display differences among online catalogs. Definition of standard machine-readable record formats, equivalent to the MARC format, for other kinds of information, such as indexing and abstracting information, could lay the foundation for the definition of standard display formats of these kinds of information as well as improve information portability between systems. These standard display formats could be included in systems as a parameter-driven option that supplements the vendor's normal record display formats.

Variations in system-specific messages could also be handled by the strategies we have outlined, but they are likely to take low priority.

Overcoming Vocabulary Differences

The problem of separate, unrelated controlled vocabularies is certainly not new, but, as we attempt to provide the user with integrated information access, it becomes more critical.

Barring the abandonment of controlled vocabularies in favor of new, efficient automated retrieval techniques that use the natural language of document surrogates (i.e., citations and abstracts) and documents themselves, controlled vocabularies will remain as a major access tool that unites like documents in spite of their natural language differences.

The basic problem is how to interrelate disparate vocabularies so that the user can easily find records in databases that use these different vocabularies. There are three basic approaches to interrelating vocabularies: vocabulary mapping, intermediate indexing language, and automated switching.

In the mapping approach, terms from one indexing vocabulary are systematically associated with equivalent terms from a second vocabulary.[67] Four kinds of mapping patterns are possible: one to the null set (if the term has no equivalent), one to one, one to many, and many to one (if the term in the second vocabulary incorporates several narrower terms in the first vocabulary). Each indexing scheme must be individually mapped to every other scheme.

By contrast, the intermediate indexing language approach establishes one neutral vocabulary upon which every individual indexing scheme is mapped.[68] Using this approach, each indexing language must be mapped only once to achieve full convertability to every other language.

Given the extensive and dynamic nature of some vocabularies, these approaches are very labor intensive; however, the third approach, automated switching, holds some promise as a way of solving the heterogenous vocabulary problem. The Battelle Columbus Laboratories have developed the Vocabulary Switching System, which uses a wide variety of computerized techniques (e.g., word and phrase stemming to locate all related terms) for interrelating vocabularies.[69] This approach derives conceptually from the intermediate language approach but "the neutral or universal lexicon is created simply by the computerized merging of existing vocabularies and free-text indexes into an integrated vocabulary or concordance without substantially altering the prevailing linguistic structure in any individual vocabulary. Then, these preserved linguistic relationships are exploited to their fullest potential in actual switching activities."[70]

The Vocabulary Switching System has significant advantages over the mapping and intermediate language approaches. Since it creates the switching language by merging and supplementing the source vocabularies, it is more flexible than these approaches, and it dramatically reduces the human effort required to deal with the heterogenous vocabulary problem. Because it concentrates on matching the terms of the user query with the augmented terms of each vocabulary, it avoids the thorny problem of complete conversion between different vocabulary systems. As Chamis concludes:

> Switching vocabularies have been shown to have a large potential for facilitating the selection of appropriate search terms, vocabularies, and associated databases. The experimental VSS shows promise as the basis for a switching system which could be used to provide an integrated subject access to part or all of the databases available from a particular vendor.[71]

Integration With Workstation Software

For the scholar, access to information is only the first step in the process of creating new knowledge. In raw form, downloaded information has limited utility.[72] Scholars will want to utilize their electronic files in a number of ways: to retrieve information; to analyze information with textual and statistical procedures; to compare and combine information; to reformat information automatically in order to deal with citation format differences and other problems; and to produce new works in electronic and printed formats.

Two problems impede the scholar's use of computerized information. First, the systems that supply the information format it differently. This problem can be addressed by creation of "filter" programs that reformat ASCII output from different systems into a standard format for use with workstation software.[73] Second, given the decentralized nature of higher education, we can expect faculty to adopt a wide range of workstation software to perform information management functions, and each software package will have different data import formats and capabilities. Thus, a larger number of filter programs will need to be written than would be the case if standardized information management software was used on campus. This problem can be diminished if the library and the computer center can establish informal campus-wide standards by working together to identify appropriate information management software and by establishing volume-discount purchase agreements for this software.

While the scholar's knowledge is shared with the scholarly community in the form of papers and other sorts of communications, the scholar's knowledge base--the carefully selected information that is in his or her electronic files--is not available to that community. At the University of Michigan, a prototype system was developed, called the Information Exchange Facility, that promotes information sharing by allowing scholars both to download and to upload bibliographic information between workstation and campus mainframe software. This interesting concept was refined and expanded in the design of a second system called BIBLIO, which is intended to support bibliographic information exchange between scholars and on-campus interest groups, the university community as a whole, and external information vendors.[74]

An Example of Heterogenous System Integration

The prototype Department of Defense Gateway Information System (DGIS), which is being developed by the Defense Technical Information Center, is a sophisticated attempt to provide users of heterogenous systems with an integrated information environment.[75] An online directory is being constructed of local databases, and directories of remote databases, human experts, and specialized computer systems will be put in place later. The system employs a common-command language, which allows users to search four remote vendor systems with a single set of commands. This is a knowledge-based component, written in the PROLOG logic programming language. DGIS incorporates an electronic mail facility, a feature that allows users to hold interactive "conversations" with each other, and automatic system connection capabilities. The system will give users a variety of post-processing capabilities including:

- o translation of downloaded files into standard bibliographic format,
- o merging the translated files into a single file,
- o elimination of duplicate citations,
- o cross-correlation of fields,
- o frequency counts,

- o analysis of data field use,
- o preparation of detailed indexes,
- o sequential review of citations,
- o multiple level sort,
- o citation reformatting[76]

A number of extensions to the system, based on artificial intelligence technologies, are being considered, including (1) a complex expert system used to analyze and refine natural-language search requests in relationship to available databases; (2) integration of multiple-database vocabularies to enhance searching; (3) a system to help the user select numeric databases and manipulate the data contained within them; (4) foreign language translation capabilities for search queries, retrieved results, and electronic mail messages; and (5) a multi-tasking, AI-based hypermedia system.[77]

Conclusion

We are in a period of significant change--one that demands that we stretch our imaginations to help create the academic information environment of the future. For as Lewis has said "though technological developments will force changes, we can shape the way technology is used."[78]

Reflecting its increased use of computing technology, the university will undergo significant changes in the next 10 to 15 years. These changes will focus primarily on information retrieval, analysis, and management; production of scholarly documents; and communication. While progress will be made in developing computer-based instructional materials and procedures, it is unlikely that the educational process will be dramatically altered unless major changes are made to fundamental aspects of scholarly life, such as rewarding teaching to the same degree as research and publication. Given the weaving of computing technology deep into the fabric of the future university, it could be called the "electronic university"; however, it should be understood that the university will not be so changed as to become a new entity. As it evolves into the electronic university, the university will still turn to its library as the primary provider of scholarly information.

In the foreseeable future, academic libraries will increase the number and diversity of public-access computer systems, both local and remote, that they make available to users. Dependent upon the unique needs of its institution, each library will devise the right mix of systems and will address the issue of how to provide integrated access to as many of these systems as possible. This effort will be a major, long-term undertaking, which will have significant implications throughout the library. Academic libraries already face serious challenges related to their traditional collections in the areas of collection development, storage, and preservation. Since these activities are unlikely to be abandoned, fiscal concerns will be paramount as libraries broaden their information resource and service offerings through public-access computer systems. Once the thorny problem of integrating public-access computer systems has been overcome, these unified systems will increasingly become the "heart" of the evolving electronic university; however, the lifeblood of information that flows through this heart will be in both print and electronic form.

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