Optical Disk Technology and Information

Charles M. Goldstein

Optical disk technology includes the storage and retrieval of random access graphics on video disks as well as the storage of digital information. The video disk is already finding applications in the delivery of graphics to complement on-line interactive information systems. In addition, the application of optical disks to digital storage represents one of the most promising developments in computer mass storage technology in recent years. Although this new technology is undergoing a rather long gestation period, its potential for information storage and retrieval (IS&R) should be realized in the 1980's. In this article I review the techniques for recording information on optical disks (*1–3*) and then address the potential impact of the technology on IS&R (*4*) and the scientific enterprise.

Summary. The optical video disk, spawned by the home entertainment industry, and its counterpart, the optical digital disk, both hold great promise for information storage and retrieval and the scientific enterprise. Optical digital disks for computer mass storage are currently under development by many firms. In addition, efforts are under way to allow encoding of digital information on video disks. This is desirable as an inexpensive publication medium for machine-readable data as well as a means of obtaining both video and digital information on one disk. Potential applications of this technology include inexpensive on-line storage, random access graphics to complement on-line information systems, hybrid network architectures, office automation systems, and archival storage.

Optical Video Disk

Recording technology. Internationally, there is considerable activity in the development of video disk recording technologies. This article is limited to optical disk technologies because of their special importance for IS&R. Even here, different approaches exist. However, two firms that have pioneered in bringing the optical video disk technology to the marketplace, MCA (now DiscoVision Associates or DVA) and Magnavox-Philips, have agreed on a common disk format. This format contains information coded in the form of microscopic "pits" in a reflective information surface. The information surface is covered by a transparent plastic layer. Playback is accomplished by focusing a laser light beam on the information surface and monitoring the reflected light pulses. No light is reflected from the pits. The reflected light is a frequency-modulated signal resulting from the differing lengths of the pits and the "land" between them (Fig. 1). Thus the encoding is not just a series of 0's and 1's, as is customarily the case for computer storage. There may be as many as 14 billion pits per side of a 1-hour (two sides) video disk with spacings between concentric tracks of about 1 micrometer. With these dimensions, dust particles only a few micrometers in diameter at the information surface could obliterate many signal elements; however, the protective transparent surface serves to keep such dust away from the information surface and outside of the focal plane of the "optical stylus," thus minimizing information loss.

In addition to optical recording technologies that utilize reflecting surfaces and pits, others employ both photographic and photochromic processes (*2, 3, 5*) and the Thompson CSF Videodisc System employs a transparent, nonreflecting disk. In this system, the transmission of light through the disk rather than light reflection provides the information-carrying signal (*6*).

Production of video disks. Optical video disks are produced by a mastering and replication process (*7*). In the DVA process, material to be mastered is first recorded on, or transferred to, a 2-inch helical video tape. A glass master disk is created by first exposing the prepared, photosensitive surface with a laser beam modulated by the output of the signals recorded on the video tape. The glass master is then photoetched. From this, multiple nickel metal "stampers" are produced by a plating process. These stampers are then utilized in an injection mold process to stamp one side of the disk. After addition of a reflective coating, two sides are joined to form a single two-sided disk. These processes require controlled clean-room environments and major investments in facilities.

Mastering and production services for the DVA/Philips formatted video disks are presently available from both DVA and Sony. Costs for creating the master may be $2200 to $4000 or more per side depending on the amount of preediting or processing required (for instance, transferring from film to video tape). For small quantities, replication costs of $10 per two-sided disk have been quoted. For large quantities, costs are determined by negotiation and should drop sharply as the production run increases. The 3M Corporation is planning to establish mastering facilities for the production of Thompson disks as well as DVA/Philips disks in the United States.

Player and disk formats. Video disk player and disk formats may be classified as consumer or industrial (institutional) types. The consumer and industrial players differ in the amount of control, intelligence, signal quality, and robustness they provide. Consumer models sell for about $800, while single-unit costs for industrial models are about $3000. It is the latter that will be of primary interest to the IS&R community. Consumer model players are presently being marketed by Magnavox and Pioneer. Industrial players are being marketed by Sony, DVA, and Thompson CSF. The DVA model 7820 industrial player is shown in Fig. 2. The newly announced RCA video disk players employ a physical stylus and grooved video disk records; they are of no potential interest for IS&R since they preclude random access and still or "freeze" frame capabilities.

Industrially formatted disks contain concentric tracks with one video frame per track. Each side of a 30-centimeter video disk contains 54,000 frames in the

The author is chief of the Computer Technology Branch, Lister Hill National Center for Biomedical Communications, National Library of Medicine, Bethesda, Maryland 20209.

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U.S. standard NTSC (National Television Standards Committee) video format, or 47,000 frames in the higher resolution European video formats. This one frame per track format allows random access and freeze frame capabilities, both of which are of critical importance for IS&R, as discussed later. At 30 frames per second, the U.S. formatted disks have a video playback time of 1/2 hour per side.

DVA has also introduced a consumer disk format for the entertainment market that allows 1 hour of continuous playback per side, or 2 hours per disk. This format encodes frames in a continuous spiral and, like the RCA video disk system, is of little interest for IS&R since it, too, precludes random access and freeze frame operation.

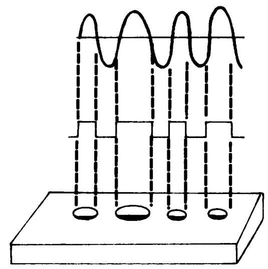

Fig. 1. Pulse-width encoding.

Digital Storage

Although the spur to the development of optical disk technology has been the entertainment market, it was also recognized that this technology could be exploited to store digital information. Two approaches have been identified: (i) to encode digital information on a standard video signal and then obtain the video disks by the mastering and replication process, as discussed above, and (ii) to record digital information on site at the computer. The latter method was developed by Philips Laboratories, North American Philips, under contract to the Department of Defense's Advanced Research Projects Agency and is designated as "optical digital disk" technology to distinguish it from the digital applications of the optical video disk.

Optical Digital Disks

Philips DRAW process. The Philips optical digital disk technology (*8, 9*) utilizes a specially prepared disk. The inside surfaces of two glass or plastic disks are coated with a special reflective metal film (usually tellurium), separated by an air space, and hermetically sealed (see Fig. 3). This disk is mounted in a recorder/player connected to a computer. In use, a relatively high-powered laser beam is focused through the protective surface so that information is "burned" into the inside information surface (see page 856). In the recording process, the disk carries its own "clean room" with it. Another advantage is that the data can be read immediately after being recorded. The schematic of the Philips DRAW optical system in Fig. 4 shows both the record (or "write") and "read" paths. Philips has designated this as the Direct Read After Write or DRAW process. Once the information is burned into the information surface it cannot be erased and is, consequently, "read-only." In the Philips DRAW information system, data are recorded on 40,000 tracks per disk side for a total capacity of over 10 billion bits (1 billion characters) per side. Each track of the optical disk contains 32 addressable sectors of 15,200 bits each, and research is under way to extend the data storage to 100 billion bits (10 billion characters) per side. A more detailed discussion of the Philips DRAW process may be found in (*9*).

DREXON draw disks. The Philips DRAW disk is susceptible to deterioration if air permeates the seals between the two surfaces and oxidizes the metallic film containing the information. A new "draw" disk, developed by Drexler Technology Corporation (*10–12*), avoids this susceptibility to deterioration of the information surface by eliminating the need for an air space between the disk sides. This DREXON disk has extremely small metal spheres and filaments distributed throughout a polymer. The photoabsorption of the laser light by the metal filaments (silver halide) causes the local reflectivity to change. These micrometer-wide areas of lower reflectivity correspond to the pits in the Philips-type disk, and since the metal particles are dispersed within the disk, DREXON disks are impervious to oxidation (*13*). Another advantage is that low-power diode lasers can be used to both write and read. In the future this technology may also be applied to the production of video disks, or allow the inexpensive replication of DRAW disks by use of a transmissive DREXON master. Copies would be made by light exposure through the master. Today, in small quantities, DREXON 12-inch-diameter disks cost approximately $3500 each.

Pregrooved disks. The Philips DRAW system discussed above utilizes relative-

Fig. 2. DiscoVision video disk player. [Courtesy of DVA Inc.]

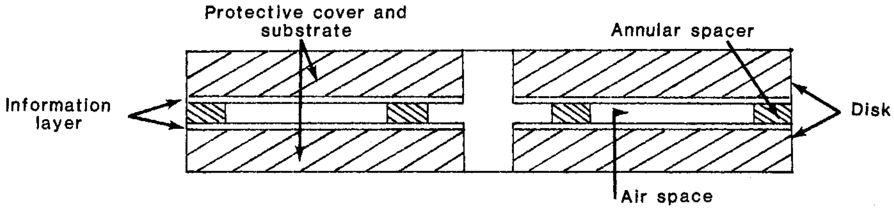

Fig. 3. Cross section of Philips DRAW disk.

ly powerful gas lasers and sophisticated tracking or indexing mechanisms to ensure precise positioning of each track. Two other systems are under development that utilize pregrooved optical disks. These systems allow less expensive and more robust tracking mechanisms and are designed for local office environments. One system has been under development by Philips-Eindhoven (*14*) for a number of years. The other, by Toshiba (*3, 15*), was shown at the 1981 National Computer Conference and should reach the market in 2 years.

Digital recording. Since optical digital disks are being developed solely as computer mass storage devices, the information is encoded in a form most suitable for digital recording and requires no video compatibility. The ability to read data as they are recorded permits immediate identification of errors. These errors may then be "corrected" by rewriting the data in a new sector and erasing the address of the bad sector from computer memory. The information remains on the disk, but knowledge of the sector is erased. Hence, information retrieved from an optical digital disk can have extremely low error rates.

Optical digital disks represent a very high-density, low-cost, archival mass storage medium. Future optical disk storage units may employ "jukebox" arrangements for on-line access of as many as 1000 disks (*9, 16*). Philips-Eindhoven has developed a smaller jukebox for use with their electronic archive and office automation system (*17*). Also under consideration are optical disk packs of six double-sided disks accessed by 12 separate read heads (*9*). Each such disk pack would have a storage capacity of 1 trillion bits or 100 billion characters in the same space now required for a magnetic disk pack with a capacity of 300 million characters. Optical disk packs will utilize smaller, solid-state laser diodes (*18*) instead of the bulkier gas discharge lasers, which will allow distances between disks to be much smaller. Other configurations under consideration include optical "diskettes" having a square format of 148 by 148 millimeters and containing 1 billion bits per diskette (*19*). Total capacity per storage unit could be as high as 10 trillion bits.

Availability. Although announced in 1979, the introduction of draw units commercially has been delayed by problems. North American Philips announced the availability of prototype DRAW recorder/player units for $150,000 and play-only units for $20,000 (*20*), but later withdrew the offer. Both RCA and Philips will entertain offers to deliver draw units but price must be negotiated.

Other firms are developing optical digital disk mass storage systems similar to the Philips system, but at present no other units have been publicly announced. Jerome Drexler, president of Drexler Technology Corporation, has stated that his company is supplying media to 18 commercial firms, of which 16 are major companies (*15*). Other firms engaged in optical disk technology are reviewed in (*2, 3, 15*).

Digital Information on Optical Video Disks

The potential for encoding digital information on the standard NTSC video signal and format was addressed by Kenney (*21*) in 1976. He pointed out the economic advantages of exploiting existing video disk production facilities for the publication of machine-readable information. There are, however, many problems to be resolved before video disk technology can be used successfully for the storage and retrieval of digital information. Paramount among these is error identification and correction. Unlike the DRAW process, the mastering and replication process for video disk production does not allow dynamic error identification and correction. Furthermore, there are many known sources of error in the production process, including errors in mastering and stamping and errors due to particulates in the disk plastic. Errors (dropouts) presently occur in the production of video disks for entertainment purposes. These errors, while often visible, are seldom offensive to viewers; however, the sensitivity of digital information to errors is much greater, since the loss or change of a single bit could cause a computer program to malfunction or an index to return incorrect information.

Another major constraint of such recording is the need to encode information into video-formatted frames. This can also be a major advantage, however, since it provides the ability to intermix digital and video information on the same disk. Frames of video, when accessed, will be directed to a video monitor, and frames of digital information will be directed first to the computer and then to whatever output device is desired.

Lister Hill Center Program. Since Kenney (*21*) identified the potential for the storage and retrieval of digital information on optical video disks, there has been no evidence of private sector developments in this area. If this technology can be successfully exploited, however, it can serve as a publication process for large databases and full-text document collections, including mixed video and digital information. Toward this end, the Lister Hill National Center for Biomedical Communications, National Library of Medicine, has initiated an R & D program to address the encoding of digital information on optical video disks and its playback on industrial-type players (*22*). The theoretical, error-free storage densities for this process are estimated to be between 20 billion and 30 billion bits, or 2 billion to 3 billion characters per side. The usable data per side will depend on the types and magnitudes of the errors encountered in the mastering and replication of digitally encoded video disks and the error correction methods employed. An experimental facility is being established at the Lister Hill Center to facilitate the study of such errors. Investigations will seek to determine (i) the maximum usable symbol rate per video line, (ii) the maximum usable number of levels (bits) per symbol, and (iii) the effect of current video disk production standards on information storage—that is, the extent to which the theoretically maximum storage is degraded by errors encountered in mastering and replication. Subsequent investigations will seek to identify where improvements in the production process can have the greatest impact on usable information storage.

Video disk interface unit. As part of this R & D program, the Lister Hill Center has developed an intelligent video disk interface unit (VIU) to allow computer control of industrial-type video disk players (*23*). Although many investigators are interfacing industrial-type players directly to microprocessors or computers, the VIU offers improved capabilities, a set of higher level commands for controlling the player, and a degree of device independence. The latter is achieved by allowing different industrial-type players to be interfaced without changing the higher level control commands used by the computer program. The VIU is presently programmed to interface the DVA model 7820 industrial player with either a terminal or a host computer. In production, the VIU should cost between $600 and $700.

Implications for Information Storage and Retrieval

The optical digital disk and the optical video disk promise to affect on-line information retrieval services in a variety of ways, some complementary and some competitive. The optical digital disk will be an important adjunct not only to large centralized services but also to distributed minicomputer-based systems where purchase of the requisite disk drives can be justified. The video disk, with its potential for publication of machine-readable databases, may provide the greatest competition for centralized, on-line services. Even here, though, the local provision of graphics, audiovisuals, and full text may be complementary rather than competitive. The most conspicuous effect of the optical digital disk will be in terms of on-line storage costs. In addition, the very scale of on-line storage that can be made available will, by itself, generate new offerings and services.

Random Access Graphics

One important application of the optical video disk will be the local provision of graphics to complement on-line information delivery, which has traditionally suffered from the absence of graphic material. The graphic material desired extends from simple line drawings, such as chemical structures, to more complex line drawings, such as those used in patent submissions, to halftones, color images, and full audiovisual sequences. The latter will be of particular importance as a complement to full-text encyclopedic databases and computer-based educational material.

In March 1981, Pergamon International publicly demonstrated an on-line system, VIDEO PATSEARCH (*24*), for searching the 700,000 U.S. patents certified since 1971. Subscribers to this service receive a special intelligent terminal with attached video disk player, a video monitor, and eight video disks containing the drawings of all 700,000 patents. The patent database is accessed by users through an on-line vendor, Bibliographic Retrieval Services, Inc. After establishing communication with the on-line database and mounting the appropriate video disk, users may call up the patent text (citation) or the corresponding patent drawings through the local video disk. The Pergamon terminal has sufficient intelligence to support a tailored user-cordial interface (*25*) that minimizes the skill required of the user to execute an effective search. The Canadian Patent Office plans to install and test VIDEO PATSEARCH (*24*). It was also recently installed in the U.S. Patent Office.

VIDEO PATSEARCH is the first commercially marketed application of video disk–supported graphics for on-line IS&R. It is certain to be followed by many other applications, such as catalogs of satellite imagery, museum collections, and medical illustrations. Each video disk will have a capacity for approximately 100,000 images. Arete, the publisher of the Academic American Encyclopedia, has announced the availability of video disk graphics to complement on-line access of the full text. The full text is to be made available on the Mead Data Central Information Service. The video disk graphics may not only provide the traditional halftone pictures and color plates, but also allow for the inclusion of random access audiovisual sequences where appropriate (for instance, to show surgical procedures or illustrate topics in physics such as the Doppler effect).

On-line Digital Storage

Economics. Cost savings in on-line computer storage may, in general, be realized by reductions in (i) cost of the medium, (ii) equipment, and (iii) physical floor space. While many discussions of computer memory technology emphasize the cost of the medium, the cost of on-line storage is primarily a function of the equipment (for instance, disk drives). In fact, some of the newer magnetic disk storage systems such as the IBM 3370 and the CDC 33502 are fixed disk systems, and hence the medium is integral with the drive. Even the floor space, estimated here as $25 per square foot or $600 per disk drive, is inexpensive when compared to the cost of the drives, as shown in Table 1. The costs shown in Table 1 for the IBM and CDC disk drives were obtained from U.S. government schedules and are to be used only for comparison. In each case, the cost of the control unit was averaged over the maxi-

Table 1. Cost comparisons for on-line storage.

Year	System	Capacity (Mbyte)	Cost ($1000) per		
			Drive	10 Gbyte*	100 Gbyte
1973	IBM 3330-11	200	28	1,430	14,300
1975	IBM 3350	317	43	1,300	13,000
1978	CDC 33502	635	27	430	4,300
1979	IBM 3370	571	29	480	4,800
1981	IBM 3380	2,500	98	392	3,920
1982†	Philips disk	2,000	20†	100	1,000
1983†	Philips pack	100,000	50†	51	51

*Gigabytes or billion characters; nominally 8 bits = 1 byte. †Estimates.

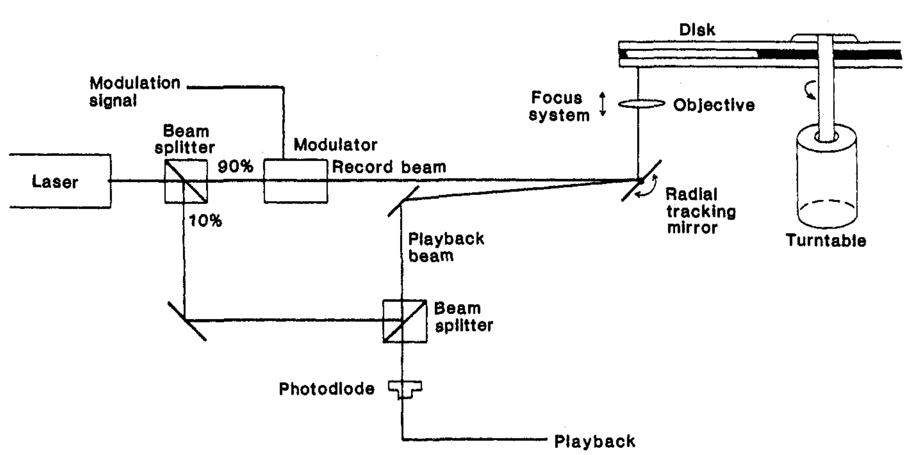

Fig. 4. The DRAW optical system. [From (*3*)]

mum number of drives that could be attached. The costs in Table 1 do not include the additional equipment in the central processor (such as extra input-output channels or special interface units) needed to support additional control units.

Table 1 therefore provides a gross picture of some economies that could be expected to accrue from the storage densities of the optical digital disk. On-line storage can account for 50 percent or more of the total equipment costs of an on-line service. The National Library of Medicine maintains more than 10 billion characters of on-line storage. Even so, the number of on-line databases it maintains is far less than the number maintained by the major on-line services such as System Development Corporation (SDC) and Lockheed. As Table 1 indicates, the most dramatic economies now foreseen are still more than a year away and are predicated on the availability of an optical disk pack with a capacity of 1 trillion bits (100 billion characters).

Access to full text. Given the availability of low-cost mass storage systems such as optical disks, there will be a trend toward greater on-line availability of full text. It is estimated that the transition of scientific journals and documents to full electronic printing (including graphics) is still 10 to 15 years away; however, the technology exists for storing journal copy in high-resolution, compressed facsimile format to support on-line browsing or demand publication. Another major effort in the Lister Hill Center, the Electronic Document Storage and Retrieval Program, is directed toward the integration and further development of these technologies. The high storage density and random access characteristics of the optical disk provide the impetus for developing complementary devices such as image scanners and laser printers.

Where full text is available in machine-readable form, the optical disk not only will provide an economical storage medium, but also has the potential for filling a gap that has long existed in the effective utilization of associative or parallel text processing, where previous efforts have concentrated on the computer processors. A major limitation has been the lack of relatively low-cost, random access storage units with both sufficient capacities and data rates. Optical digital disks and disk packs have the high data rates and large storage capacities required for these applications. Recent developments (*26*) have led to data rates of 30 megabits per second with capacities in excess of 30 billion bits per 12-inch disk, and data systems with data rates of 60 megabits per second have been shown to be feasible. Just how associative text processing will be best employed—for on-line access to text, or preprocessing of text for the creation of indices, or both—is still not clear. It is only certain that the availability of storage technologies such as these will give impetus to the reconsideration of associative processing applications.

Another potential application is to the local or regional provision of full text (with graphics) as a complement to on-line, centralized searching. The latter implies high-speed, sophisticated processing requirements, which may be best centralized, while the provision of audiovisual segments and full text with graphics to the remote user implies major communications requirements, which may be best decentralized. Since most countries impose tariffs on communications, the economic trade-offs between searching and information delivery may not be dictated by technology alone.

Distributed versus Centralized Information Delivery

The potential for distribution of machine-readable information via optical video disks or optical digital disks may appear as a threat to centralized, on-line services. Decisions between the alternatives will be based on considerations similar to those that dictate the choice between in-house and time-shared computing services. These considerations are primarily economic and include the cost of computer equipment, communications, and personnel as well as the frequency of need for the information at the going market rate. For the distributed delivery of full-text information, the difference between the optical digital disk and the proposed digital application of the optical video disk includes both publication and equipment cost. Currently, the optical digital disk can be replicated only by sequentially copying from one disk or pack to another. This should pose no major barrier to regional distribution of information, but would be very costly in quantities of 100 or more copies. Mass publication in such quantities would be in the domain of the optical video disk technology. Similarly, for single users, exploitation of the commercially available industrial players may greatly reduce equipment costs. Such players, on the other hand, will not effectively support multiple users.

Microform surrogate. When storage of journal and document pages is considered, we are addressing a potential surrogate for microforms. Although optical disks will have better random access capabilities, will they compare economically with microforms? For such a comparison it is necessary to make some assumptions about the amount of digital storage required per journal page. Although normal facsimile reproduction has a scanning resolution up to 200 lines per inch (40,000 bits per square inch), this is insufficient for high-fidelity archival storage of journal pages. It is estimated that for good reproduction of scientific journal text (not including halftones or color graphics) approximately 500 lines per inch (250,000 bits per square inch) are required. Estimates of digital compression at these resolutions range from 20:1 to 100:1. Assuming a scanning resolution of 500 lines per inch, a 50:1 compression ratio, a page size of 8 by 10 inches, and a disk storage of 20 billion bits, we estimate that 50,000 pages could be stored per disk. Depending on quantity, such video disks should cost between \$2 and \$10. Thus the cost per 1000 pages will be between \$0.04 and \$0.20. By comparison, a standard × 24 microfiche contains approximately 100 frames per transparency, and the NCR ultrafiche, used by the British Library for its "Books in English" publication, contains 2380 frames per transparency. Assuming a duplication cost of \$0.25 per transparency for standard fiche and \$0.50 per transparency for ultrafiche results in costs of \$0.20 to \$2.50 per 1000 pages. In terms of media alone, the video disk may be an economic competitor of microform for large collections.

It should be noted, however, that equipment costs will preclude competition between microforms and optical disks for individual users in the foreseeable future. Whereas a microfiche reader can be very inexpensive, access to information from optical disks will require disk players, high-resolution displays or printers, and some form of computer (or microprocessor) capability. It can be expected, nonetheless, that video disks will compete with microforms in regional centers that subscribe to major microform document collections such as ERIC (Educational Resources Information Center) and in libraries and information centers that have justified the cost of acquiring the appropriate equipment. It will also be possible to generate both microforms by COM (computer output microform) and hard copy directly from the optical disk storage.

Document delivery and demand publication. In a previous section, the optical digital disk was discussed as a potential document storage medium. A natural extension of this is the computer-driven xerographic laser printers, produced by IBM, Siemens, and Xerox, which can print the stored information at a rate of up to two pages per second (about 14 million pages annually per machine per single shift of 40 hours per week). Of these machines, the Xerox 9700 laser printer currently has the highest resolution, 300 lines per inch. These machines are expensive (about $350,000), but a high volume output can bring the cost per page to 1 cent or less. It is safe to say that, in the future, a spectrum of lower cost, albeit slower, printers will be available for distributed printing. Whether documents are printed centrally or the information is transmitted over document delivery networks to local printers or distributed on video disks for local access and printing will be a matter for future determination. The deciding factors may well be political and economic rather than technical—for instance, the establishment of communications tariffs. Note, however, that if centralized distribution is used, video disk publication is not required and the potentially higher storage densities of the optical digital disk can be employed. Extending our previous calculation for page storage to the higher densities and assuming 1000 pages per journal per year, we obtain the figures in Table 2.

Table 2. Estimated page storage densities.

Year	Storage type	Billion characters	Pages	Journal volumes
1980	Disk	2	50,000	50
1982*	Disk	20	500,000	500
1983*	Disk pack	100	2,500,000	2,500

*Estimated.

The actual state of the art is best exemplified by an application at the Library of Congress. In concert with the Xerox Electro Optical Systems (XEOS) Division, Pasadena, California, the Library of Congress Cataloging Distribution Service (CDS) is utilizing these technologies for storage and demand publication of catalog cards (*27*). Two systems have been developed to date. The first, the CARDS system, publishes on demand catalog cards from the MARC machine-readable database by use of a Xerox 9700 laser printer modified to accept card stock. The CARDS system is capable of publishing two pages a second with six cards formatted per page.

The second CDS-XEOS system, the DEMAND system, provides for demand publication of the approximately 5 million Library of Congress catalog cards not in machine-readable format, many of which are in hand scripts (including Oriental ones) and non-English character sets. In addition, a large number of the cards suffered water stains due to a broken water pipe in the storage area. The first step in the DEMAND system is a high-resolution (480 by 480 bits per square inch) digital scan of the cards, using multiple gray levels for image enhancement. The second step includes the compression and storage of the digitized image on an optical digital disk. A modified Xerox laser printer allows demand publication of the archival digitized card images. A picture of a water-stained card next to an enhanced reproduction showed the latter to be of higher quality than the original, even in areas where no staining occurred. When all archival cards are digitized and stored in the DEMAND system, CDS will be able to publish electronically, on demand, more than 6 million catalog card records. As this example proves, the technology is already in place. Its extension to the more exacting requirements of scientific publications, halftones, and color plates is being addressed in various laboratories around the world.

Hybrid network architecture. In order to clarify the concept of a hybrid network architecture, as intended here, the example of library shared cataloging will be explored. It is not reasonable to take pictures of library catalog cards for storage as video frames on a video disk because of the lack of resolution of standard video monitors. If one assumes, however, that a catalog entry has 1000 characters or less, on the average, then a video or optical disk with a storage capacity of 2 billion characters could store the contents of 2 million catalog entries.

While there are very few individual libraries with 2 million catalog entries, all libraries may wish to share access to machine-readable regional and national union catalogs. This potential for inexpensive duplication of such large collections of catalog information may result in new approaches to shared cataloging. For example, the consideration of network strategies in such areas as shared cataloging results from two conflicting premises:

1) To maintain currency, the database on file should be maintained and updated centrally.

2) It is impractical and undesirable to service a nation of on-line users from one computer center.

Regarding the first premise, it is desirable that a librarian wishing to catalog a new acquisition have access to the efforts of another librarian who has already cataloged that item. Regional network strategies have been recommended to resolve the conflict between these two premises. In such strategies, the database would be replicated at each regional center to service on-line users in each region. The regional centers would maintain currency among themselves.

The potential for utilizing the optical video disk as an inexpensive publication medium could, in the future, provide an alternative network strategy. There might be three hierarchical levels: the central update facility, local (or regional) storage of recent additions, and a cumulative, historical collection on video disk. In such a strategy, the optical or video disk–based historical collection would be published periodically (monthly, bimonthly, quarterly). The recent storage would be standard read-write storage and would be updated through the network, say weekly or nightly, from a central facility. A catalog query to the site serving the user would first search the locally available historical and recent catalogs. If the information was not found locally, the request would be automatically routed to the central facility. The frequency of video disk publication and recent catalog updates would be chosen to maintain a reasonable rate of transactions at the central facility. Hence, hybrid network architectures may provide access to distributed historical and recent data and at the same time provide centralized access to the most current data.

Office and Local Archive Systems

As mentioned earlier, Philips-Eindhoven and Toshiba are developing less expensive, pregrooved draw systems for the office environment. Both systems are intended to support the archival storage of correspondence and other office documentation. The Toshiba unit contains integrated facsimile and laser printing units, the former to scan document images for storage on disk and the latter to print documents from disk on demand. The resolution presently available is approximately 200 lines per inch. While sufficient for typewritten material, this resolution will not be sufficient for archival quality images of scientific journal pages, hence the emphasis on office systems. Such systems should, however, provide good archival electronic file storage and source data capture for many of the applications discussed in the Artemis report (*28*).

Preservation

A major advantage of optical digital disks is their potential archival quality. Accelerated aging tests in the laboratory have been inconclusive in determining expected lifetimes. At present, video disk lifetime appears to be practically unlimited. Oxidation of the substrate in Philips-type DRAW disks as well as new developments, such as the DREXON draw disks, that may eliminate this potential problem were discussed in an earlier section. Even if the present disks do not provide an unlimited archival lifetime, the manner in which the data are stored (digitally) will allow their periodic regeneration without the loss in quality now associated with successive generations of photographic images.

Optical Disks and the Scientific Enterprise

Optical disk technology also promises to make major contributions to both science and the practice of science. The optical digital disk is being investigated for computer mass storage, with a heavy emphasis on the storage of digitally scanned images. At a recent conference on picture archiving and communication systems for medical applications, many papers were presented on the use of optical digital disk technology (*29*). Applications under study or development range from the storage of digitized x-ray (*30*) and computed tomography (*31*) images in medicine to the capture and storage of satellite transmissions. In the latter case, there is a perceivable need to be able to store 100 billion bits per transmission at rates of several million bits per second at ground stations around the world (*32*). At the present time, the optical digital disk is the most promising medium for such applications because of its high storage density and high data writing rate.

The video disk is also certain to find applications in the delivery of graphic information ranging from pathology slides in medicine to catalogs of satellite imagery. In addition, the potential for storing and replicating large quantities of data at low cost may well prove to be most important to the scientific community. A new generation of scientific instrumentation may contain large quantities of optical disk–based historical data critical to the observation and recognition of new phenomena (*33*).

Conclusions

Optical disk technology promises many dramatic improvements in IS&R. Its potential for digital storage is the driving force for the development of many complementary technologies such as high-resolution digital scanning and computer-driven laser printing.

The optical disk itself is an almost ideal medium for IS&R. If it were necessary to choose between read-write and read-only archival storage, all other aspects being equal, the latter might be far more important. As scientists are able to integrate information (including data) in their research efforts, however, the impact of this robust, high-density storage technology on science may be the most dramatic outcome of all.

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