Working Paper

THE VIDEODISC REVOLUTION

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International Institute for Applied Systems Analysis
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ABSTRACT

This paper attempts to make a comprehensive analysis of present and future videodisc technologies and a thorough examination of the impacts of this technology on different information application classes and on other media. First the basic principles of this new technology are described. This is followed by a summary of some major hardware and software functions of such systems. In the subsequent chapter, the extremely broad range of videodisc applications is dealt with. In the final summarizing chapter some conclusions are drawn pointing to the vast potential of this new technology, which according to the author, could lead to a new revolution in the information and entertainment industry.

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Istvan Sebestyen

1. INTRODUCTION

We are at the beginning of a new revolution in the use of information technology, which was triggered off by the rapid development of new technologies in the field of electronics. While the performance of processors, primary and secondary storage equipment, input-output devices, and telecommunication devices has improved at an accelerated pace in recent years, the unit prices of these items have dropped dramatically. The new technologies have found their way into many different areas of application.

A major step forward was the emergence of computers in telecommunications, which marked the beginning of a new era: "telematics," a word coined by S. Nora and A. Minc [7].

The convergence of information and telecommunications technologies was only a first step and was followed by others, as new information technologies gradually started to influence other fields: processor-controlled robots perform their duties in manufacturing; industrial processes are increasingly being controlled by real-time computers; and the microelectronics revolution has started winning one battle after the other in daily life.

For example, today we can find cheap pocket calculators in practically every household and low-cost digital watches controlled by internal microprocessors have practically overrun and replaced traditional watch-making methods. Furthermore, advanced microelectronic technology has moved into so-called "consumer electronics." In the newer types of TV sets, hi-fi equipment, videotape players, etc., microelectronic devices such as processors are being applied *en masse*. The "video arena" in particular is being invaded by these modern technologies. New applications such as broadcast and interactive videotex services (e.g., ORACLE and PRESTEL in the United Kingdom) are marking the beginning of a new era, which might be called "videomatics," or a convergence of video and information technologies.

With the advent of laser technology and optical fibers, revolutionary changes are now expected in the field of information storage and telecommunications. In this paper an attempt is made to understand, analyze, and assess, especially, the impacts of laser and optical storage technology on the converging fields of information technology and consumer electronics. The study focuses on a new device, which we will call "videodisc".

The structure of the study is as follows. First a short overview of the videodisc technologies will be provided, showing why it will achieve a major breakthrough. In Chapter 3 the "dualistic" nature of videodisc technology will be explained: on the one hand such devices will be portrayed as "interactive TVs"—as looked at from the consumer electronics point of view—and on the other hand, they will be seen as cheap mass storage devices for random access of coded information—as looked at from the information technology angle. In Chapter 4, the hardware and system software aspects of videodisc systems will be dealt with briefly and major operational functions of videodisc players will be discussed at some length. In Chapter 5 an attempt will be made to collect all the major classes of videodisc application. Some of their requirements can be met by other technical means and media—perhaps in a less convenient way and at a higher costs. Other applications, however, are brand new—and probably will have considerable impact on future life styles. Chapter 6 briefly summarizes the study and the major conclusions to be drawn from it. It is hoped that by that point the readers will agree with the author: the Videodisc revolution is coming and it will greatly affect our lives, as did the book, the radio, the tape recorder, the telephone, and the TV before it.

2. A DESCRIPTION OF VIDEODISC TECHNOLOGY

Harry Collier [22] calls the videodisc scene at the beginning of the eighties a "jungle." Many forms of videodisc technology, designed for slightly varying purposes are now in existence or are being developed. It is not the aim of this paper to make a full analysis of the technology itself; this is done at some length by other authors. See, for example, Barrett [23] and Sigel et al [29]. Nevertheless before discussing the application classes and possible impacts of this new medium we should briefly discuss the piece of hardware that will be the focal point of the study.

The first videodiscs, developed in the early seventies, were intended for use in the entertainment industry. Since then, however, strong interest has arisen for their use in information and document storage, retrieval, computer-aided instruction, etc. An essential feature of this technology is that it lends itself readily to the integration of text, image, and audio information and at the same time, it is programmable and can be randomly accessed. However, each of the above types of application places different requirements on the equipment's development, and thus after only a few years of development, a number of different forms of videodisc technology have come into being. These technologies can be classified according to the following criteria:

- analog versus digital information coding
- mechanical (contact) versus non-mechanical (non-contact) pick up of information from videodisc records
- mechanical replication versus laser beam recording of information onto records.

Analog versus Digital Information Coding

At present there are several systems using each of the two type of coding. What does analog and digital coding mean in the case of videodisc technology?

As will be described at some length in the following chapter the information units on a videodisc record are tiny pits engraved in the surface of the disc. In the case of analog coding the information stored is coded in the length of the pits; the longer or shorter the pits are, the higher or lower the analog value (e.g., voltage) produced by the sensor, which reads the information serially. Digital coding can be regarded as a special case of analog coding; in the case of digital coding only two analog values exist: zero and some discrete value. This means that on the surface of the videodisc record either there is a pit under the information sensor (information "1") at reading time or there is none (information "0").

From the storage and reading point of view analog and digital videodiscs are thus very similar. This gives the hope that one day it will be possible to produce videodisc devices which will be able to handle both type of codes—analog and digital. As we will show later, this would bring major advantages to the system. At present no such system on the market or in development is known to the author.

Why is it that already at the beginning of the videodisc era, two different types of coding techniques are being applied?

The simultaneous emergence of analog and digital coding techniques has both historical and technical explanations. Analog storage for videodiscs was linked to the effort to store analog television frames according to NTSC, PAL, or SECAM standards on videodisc. It has been found that the best type of storage is achieved when pits are engraved at the speed of the FM carrier frequency of about 8 MHz onto the surface of the videodisc, where the length of the individual pits are proportional to the modulation on the carrier frequency (Figure 1). With this techniques any TV signal can be recorded and read, including their usual properties: thus about 200,000 pixels per videoframe, sound and color coding, and in the vertical blanking intervals even teletext type digital information could be stored.

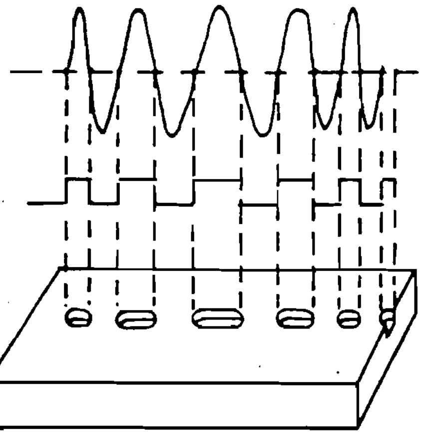


Figure 1. Micropits engraved on the disc of an analog optical recording system.

Digital storage applied to videodisc emerged when Philips in the Netherlands realized that through this technology much more coded alphanumerical information (text, data, computer programs) can be stored highly economically than by any other information storage techniques.

It was soon realized, however, that in principle other types of information as well should and can be stored on videodisc: first of all, on the analog videodisc "color TV" type freeze-frame pictures, which is no more than repeated access to the same analog TV frame, and second, on the digital disc the storage of "Facsmile" type black and white static pictures with high resolution.

Since then, it has been recognized that if the same videodisc handled all pf the above-mentioned classes of information, i.e.,

- coded alphanumerical information,
- "Facsimile" type static pictures,
- "Color TV" type freeze-frame pictures,
- "Color TV" type motion pictures, and
- audio (sound) information,

one would get a revolutionary new piece of equipment, which would allow not only vast amounts of storage but also flexible mixing of coded alphanumerical, audio, and video information. This would lead to new, revolutionary fields of applications.

Along this line we see the same trend of development for both analog and digital videodiscs. Analog videodiscs will be developed to be able to handle coded alphanumerical information in an efficient way; digital videodisc will be able to handle voice, "color TV" type freeze-frames, and maybe later at some point—although this is far from the road— produce "color TV" type motion pictures.

Which coding techniques will actually "win" is almost impossible to predict at this time. Both technologies will predominate in certain information classes for a long time, such as for analog videodisc players, the "color TV" type moving frames. Or it is possible that one day a videodisc player will enter the market which will combine both coding techniques and utilize their advantages when handling different information application classes.

Depending on the type of information stored, analog and digital techniques have their advantages and disadvantages in comparison with each other.

a) *Coded alphanumerical information* such as digitally coded text, data, and computer programs can be stored ideally through digital videodisc technology. Digital coding and storage allows the most sophisticated data compression and error recovery. In addition this type of data is immediately ready for further data handling and processing purposes without any special preparation or conversion. It may sound strange, but in principle, it is possible (with the addition of some hardware features) to store digitally coded alphanumerical information through analog videodisc technology as well, in a "pseudo" digital form. In this case, obviously, the degree of data compression is less favorable than that used in the real digital technology. At present, there are two possible ways in which digitally coded information can be mixed with the standard analog television signal to be stored on analog videodisc records: one technique is described by Barrett [23] and Sigel [29]. They suggest to replace the active picture material in the standard color video signal with data, while retaining the various synchronizing signals that are used by playback electronics to identify an analog video signal. Encoded in this fashion, according to Barrett, at a data rate of 7.16 Mbits per second in an NTSC signal, a total of 375 stored bits per line can be stored. The total bits per TV picture could be 185,625 bits. Utilizing a standard 108,000-track analog videodisc a total storage capacity of 2×10^{10} bits per disc could be reached. Assuming 30-40% for error recovery purposes this would lead to the impressive figure of $1.2\text{-}1.4 \times 10^{10}$ user bit per disc.

The other technique which would allow the storage of a limited amount of coded alphanumerical information on videodisc utilizes the opportunities provided by the well-known teletext technology mentioned before. According to Sigel [29], as it is implemented in Europe, teletext can transmit as many as 160 alphanumerical characters hidden within four scanning lines of television frames each, which are restored to "pages" of alphanumeric and crude pictorial data by a special decoder. On a full videodisc record (PAL/SECAM) 1.44×10^7 characters—the full Encyclopedia Brittanica having roughly 2.2×10^8 characters(!)\mcould be stored.

One possible application of such character might be to provide subtitles to videodisc motion picture programs for handicapped people or for subtitling a program in a foreign language.

Another might be the transmission of data into a computer while pictorial information is being watched; the videodisc controller could be feed with programming instructions to modify the videodisc control program, as will be explained later. Since teletext is also available with standing frames, it might be used to provide descriptive text for freeze-frame pictures.

b) *"Facsimile" type static pictures* are more suitable for digital videodisc systems. Their high quality resolution according to CCITT's Group III standard can only be assured by digital coding technology. Such pictures, however, can only be shown on special high resolution monitors or be printed out by appropriate matrix printers. This type of information is less important for the residential videodisc user, but will find major application in office automation and document filing systems. Storage of "facsmile" type static pictures on analog disc in digital fashion is principally possible as described in the previous paragraph. However, at present, no such solution is known.

c) *"Color TV" type freeze- frame pictures* are primarily suitable for analog videodisc systems. Appropriate digital coding, perhaps using some PCM decoding methods, would in principle make it possible for digital videodisc systems. However, at present, no such application is known to the author.

d) *"Color TV" type motion pictures* are typically suitable for analog videodisc systems as described above. It seems at present that the coding of motion pictures on digital videodiscs is beyond the presently known disc storage and data processing speed capabilities. According to J.W. Klimbie [30] about an 80-100 Mbit/sec processing speed would be required and on the presently known digital videodisc only about a 10 second motion picture program could be stored.

e) *Audio (sound) information* at usual TV broadcast quality can be easily stored on analog videodiscs. The storage of sound on digital videodisc is in principle possible too.

The basic principle behind recording voice on digital videodisc players will be PCM. PCM is an acronym for Pulse Code Modulation, a typical digital technique. Conventional audio and video systems, relying on analog techniques, handle sound and video signals without modification. The key principle behind PCM is that both the frequency and the levels of the signals are handled in an intermittent form regarding both the time and their levels. Sound level and frequency are encoded with a binary coding system using only "1" or "0" and are then recorded as equal-amplitude digital pulses. And here lies the secret of PCM's capability for yielding specifications superior to those of conventional systems.

What are the advantages of digital audio recording in consumer electronics? While analog recording techniques have been remarkably improved, they are still limited by a number of weaknesses that result in distortion and dynamic range limitations. These limitations are inherent in the tapes, heads, and other mechanical parts, and it is virtually impossible to eliminate them completely.

With digital systems, the sound or image signal is recorded and transmitted in the form of digital codes and this has a whole host of advantages, among them:

- Wide dynamic range
- Flat frequency response regardless of input level
- Extremely low distortion
- Superior transient characteristics
- No deterioration even with repeated duplication
- Error correction capability

The basic principle of the PCM recording process is shown in Table 1 [16].

It should be noted that the technology for digital recording on optical discs is presently developing in two different directions: "videodiscs" and "digital audio discs." The storage principle is basically the same on both. However, usually the quantity of data stored is considerably higher on videodiscs because of its physical size. Needless to say, in principle, it also possible to store voice information on videodisc devices.

In principle, about 10 hours of super hifi quality sound could be stored on an average digital videodisc record. It is no doubt that there will be special applications when this capability of the digital videodisc recorder will be utilized.

As we have seen at present no videodisc system, be it analog or digital, exist which would fulfill the basic requirements—vast information storage and media mixing capability—of an "ideal videodisc system." In Table 2 the characteristics and requirements of some present and future videodisc systems are shown. Whether the "ideal videodisc system" will be an analog, digital, or a mixed system is hard to predict at this stage.

Mechanical versus Non-Mechanical Information Pickup from Videodisc Records

Although there are a few systems with the mechanical pick-up on the market (one, the Selectavision of RCA, for example, uses a special needle on a grooved capacitance disc), they seem to be less important, as this technology has several disadvantages that exclude it from being used for the model applications to be discussed throughout this paper. One drawback is that it does not allow random access to the recorded information which excludes its use for information retrieval purposes. Another deficiency is that so-called "freezed frame" pictures cannot be shown using this method (these deficiencies are not true for the VHD system of JVC). And last but not least, the lifetime of both needle and record is limited

Table 3. Principle of the PCM recording process

What is the basic principle of operation behind PCM?

There are three stages in the digitalization; sampling, quantizing, and encoding. The quantizing and encoding functions are handled by the A/D (analog-to-digital) converter, and the reverse function is performed by the D/A (digital-to-analog) converter.

(1) Sampling

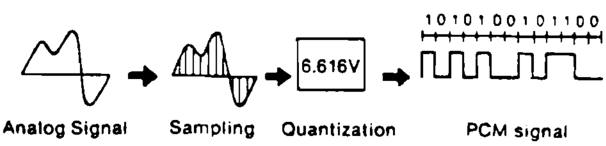
The sampling circuit serves to convert the analog signals into PAM (pulse amplitude modulation) signals at fixed time intervals. These intervals are commonly known as the sampling intervals and their reciprocal as the sampling frequency. Analog signals whose frequency is less than half that of the sampling frequency can be completely restored to their original form even after digitalization. The sampling circuit is usually associated with a holding circuit since there are limits to the operating speed of the quantizer. The sampling frequency for digital audio disc is usually 32,000 KHz, for studio applications, higher.

(2) Quantizing

Quantizing refers to the process where the levels of the individual sampled signals are divided into fixed steps. The finer these steps, the more accurately the signal level is expressed, and the better the dynamic range and signal-to-noise ratio. If the number of quantizing bits is taken as "n", then the number of steps which can be expressed becomes 2^n. In equipment which aims to produce top-grade hi-fi, "n" is usually equal to 14-16 bits due to the sound quality, economic feasibility and other considerations. In PCM video systems 3-4 bits can be used to express brightness of a spot.

(3) Encoding

The signals which have been converted into discrete values with respect to both time and their amplitude by sampling and quantizing are further converted into pulse codes and recorded. A binary code (0 or 1) is normally used for this purpose.



PCM Recording Process

Videodisc system	Information storage		Information pickup		Pickup principle	Information recording		Media mixing capability	Random access capability	Type of information stored					Price (US$)	
	analog	digital	mechanical contact	non-contact		Mechanical replication (stamping)	Laser beam recording ("write only")			audio	video single frames	video motion	coded data/text	videodisc control program	equipment	record
Selecta Vision (RCA)	X		X		capacitive	X		X		X		X			500 and above	15 and above
Video High Density (JVC)	X		X		capacitive	X		X	X	X	X	X			?	?
Philips/Magnavox	X			X	optical	X		X		X		X			700	16-24
MCA/Pioneer	X			X	opticall	X		X		X		X			750	16-24
Discovison Association (IBM/MCA)	X			X	optical	X		X	X	X	X	X		X	2,500	6-25
Thomson-CSF disc	X			X	optical	X		X	X	X	X	X			2,000	10-20
Digital Optical Recording (DOR) Philips		X		X	optical		X		X		X		X		100,000 (in 1982) OEM price 10,000 (in 1985)	250-300 (in 1982) 100 (in 1987)
Document filing system "DF-2000" Toshiba	X			X	optical		X		X		X				45,000-60,000 (in 1982)	140 (in 1982)
Optical disc digital data recorder/player (RCA)		X		X	optical		X		X		X		X		?	?
DREXON disc (Drexler Technology Corp.)		X		X	optical	X	X		X		X				3,500	50
"Ideal videodisc systems" (not available yet)	?	?		X	optical	X	optional feature	X	X	X	X	X	X	X	500-5000	5-50

Tablel 2. Characteristics of present and future videodisc systems

due to the high rotation speed of the disc and the mechanical contact between needle and record. Therefore we have limited the following discussion to technologies with non-mechanical pickup capabilities.

Pickup from videodisc records can be either capacitive or optical. The basic principle of the capacitive pickup techniques lies in sensing the change of the electrical capacitance between a conductive surface on the disc and a thin metallic electrode carried by a stylus tracking either in the groove (mechanical pickup) or smoothly above it on an "air cushion" (non-mechanical pickup). Optical pickup techniques are always non-mechanical and are based upon the change in the optical characteristics of the videodisc record under a laser beam spot. This technique will be discussed in more depth, since it is regarded as more suitable for major videodisc applications.

Mechanical Replication (Stamping) versus Laser-Beam Recording of Information onto Records

Both methods of record production are of basic importance for the videodisc applications that follow. The *"mechanical"* manufacture of videodisc records will allow mass production of programs for videodisc players, including movies, encyclopedias, electronic dictionaries, telephone directories, railway timetables and similar products that can be sold and distributed in large quantities. At present information for "mechanical" replication arrives at the videodisc factory on videotape.

In the case of the analog Philips videodiscs [26], the beam of a 100 MW laser is modulated with the tape's signals and is focused onto a rotating glass disc coated with a photosensitive emulsion. When the exposed disc has been developed and etched, it contains some 25,000 million pits. This master disc is then coated with silver and replayed to check its quality. If the disc is acceptable, the next stage is to electroplate it with nickel and coat it with aluminium to produce a "father" disc: this negative replica of the master is stripped from the glass, and electroplated with nickel to produce a "mother" on positive replica of the original master. From this another electro-nickel plating process produces a negative "son" or stamper, which is used in the production process. The stampers are used to make "half" discs, pairs of which are glued together to make the final double-sided product.

However, at the time of this writing there remain some "snags" in this production process. In a UK factory, according to press reports [26], failure rates vary from 10 to 90 percent and are quite unpredictable. It can be hoped however, that these "infantile disorders" in videodisc record production will be overcome in the future.

The other type, *"non- mechanical"* information recording is carried out with a laser beam, which burns the information onto an empty videodisc record in a sequential recording process. This technology does not allow real mass production of videodisc records; it is, however, of utmost importance for applications such as archiving, filing, and office automation. A similar technology used in the Digital Optical Recording System (DOR) of Philips is described in the following section in more detail. In

Table 3 the application classes classes are listed according to the recording technology to be used. The switching point between the two recording technologies lies at a production level of around 100 copies.

In dealing with the above classifications this study will focus primarily on videodiscs with multimedia mixing capability that use non-mechanical pickup (primarily optical) reading techniques allowing random access to frames and with mechanical (stamping of records) and laser-beam recording techniques. As shown in Table 2, such systems which combine all the above requirements do not exist yet, although their characteristics are individually part of one or other presently known systems. In Table 2, no attempt is made to compile all videodisc systems presently known.

A Description of Digital Optical Videodisc Technology

Optical videodisc technology has changed little since 1978 when Philips launched its first laser-optical system (Philips/Magnavox) [1]. A 30 cm record, superficially resembling an audio disc with a grooveless surface, is coated with a reflective material (Figure 2). The disc's surface is covered with a spiral of tiny pits. For playback, the disc is rotated at high speed on a gramophone turntable while a finely focused laser beam tracks from the inside outwards. As each pit passes through the laser beam it makes a minute alteration in the pattern of the reflection off the disc's surface. These changes are detected by a photosensor arranged along the same axis as the laser beam. The photosensor produces an electrical signal that can be decoded to produce color television pictures,

Table 3. Applications for mechanical replication and laser beam recording of information

Mechanical recording (replicating of records)	Laser beam recording
Entertainment	Mass storage (few copies
Encyclopedia	Archives of data
Automated dictionary	Program archives
Electronic directory	Document filing
Information bank	
Electronic publishing	
Timetables	
Education	
Mass storage, archives (many copies)	

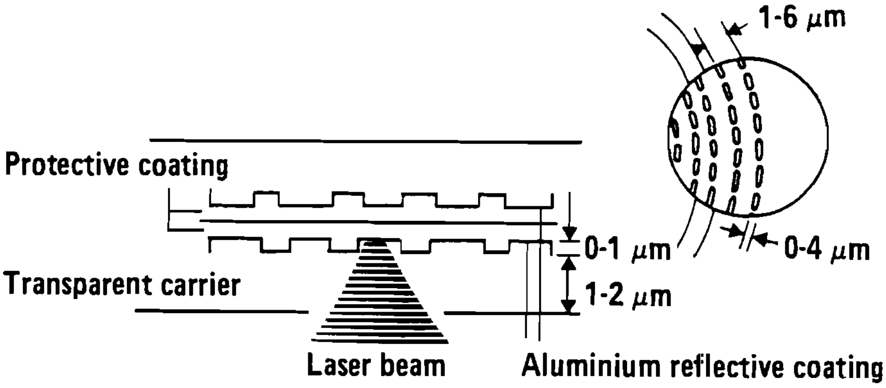


Figure 2. Simplified diagram of a videodisc record based on the laser beam reflection principle (Philips/Magnavox) [1].

stereo sounds, or (in digital systems) special codes for digital information. A similar technique for optical storage such as the one used by Philips' other system, the experimental *Digital Optical Recording* (DOR) system—a one-time writing and read only system—is shown in Figure 3.

The DOR system uses a 12 inch disc formed from two glass substrates placed back-to-back in a sealed air-tight construction. The so-formed experimental optical disc has a spiral groove equivalent to 45,000 usable tracks divided into 128 sectors. Each track/sector combination is given an individual segment address. In this way segments can be found in random access mode. DOR is in principle an empty disc, as are magnetic tape and discs. DOR discs can be written (once only) by the user. The user may write about 1,000 bits of information in each segment. Thus, on the experimental DOR system, it is possible to store 5 x 10^9 bits per side; since the disc is double-sided 10^{10} bits can be stored per disc. Philips sources say [30] that in the final version of DOR double-side 2 GByte user information (1.6 x 10^{10} bits) can be stored.

The disc is pregrooved, and the recording surface is completely protected: it is engraved and read through the glass substrate. Engraving is carried out by so modulating the diode laser beam that a hole less than one micron in diameter is burnt in the sensitive layer; once engraved, the disc cannot be rewritten and retains its properties for at least 10 years, making it suitable for archival purposes.

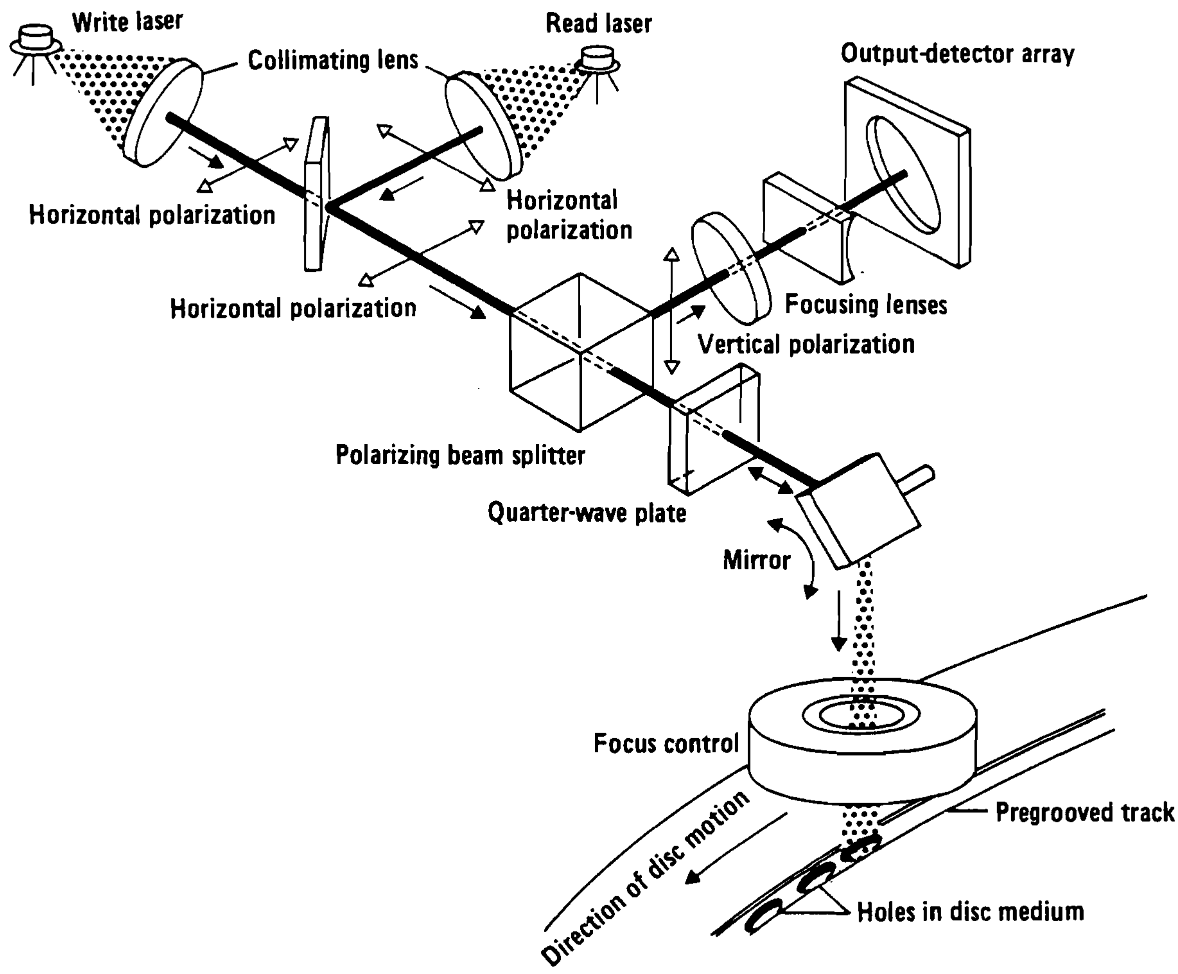


Figure 3. The optical disc memory for data storage and retrieval--such as the Philips DOR system--employ laser light to write data by burning holes in the medium on a spinning disc. The laser for writing the data is shown at the far left. A laser for reading the data is shown at the center top. Its light reflects from the disc at the places where no hole has been burned, then makes a second passage through the optical train of the device, arriving back at a beam splitter with a vertical polarization. This reflects the beam to a detector array. The reflected light also yields feedback signals for control of tracking and focusing [2].

Another type of systems, used for example, by Thomson-CSF (another analog videodisc), is based on the so-called laser transmission principle. The beam shines through the disc that has been previously burned by a laser, the photosensor being situated on the other side of the record. Thomson's system utilizes a flexible rather than a rigid disc (12 inches) carrying approximately 30 minutes' (or 54,000 frames) on each side. Since it is a transmissive system, though, any of the 108,000 frames can be randomly accessed without flipping over the disc, simply by changing the focal point of the optics from one side to the other.

While conventional audio discs have practically only one long track of information along a spiral line going from the outside inwards on each side, video discs have numerous tracks (e.g., up to 54,000 per side on DISCOVISION's PR-7820 model,* each separated by 65 millionths of an inch) along concentrical circles containing independent frames of information. When the PR-7820 is working in video mode, each track contains information for one TV picture, with approximately 200,000 picture elements per frame. Sound and computer instructions are recorded on the disc as well. On the model PR-7820, a helium-neon laser is used to "read" the information from the disc, which is spun on a turntable at 1800 rpm, 54 times the speed of a normal 33-1/3 rpm audio turntable.

* Another analog system manufactured by Discovision Associates (subsidiary of IBM and MCA, Inc.).

3. VIDEODISC AS A TYPICAL "VIDEOMATICS" DEVICE

There seems to be much confusion about the possible role of videodisc technology and its impacts on different fields of consumer electronics such as video recording, hi-fi, personal computing, and the like—and also on various fields of information technology such as mass storage of information and random retrieval. In order to assess videodisc technology and its potential impacts, we shall follow a two-sided approach: first, we will look at it from the consumer electronics, mainly audio-video recording, point of view, and then we shall examine this phenomenon from the information technology angle. Finally, the "dualistic" nature of this technology will be shown, classifying videodiscs as typical "videomatics" devices. *The term "videomatics" has been defined [6] as the convergence of video and information technologies on the analogy of the term "telematics"—or French "telematique"—coined by Simon Nora and Alain Minc in their famous report to the President of France [7].* When Nora and Minc use telematics to describe the growing link between computers and telecommunications they point out a new concept: the computer is not only a computation machine but also a telecommunications device. The term "videomatics" is used to describe the growing interconnection between computers and audio-video technologies such as television and video recording. The term videomatics defines the computer not only a computational and telecommunications device, but also a machine for controlling, mixing, and processing textual, audio, and video information.

3.1 Videodisc Technology as Seen from the Consumer Electronics Point of View

Comparing videodisc technology as described in this paper with the presently known standard videotape recording technology, we see certain basic differences in recording and playback:

a) most future videodisc players will, we believe, use in some form digital signals (independently whether they use analog or digital coding for storage); videotape recorders usually work with analog signals;

b) video frames (individual pictures) can be addressed separately on videodiscs but not on videotapes;

c) on videodisc access to picture frames is random; in videotape recorders, it is sequential;

d) at present, videodiscs are "read only" devices (and "write once" in case of digital optical recording systems); whereas videotape recorders may be used to record and/or erase selected programs;

From the technological point of view, videodisc player and videotape recoder are completely different. The only similarity is that TV-like video information (movies, sport events, etc.) can be replayed on both types of device. (Incidentally, this was the original purpose of the commercial videodisc design.) If the only criterion for comparison were this one, there would probably be no market for videodiscs, since their unit prices are and still would be somewhat higher than those of videotape recorders. A one-hour videodisc program will cost approximately five times (£15) that of a one-hour continuous program on videotape (£3) [1]. However, the videodisc will bring new attractive consumer oriented application as well, which will make it worthwhile to have a videodisc in any home studio.

3.2 Videodisc Technology as Seen From the Information Technology Angle

Looking from the point of view of computer technology and comparing the videodisc technology with other (mainly magnetic disc) technologies, the following differences can be observed:

1) The videodisc technology (more precisely in our case optical disc technology) attains the greatest *storage density* of any of the information storage technologies presently known (see Figures 4 and 5).

   In magnetic storage the cell size is limited by the magnetic particle size limit, which sets the ultimate magnetic limit somewhere below 10^6 bits/in^2, corresponding to a memory cell size of approximately 2 microns.

   In optical storage the cell size is limited by the optical diffraction limit which sets the ultimate limit for optical recording above 10^8 bits/in^2, corresponding to a memory cell size on the order of 0.4 micron. These limits are affected by ambient temperatures and by the wavelength of the light used; for instance, the limit for silver halide film is lower than this owing to limitations on the optics and the requirement to work with visible light. Figure 5 gives a reasonable projection of the limiting capabilities of various storage media.

2) The *access time* to videodisc is similar to those of the magnetic moving head discs, i.e., between 10^{-2} and 10^{-1} seconds. The recorder/playback system of the Philips DOR system, for example, enables a record to be accessed with a mean random access time of 135 milliseconds; the very compact optical system weighing only 40 grams is mounted on an arm that is driven by a linear motor. The arm has an optical grating, which very quickly brings the optics to within 50 tracks of the one selected. Direct reading from the disc then enables rapid selection of the exact track. Less sophisticated videodisc players allow longer access times (up to five seconds).

3) The *storage capacity* of videodiscs is remarkably high.

   In Table 4, the storage capacities of various videodisc systems are compiled according to different types of storage "measurement units." No attempt is made to collect information on all presently available videodisc systems; the table is intended to provide only a general picture of the storage capabilities of present and future videodisc systems.

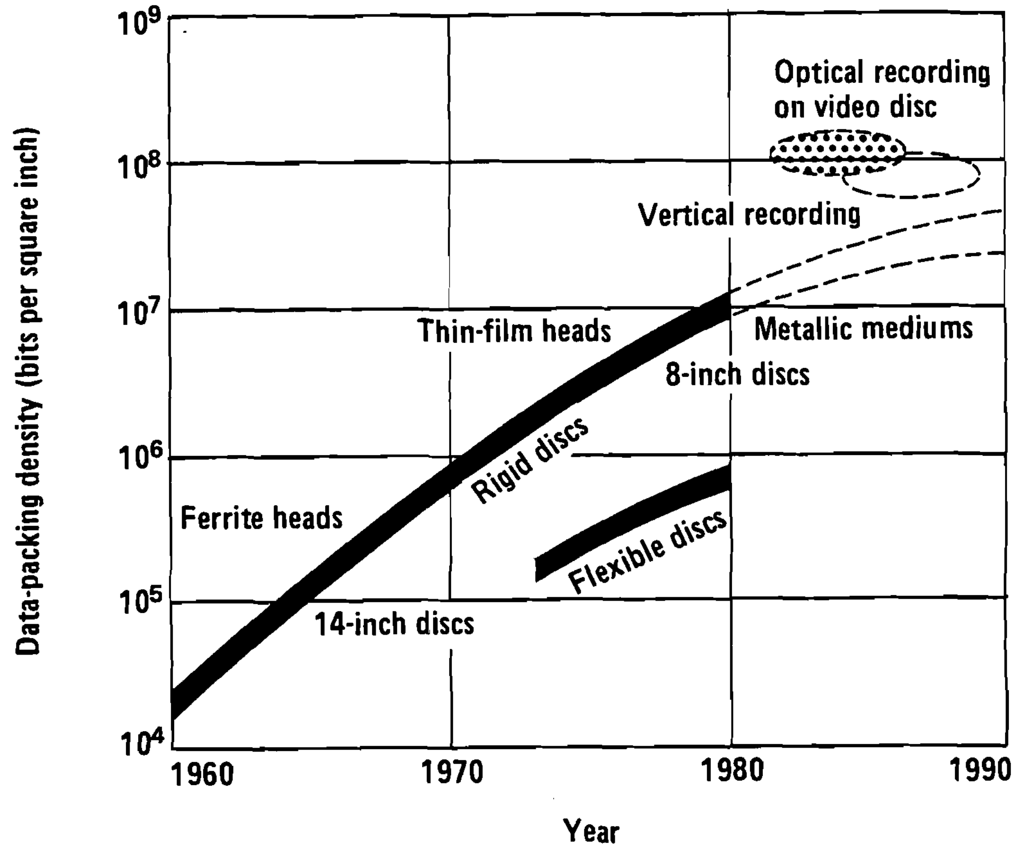


Figure 4. Data package density of storage technologies. Advances in disc technology are reflected by advances in the packing density of data, expressed in this chart as bits per square inch on the surface of a disc. In rigid discs the magnetic medium is coated onto an aluminum substrate; in "floppy," or flexible, discs it is coated onto Mylar plastic. Two improvements are foreseen for the magnetic technology: the use of metal film instead of iron oxide as the medium on rigid discs and the recording of data in regions of magnetization oriented vertically, or perpendicular to the plane of the disc, instead of horizontally, the current practice. Videodisc technology might attain the greatest storage density of all [2].

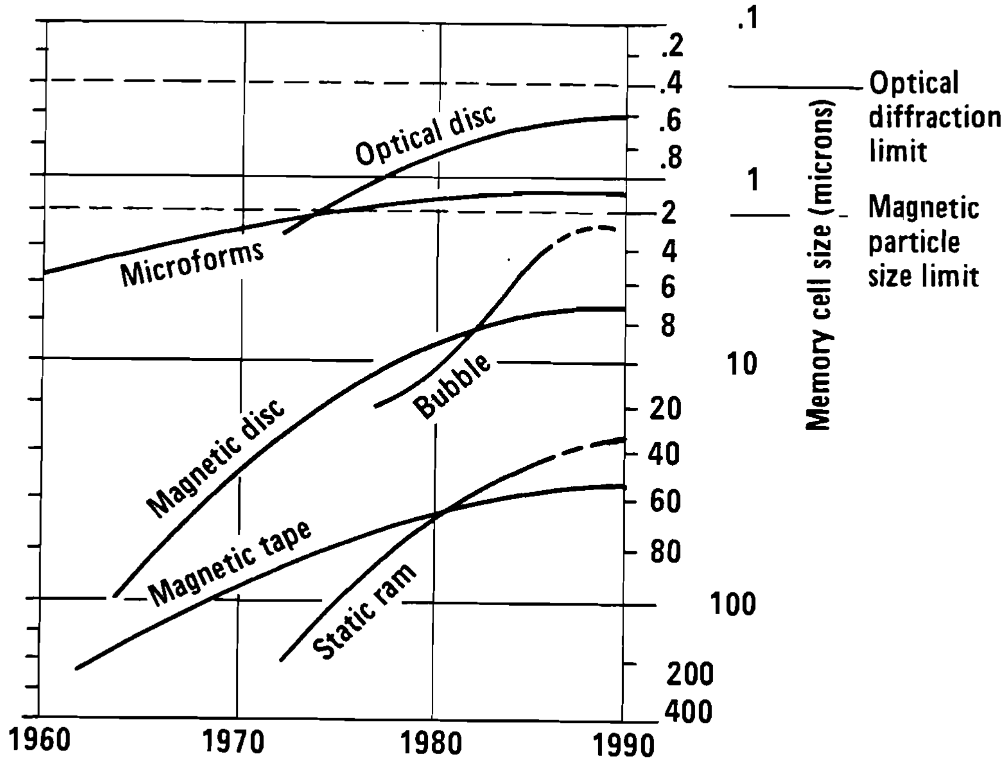


Figure 5. Trends in information storage [22].

As an example of a typical digital storage device the Digital Optical Recording System (DOR) was taken. The experimental system as mentioned previously may store double-sided 10^{10} bits of user information; however, according to Philips sources [30] this will be upgraded to 1.6×10^{10} bits or 2 GBytes of storage capacity.

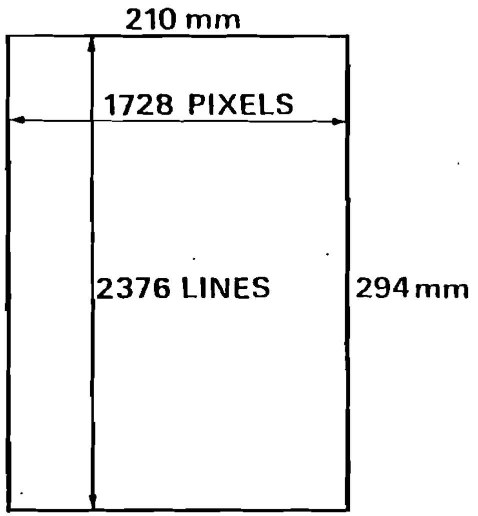
If, on the experimental system, coded characters are stored, each page will require about 4×10^4 bits. If, however, one stores optically scanned data according to the Group III facsimile standard of eight lines per millimeter, 4×10^6 picture elements will be produced per page, or 4×10^6 bits in black and white (see Figure 6). Using data compression techniques one can reduce this by a factor of 10, so that on the average 4×10^5 bits are required to record a page; i.e., a disc would hold a maximum of 25,000 facsimile pages.

As a comparison, it should be mentioned here that an average TV picture contains "only" about 2×10^5 picture elements, although with grades in colors, which is less by a factor of about 20 than the Group III facsimile standard picture of the DOR system. The reslution quality of the TV picture is accordingly also lower, but for moving pictures it is fully acceptable.

Videodisc system	Mode of information storage	Storage capacity per disc: "atomic" information units (pits)	usable digital bits	characters	"VIDEOTEX like" frames	Standard resolution (TV) pictures 200,000 pixels	High resolution (Facsimile III) pictures 4 million pixels	Length of color TV movie program at normal speed	Length of audio program
Experimental Digital Optical Recording Philips (DOR)	digital	$2.1 \cdot 10^{10}$	$1.05 \cdot 10^{10}$	≈ $1.25 \cdot 10^{9}$ (digital coding)	$1.3 \cdot 10^{6}$ (coded 1 VTX frame = 960 characters)	$5 \cdot 10^{4}$ (with data compression)	$2.5 \cdot 10^{3}$ (without data compression) $2.5 \cdot 10^{4}$ (with data compression)	-	-
New series of Philips DOR (available 1983)	digital	$2.3 \cdot 10^{10}$	$1.6 \cdot 10^{10}$	$2 \cdot 10^{9}$ (digital coding)	$2 \cdot 10^{6}$ (digital coding)	$8 \cdot 10^{4}$ (with data compression)	$4 \cdot 10^{3}$ (without data compression $4 \cdot 10^{4}$ (with data compression)	-	-
Discovision Association (IBM/MCA) PR-7820	analog	$3 \cdot 10^{10}$	-	≈ $1.2 \cdot 10^{8}$ (TV mode-NTSC)	$1.08 \cdot 10^{6}$ (TV mode-NTSC)	$1.08 \cdot 10^{5}$ (TV mode-NTSC)	-	1 hour (TV mode)	1 hour (TV mode)
Thomson-CSF disc TTV 3620	analog	$3 \cdot 10^{10}$	-	≈ $1.2 \cdot 10^{8}$ (TV mode-NTSC/PAL/SECAM)	$1.08 \cdot 10^{5}$ (TV mode-NTSC) $9 \cdot 10^{4}$ (TV mode-PAL/SECAM)	$1.08 \cdot 10^{5}$ (TV mode-NTSC) $9 \cdot 10^{4}$ (TV mode-PAL/SECAM)	-	1 hour (TV mode)	1 hour (TV mode)
"Future analog videodisc system"	analog	$3 \cdot 10^{10}$	$1.2-1.4 \cdot 10^{10}$ (digital coding) and $1.15 \cdot 10^{8}$ in (Teletext mode)	$1.2 \cdot 10^{8}$ (TV mode) or $1.5-1.7 \cdot 10^{9}$ (digital coding) and $1.44 \cdot 10^{7}$ in (Teletext mode)	$1.08 \cdot 10^{5}$ (TV mode) or $1.5-1.8 \cdot 10^{6}$ (digital coding) and $1.08 \cdot 10^{5}$ in (Teletext mode)	$1.08 \cdot 10^{5}$ (TV mode) or $1.5-1.8 \cdot 10^{6}$ (digital coding) and $1.08 \cdot 10^{5}$ (Teletext mode)	$3-3.2 \cdot 10^{3}$ (digital coding without data compression) $3-3.2 \cdot 10^{4}$ (digital coding with data compression)	1 hour (TV mode)	1 hour (TV mode) 7.5 hours (digital audio)
"Future digital videodisc system"	digital	$11.2 \cdot 10^{10}$	$8 \cdot 10^{10}$	$10 \cdot 10^{9}$ (digital coding)	10^{7} (digital coding)	$4 \cdot 10^{5}$ (with data compression)	$2 \cdot 10^{4}$ (without data compression) $2 \cdot 10^{5}$ (with data compression)	-	50 hours (digital audio)

Table 4. Comparison of videodisc storage capacities.

A4-DOCUMENT



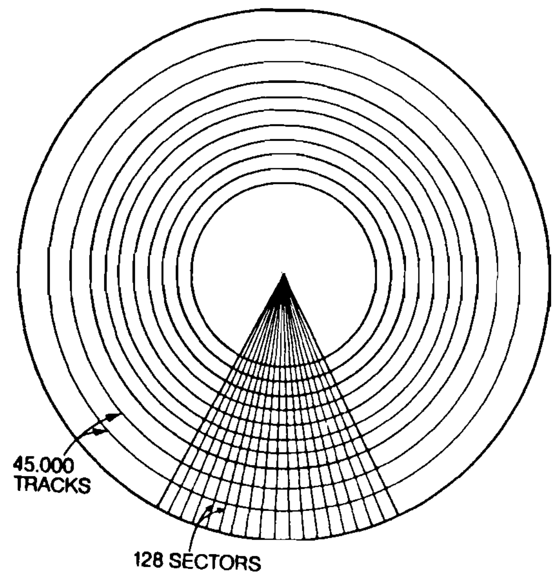
ALPHA NUMERICAL:
50 LINES x 80 CHARACTERS = 4 kBYTE

PICTORIAL:

2376 x 1728PIXELS = 4,105,728PIXELS

≈500kBYTE

12" EXPERIMENTAL OPTICAL DISC
(2-SIDED)



$1 \cdot 10^{10}$ BITS/DISC USER SPACE
45,000 TRACKS/SIDE
128 SECTORS/TRACK
1 PICTORIAL A4 ≈ 32 TRACKS

HIGH RES./WITHOUT COMPR.	2,500 A4's/DISC
HIGH RES./WITH COMPR.	25,000 A4's/DISC
STANDARD RES./WITH COMPR.	50,000 A4's/DISC
ALPHA NUMERICAL	500,000 A4's/DISC

Figure 6. Philips experimental DOR disc.

With the new type of DOR system obviously the above storage figures go up accordingly.

The storage capacity of analog videodisc models are also impressive/ DVA's Model PR-7820 stores almost 30 billion bits of analog information. This allows the storage of approximately 1.2 x 10^8 characters in "TV mode", considering that on one TV screen no more than 1000-2000 characters can be shown because of the relatively low resolution of the screen. If "videotex-like" frames* are shown on videodisc—which in the case of analog storage does not have a particular meaning—this only allows one to compare it with the "videotex" storage capacity of digital videodisc systems in which 1.08 x 10^5 frames can be stored. In freeze-frame mode obviously also 1.08 x 10^5 pictures can be stored (1 picture per track). When "color TV" type motion pictures are stored, a one-hour program can be played on a two sided videodisc record.

Future videodisc records will contain in addition, as pointed out earlier, other types of information; thus on a future analog system 1.5-1.7 GByte of digital information might be stored in a "pseudo" digital fashion and 1.44 x 10^7 characters in teletext type mode. Future digital videodiscs will be able to store digitally up to 50 hours of super-quality audio hifi program.

The vast storage capacity of a single record closes a wide gap in terms of access time between the so-called random secondary storage devices (e.g., disc) and tertiary storage devices (e.g., magnetic tape, mass storage systems) (Figure 7). The new technology in this category offers herewith new categories of applications, previously unknown in in the era of "classical computer technology," such as on-line storage of mass information like encyclopedias, and voice and picture images for storage, retrieval, and processing. In closing this gap (see Figure 7), we also get in hand a technology allowing computer-controlled manipulation of classical TV broadcast-like information. As mentioned earlier, *we will see a convergence of the information and video technologies, to be called "videomatics," similar to the convergence of the information and telecommunications technologies known as "telematics."* In Figure 7, in the range of $10^{-6} \div 10^{-3}$ second access time, another rather broad "gap" can be observed (called "the gap"), which cannot yet be fully covered by operational storage technologies.

4) The *price* of videodisc allows cheap, randomly accessible mass storage of digital information (see Figure 8). A very simple but illustrative way to look at the impact of a technology is through the so-called "wedge" illustration [5]. Its principle is shown in Figure 9.

* "Videotex-like" frames are used throughout this study to define the unit for the maximum of alphanumerical information that could sensibly be put on an ordinary TV screen.

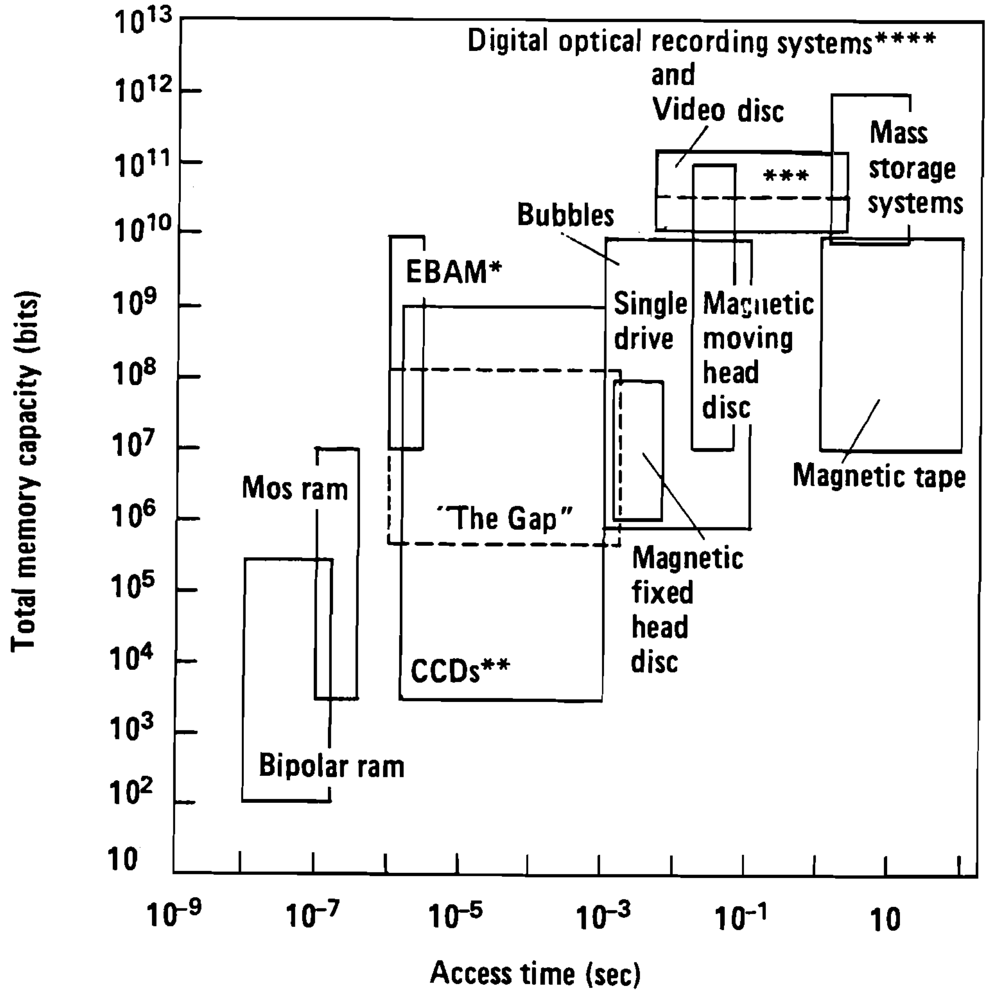
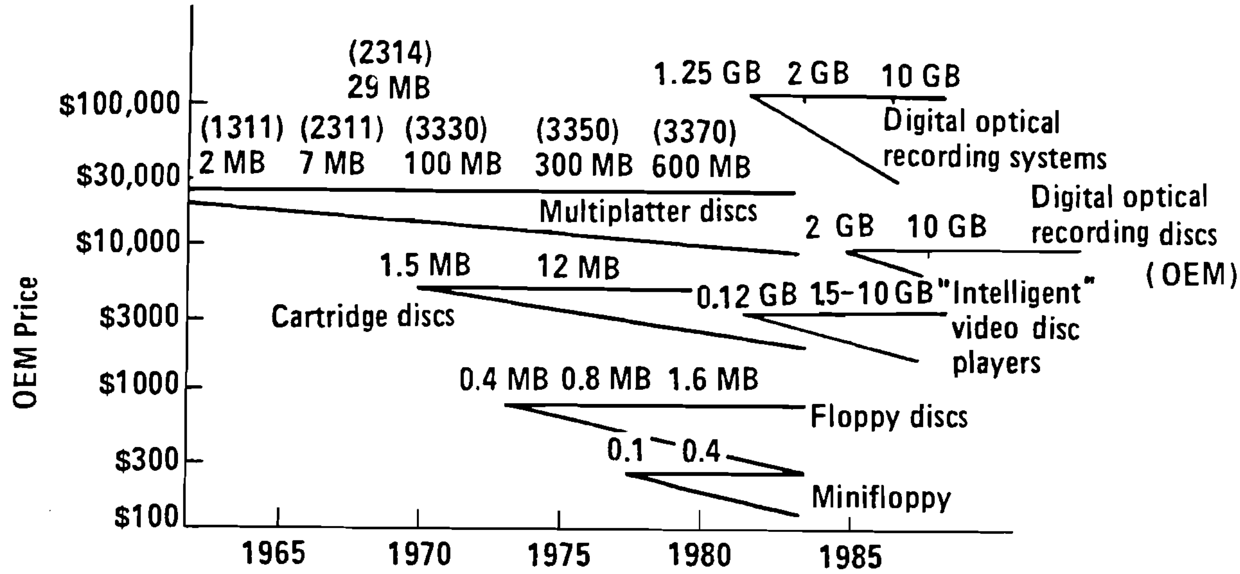


Figure 7. Total memory capacity of storage technologies in terms of access time; (data exclusive of videodiscs were taken from [4]). Remarks: the capacity of the moving disc head represents maximum system capacity and not that of a single drive, which would be around $4.8 \cdot 10^9$ bit. *: EBAM—Electronic beam accessed memories (under development), **: CCDs—charge-coupled devices (new technology), ***:100 G bit videodisc already under development would be available before 1985 [22,28], ****: The Philips juke-box system MEGADOC will be able to store around 128 GBytes of information. Philips is also working on linear selectors with a mass storage capacity of 128 GBytes ($\approx 5.12 \cdot 10^{11}$ bit) and an access time of around 10 seconds.



Figire 8. "Performance" and "learning curves" for families of moving head discs. (Data for magnetic discs are taken from [3].)

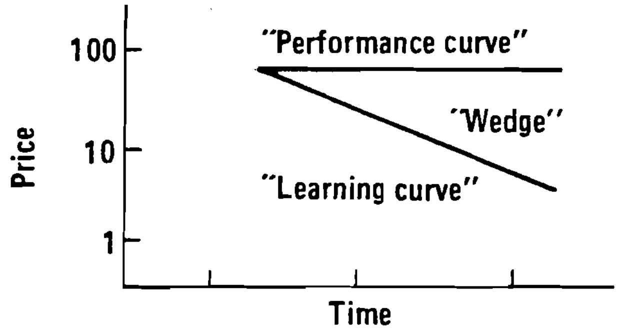


Figure 9. The principle of "performance" and "learning" curves. The "wedge" illustrates the two directions in which a product can evolve: a manufacturer can either keep performance constant and reduce the cost or keep the cost constant and increase performance. [5].

The tip of the wedge represents the introduction of a product. The wedge itself traces the evolution of any one of the product's key features (a disc drive's capacity in megabytes, for example).

The product can evolve in either of two basic directions. As technical advances lower manufacturing costs, the price of the product will follow a downward curve. This path has been labeled the "learning curve" (Figure 9) and is analogous to the term "experience curve" used in the semiconductor industry. The second path involves increasing the functionality of the product while keeping its price constant. In other words, as the manufacturing cost for the product's initial capability decreases, more capability can be added without raising the manufacturing cost and price beyond its original point. This path is the "performance curve" seen in Figure 9. Normally, a product grows into a family of products by following both paths. This concept offers a perspective on all computer hardware development, and provides a convenient way of looking at hardware technology trends.

Figure 8 shows the evolution of disc technology over the last 20 years. The chart shows four wedges—one for multiplatter discs, one for single-platter cartridge discs, and two for flexible discs. A fifth wedge is emerging between the cartridge disc and the floppy disc (i.e., nonremovable Winchester), although it is still too early to plot its path.

The videodisc is represented by a sixth wedge, likewise emerging between the cartridge disc and the floppy disc. We have tried to predict its path (Figure 9). For cheap videodisc players we have taken as a starting point the present analog type of system (such as the one produced by Discovision Associates) and have predicted that cheap digital or analog optical videodisc players will be available in the future at the same price level. The price of a DVA Model PR-7820/3 is about US $2,500, of a universal external interface, US $225, and of an videodisc record, US $5 (without royalty for the program stored). A second category of the new device is represented by the digital optical recording devices, which is also represented separately as an OEM device.

In Figure 10 *storage unit costs* are shown in terms of *access time*. For a videodisc system using mechanical (cheap replicated) videodisc records the average storage cost per information bit is about $0.6 \cdot 10^{-6}$ cents (US). This is not only the cheapest storage presently known on random access devices but also the cheapest storage in the entire field of information technology. In comparing this technology with that of magnetic moving head discs, a single videodisc storage unit is cheaper by a factor of 10^4(!). Such an achievement in cost savings obviously represents a revolutionary breakthrough in the field of random access storage devices. According to [23] it can be expected that a storage price of between 10^{-7} and 10^{-8} cent per bit stored should be achievable by 1985. However, it is also expected that the other storage technologies listed on Figure 10 will undergo similar price improvements and will cost less by a factor of at least 10. A shift in this direction can already be seen in Kenney's comparison Table 5 [24], which is based on more recent data.

For its Digital Optical Recording systems Philips expects that the user will have to pay between US $250 and $300 for a disc record; it is hoped that in the second half of the 1980s this price will fall below $100. The company plans to have a starting price in 1982 of around US $100,000 for the disc drive itself. The price could be half of that in the following year if a sufficient volume is produced and sold. It is expected that in the second half of the decade the DOR disc drives could be sold at an OEM price of around $10,000 per unit.

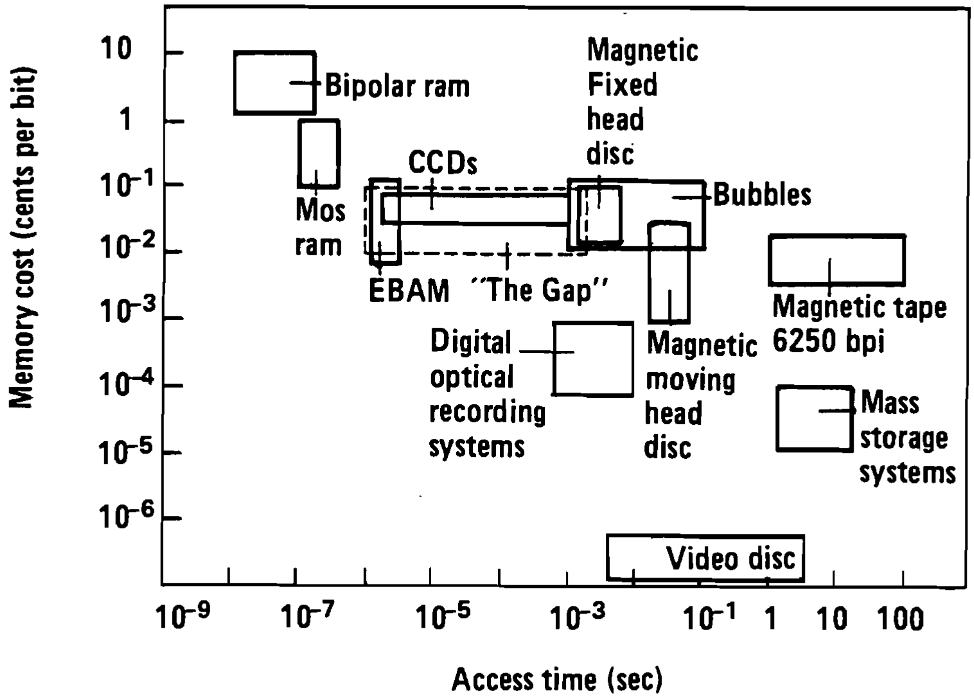


Figure 10. Unit costs versus access time of storage technologies (data exclusive videodisc technology are taken from [4]).

Table 5. Characteristics of mass storage devices taken partly from Kenney [24].

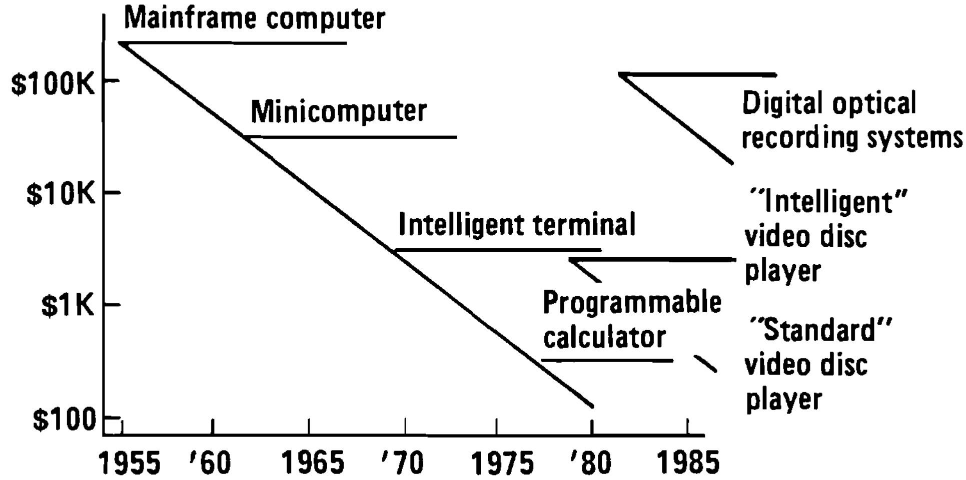
Device	User capacity (Mbytes)	Access time (ms)	Data rate (Mbits/s)	Hardware cost (dollars)	Media cost (dollars)	Media cost/bit (cents)	Archival life (years)
Magnetic disc IBM 3340	70	35	7.0	20,000	2,200 disc pack	$3.1x10^{-5}$	2-3
6250 bits/in tape IBM 3420-8 (2000 byte records)	91	45,000	3.3	28,440	16.50 2,400 ft reel	$1.8x10^{-7}$	1-2
Mass storage system IBM 3850	462,500	16,000	7	2,400,000	188,000 (9,400 cartridges $20 each)	$4x10^{-7}$	1-2
Philips optical disc (DOR-OEM)	2,000	100-500	5-10	10,000	250	5×10^{-6}	>10
Philips MEGADOC juke-box	128,000	3,000	20-50	200,000	16,000 (64 discs at $250 each	1.5×10^{-6}	>10

Thus the projected unit storage price in an Digital Optical Recording system such as that of Philips will be around 10^{-3} cent per bit in 1982 and around 10^{-4} cent per bit in 1985. This is considerably higher than the cost per information unit predicted for stamped (replicated) videodisc record systems. Therefore, in applications such as office automation where digital optical recording systems would be applied, the prices are still attractive, but they cannot be compared with storage unit cost of videodisc systems using "mass produced" videodisc records.

5) *Semiconductor technology:* The orders-of-magnitude advances that were characteristic of semiconductor technology have produced similar startling changes in the price and performance of processors.

Figure 11 illustrates the learning curve for a mainframe computer of 1955 vintage. By the mid-1960s, the emerging minicomputer had achieved the same or better performance at a price nearly ten times lower. By the early 70s an intelligent terminal had reached the same level, but now the price was almost 100 times lower. In 1977 a handheld programmable calculator with a performance equal to that of

Figure 11. Constant performance plotted against mainframe price (Figures except videodisc are taken from [3]).



the 1955 mainframe computer was available at a price almost 1000 times lower than its much larger predecessor.

Standard analog videodisc players, which were first introduced to the consumer electronics market around the end of the seventies, are expected to slide down along the learning curve to about US $400 by 1985. At the same time, more sophisticated intelligent digital videodisc players controlled by advanced microcomputers with capacities of 256-512 KB RAM will be sold as dedicated data bank computers. Such devices, as will be shown later, will be able to perform as third party computers ("data hosts") on interactive videotex systems, thus videodisc development will influence the videotex technology as well.

6) *The "read only" nature of the videodisc:* Videodisc records as we presently know them are non-erasable: the data, once written—or more accurately, burned by a laser beam or stamped by the stampers—cannot be changed. Reading the data with a laser light of

lower intensity does not (and should not) alter the information stored on the record. But videodisc technology is still in its infancy; it is hoped that in the future it can be developed into a form in which the data can be erased and rewritten many times. Intense research in this direction is being undertaken at different research centers around the world: the Japanese firm Matsushita is planning to bring such a system to the market in about two years' time.

In the opinion of the author, the "read only" nature of videodisc is, not hindering factor, since large, low cost random access data archives—even with read-only characteristics—can be utilized in many essential applications. This will be shown in Chapter 5. These applications include their use as backup archive systems in computer centers and as videodisc reference books (encyclopedia) like the Encyclopedia Brittanica or so-called "automated dictionaries" like Webster's New Twentieth Century Dictionary of the English Language. Multilanguage dictionaries are another excellent, long awaited "read only" applications.

The compilation and preparation of information for videodisc application such as these is very difficult, requiring special professional skills and other major resources (labor, investment in equipment, etc.). In other words, this sort of information must be collected and prepared by specialists and could not be done at the cottage industry level. Thus it is most unlikely that there would be the wish to overwrite such valuable information. Moreover copyright seems to be another major issue for this sort of information. Thus it can be expected that a special new branch of industry, "electronic publishing," will emerge.

In using videodisc for archival purposes, the "read only" nature of this medium gives it a major advantage over "erasable" and/or "reusable" media such as magnetic tapes or magnetic discs. Not only can the information not be erased by mistake, but it can not be even altered, if one wishes to do so. Thus the medium can "freeze" information in its current state for documentation purposes. This capability is of utmost importance for certain office automation and archive purposes.

The erasable and reusable nature of other media such as RAM memory or magnetic disc memory makes them most convenient for generating and modifying information, documents, data, etc. For example, this paper was put on to a computer with word processing facilities and could then be conveniently modified. After about five iterations, the author came up with what he felt should be the final version, which could then be published, copyrighted, and thus "frozen." In the past this "freezing" has been done on paper through the printing process; in the future it can be done on videodisc by optical storage as well.

The content of a given videodisc record can be read and modified by appropriate computer hardware, but in digital optical recording rewriting can only be done on a new, empty videodisc record. The old record would serve as an archive of the previous state of the information content.

Many problems still remain in the handling of official, legal types of documents by means of office automation devices. One such problem is how to store signatures so that they can be legally recognized as being original. This might be done through fine laser scanning of original signatures. In the case of the videodisc the large storage needs of this information would not represent a hindering factor. In the future, with more sophisticated pattern recognition methods, the computer could even be used to check the validity of the signature.

A major problem arises, however, if, say, the text of an official one page signed letter is modified by a word processing machine while the original signature is left untouched. If one were to store the modified letter on another videodisc record, readers of it could be easily mislead to believe that it represents the original version. A way has to be found out (and generally accepted) for detecting a given text to a certain signature and vice versa. There must be some method (probably a combined hardware and software process) for detecting changes either in the text or in the signature, indicating that the original assignment between text and signature has been disturbed. Videodisc represents progress along this line since the original version of the document will remain available; the question remains as to which version is the original and which is the modified one. If traditional magnetic or RAM memory are used, this question will not even be raised.

We can summarize by saying that in light of the broad field of applications for videodisc, and taking into account the other aspects mentioned above, such as the preparation of mass information and production of videodisc records, the "read only" nature of the videodisc technology does not seem to be a hindering factor in their applicability; in fact, for archiving purposes, it has advantages.

7) *Data accuracy problems:* Errors due to faults in videodisc production (e.g., in mastering and replication) cause major problems of data accuracy. Failure rates are high. (As mentioned earlier, for videodisc records with TV-like programs failure rates vary between 10 to 90 percent at a Philips factory in the UK.) and are quite unpredictable. Unwanted particles (dust, dirt, etc.) are unavoidable in any system and in videodisc recording a particle just a few microns in diameter can prevent the recording of many signal elements or obscure them after recording. The effects of this type of "dropout" are less significant for television recordings since redundancy in individual frames coupled with the persistence of vision reduces their effects to negligible proportions. Nevertheless, there are serious problems with recording even television-like programs on videodisc records [26]. The situation is even worse if a stream of coded,

compressed text or data is to be recorded, since dropouts can obliterate a whole block of digits and cause significant numbers of errors. Methods for overcoming these problems through protection of the storage media surface and introduction of error control coding are being extensively researched and introduced. Whether or not tis problem is solved will be decisive to the success of this technology.

Data accuracy is not a new problem in information storage and transmission. However, the "read only" or "frozen" nature of videodiscs makes a solution to the problem of data accuracy most difficult. In other storage or transmission technologies, the computer system itself attempts to correct false data by means of parity checks and other error recovery methods; in cases of data transmission errors, where correction is not possible, the system is requested to repeat the transmission. In case of data read from magnetic disc, repetition of data access is usual practice, too. If it turns out that, after a few more trials, a certain disc track cannot be used by the system any more, preallocated "reserve" tracks will be introduced to replace the old track. However, such methods are not possible with replicated videodiscs. With the digital optical recording system it is somewhat easier, since the information can be checked immediately after writing and if the original information cannot be restored by using error control coding methods a new track would immediately be allocated for the same stream of information which now could be repeatedly burned onto the disc. The mass produced (replicated) videodisc records would allow no such possibility; the original information has to be restored—supported by sophisticated error control coding methods by any means—on the basis of what is on the videodisc record.

Nevertheless, videodisc experts are confident that in the long run, this can be done: as J.W. Klimbie [30] from Philips Research Laboratory says, this is already applied, and works satisfactory, in their DOR system where the empty disc is preformatted in a similar manner as their mass-produced video long-play disc and where each DOR sector contains its individual address.

As an example for error recovery, let us consider the Philips DRAW (Direct read after write) [27] method used in the experimental version of the DOR system.

There are 45,000 tracks on each side, every track containing 128 sectors of 1,900 bits. Each sector has a unique address and 1,024 bits of protected use data, followed by a secondary error-checking code. The error correction bits are split up into 22 so-called code words of 16 characters of 4 bits, which are interleaved throughout the sector. If later, when the information is read, error bursts are distributed over many code words. It is claimed that a primary and backup error-encoding system corrects the error rate to less than 10^{-10}.

The primary encoder and interleaver introduce structured redundancy to enable detection and correction of all errors except very long bursts. The backup error-correction system monitors the playback quality during recording. Any discrepancy between the incoming data and the recovered playback signal that approaches the correcting power limit of the code causes the system to rewrite the entire sector in the next block. This burst-trapping method virtually eliminates zero uncorrected errors, even in the presence of large defects. When no errors (or correctable errors) are detected, an ACCEPT code is written. The design provides for subsequent indirect addressing by leaving in the sector a gap that may later be recorded with a posting sync sequence and also with the post (or indirect address).

The error-detection correction system [23] transfers input data from a source to a double, one-sector buffer (Figure 12).

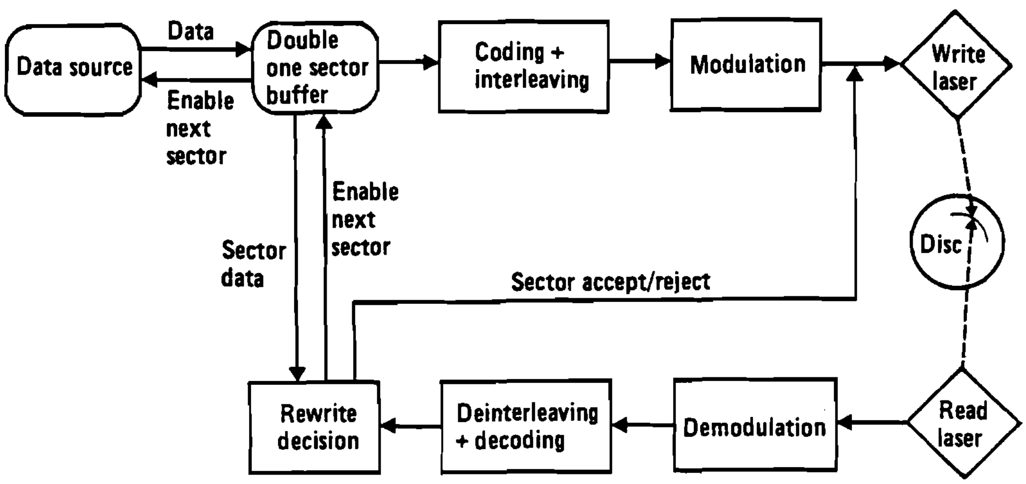


Figure 12. Error detection/correction system

The first sector is coded, interleaved, modulated, and then used to drive the recording laser. Modulation matches the data spectrum to the spectral requirements of the record/read process. As writing is recorded on the disc, it is read—through the same objective—to check the accuracy of the recording. Should the sector recording exceed (or, equal) the error-correcting capability of the system, a secondary error-checking REJECT code is written, and the "enable-next-sector" signal is inhibited. In this way "bad" sectors are rewritten. Errors may occur only through disc degradation or improper reading.

If, however, the sector recording satisfies the error-correcting capability of the system, as determined from the playback signal, the secondary error-checking ACCEPT code is written. The "enable-next-sector" signal is then given, and the data source is advanced.

There are other ways of detecting and correcting errors, of course, without direct playback and secondary error checking, but they would require a more robust coding-interleaving scheme that would be less efficient and would decrease the usable disc capacity. It is this technique which has to be applied for reading "mass produced" (pressed) videodisc records.

The complexity of the data accuracy problem in this technology will cause many headaches in the years to come. First the problem has to be solved satisfactorily, and this applies also to mass produced (pressed) digital videodisc records; then it has to be standardized in order to assure that the technology will achieve full market penetration. If too sophisticated hardware or software methods have to be applied, to the mass-production of digital videodisc records and their playback this might have a negative effect on the very favorable cost level of this storage technology. But answer to this question can only be expected in the coming years.

3.3 The "Dualistic Nature" of Videodisc

As we have seen, videodisc has a "Janus-faced dualistic" nature. On the one hand, it fulfills technically all the requirements for a consumer electronics product: it can play back prerecorded video information, it can present slow or fast motion, it has two channel stereo sound, and it can perform several other consumer electronics functions. One can argue about whether or not it satisfies these needs as efficiently and cheaply as standard videotape devices, but this is not the point. The basic issue is that in addition to these functions, videodisc can perform a number of qualitatively new functions. The other side of the "Janus face," which looks in direction of information technology, sees a "gap-filling" technology in the field of fast random mass storage devices, with the added advantage of extremely low costs. In particular, the technological revolution of the videodisc, backed by optical storage and microcomputer technology, provides a new basis for the storage and manipulation of large quantities of textual, audio, and visual information. The videodisc drive's ability to perform the above-mentioned consumer electronics functions represents only a small fraction of the capabilities for its built-in microcomputer. A new horizon of videodisc applications is described at length in Chapter 5.

4. OPERATIONAL FUNCTIONS OF VIDEODISC PLAYERS

4.1 "Classical" Functions

As mentioned earlier, the typical videodisc player presently available on the market can randomly access over 54,000 videodisc tracks per disc side. The most classical function of this type of videodisc player is motion playback of video image frames.

Clearly, the present format of a videodisc image frame follows the standard TV-video and audio format. Hence for the USA, according to NTSC standards, 525 lines (about 150,000 picture elements, but not bits) must be produced at a speed of 30 frames per second. In Europe, this must be done in accordance with PAL, SECAM, or other TV techniques: 25 frames per second, each frame having 625 lines (210,000 picture elements per frame). Since in principle the access to videodisc frames is random, the microcomputer-based videodisc controller executes an internal program for generating sequential frame access, moving step by step from the first frame near the center of the disc to the last one at the outside. A possible flow of control is shown in Figure 13.

The flow chart in Figure 13 also includes other classical functions of the videodisc controller, such as slow motion, fast motion, freeze-frame, and reverse motion.

The most important videodisc functions (both classical ones and those related to information technology) are compiled in Table 6, which describes the major operational features of a videodisc controller.

4.2 The Information Technology-Related Functions of Videodiscs

Before discussing the information technology-related functions of videodisc, we should again summarize the existing new technologies that form the basis for them.

a) Ultra high density storage of any kind of analog or digital information.

b) Fast random access to addressable units (frames) of information by means of a highly focused laser beam;

c) Application of microcomputers to control the functions of the videodisc handling program, which adds greatly enhanced local intelligence to the system.

d) A broad variety of possible hardware interfaces to other types of applications, techniques, and services, such as TV, hi-fi, personal computer, remote and local host computer, telecommunication and computer networks, videotex systems, and combinations thereof.

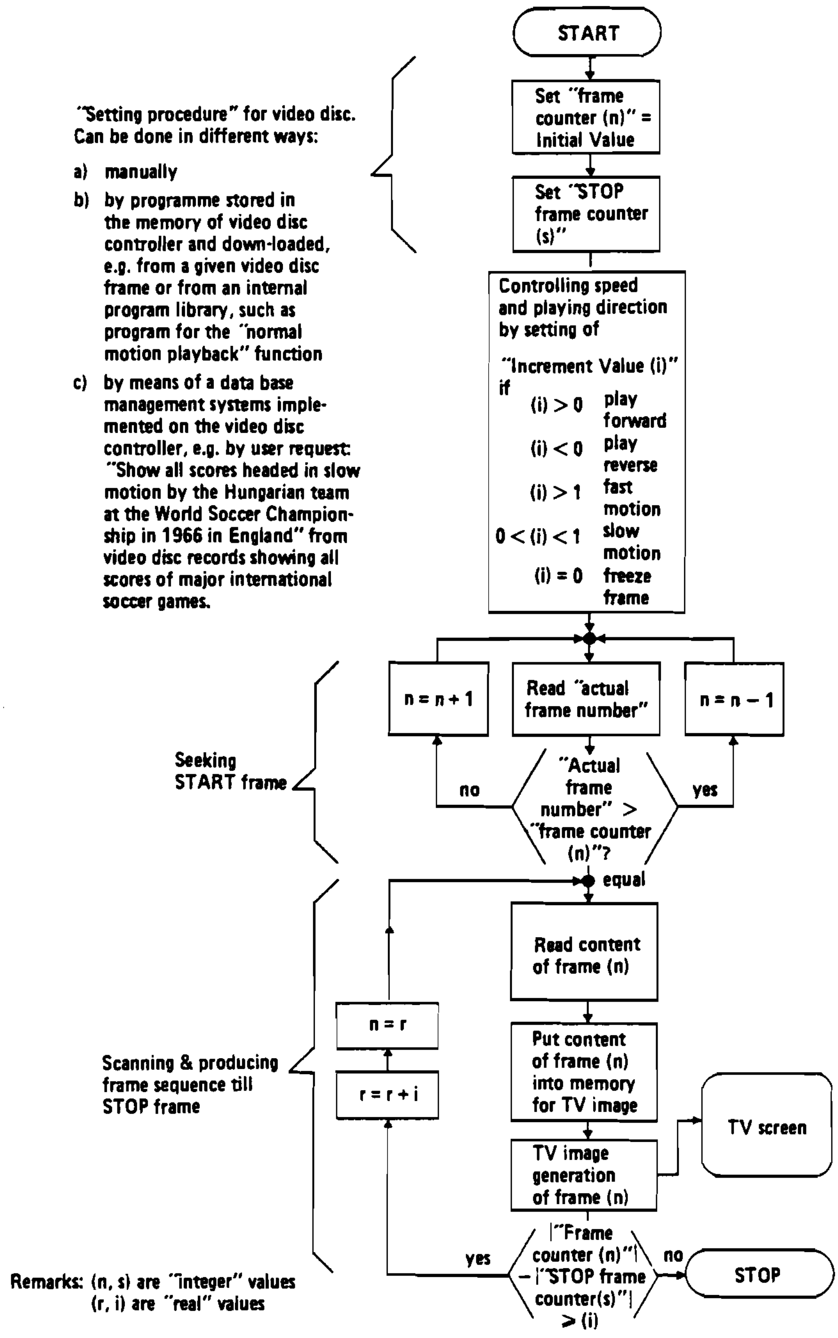


Figure 13. A simplified flow chart of the "videodisc frame display" controlling program

Table 5. Operational features of a videodisc controller

	Operational features	Initial frame $[f_i]$	Stop frame $[f_s]$	Frame counter increment $[i]$	Frame counter decrement $[i]$	Access to frame with time delay	Function
1.	Normal video play forward	$f_i < f_s$	$f_i < f_s$	one by one	-	-	Read content of track and display on TV screen
2.	Video play forward, fast motion	$f_i < f_s$	$f_i < f_s$	more than one	-	-	Read content of track and display on TV screen
3.	Video play forward, slow motion	$f_i < f_s$	$f_i < f_s$	one by one	-	yes	Read content of track and display on TS screen
4.	Normal video play backwards	$f_i > f_s$	$f_i > f_s$	-	one by one	-	Read content of track and display on TV screen
5.	Video play reverse, fast motion	$f_i > f_s$	$f_i > f_s$	-	more than one	-	Read content of track and display on TV screen
6.	Video play reverse, slow motion	$f_i > f_s$	$f_i > f_s$	-	one by one	yes	Read content of track and display on TV screen
7.	Freese frame	$f_i = f_s$	$f_i = f_s$	none	none	-	Read content of track and display on TV screen
8.	Frame by frame, forward	$f_i < f_s$	$f_i < f_s$	one by one	-	yes (manually)	Read content of track and display on TV screen

Note: f_B = first frame of the videodisc
f_E = last frame of the videodisc
where $f_B \leq f_i \leq f_E$ and $f_B \leq f_s \leq f_E$

	Operational features	Initial frame [f_i]	Stop frame [f_s]	Frame counter increment [i]	Frame counter decrement [i]	Access to frame with time delay	Function
9.	Frame by frame, reverse	$f_i > f_s$	$f_i > f_s$	-	one by one	yes (manually)	Read content of track and display on TV screen
10.	Individual frame access	$f_i \neq f_s$	$f_i \neq f_s$	one by one	-	-	Search for individual frame
11.	Frame number display	-	-	-	-	-	Displays frame number
12.	Selectable audio	-	-	-	-	-	Two channels of high fidelity audio can be stored in addition to videoframes, enabling either streophonic sound, dual language, or question-answer format
13.	Programming	-	-	-	-	-	In the model "PR-7820," 1024 bytes of non-volatil memory programmed either mannually (combination of previous instructions) or automaticaly by pre-programmed videodiscs

The information technology-related functions provided by an "ideal" videodisc controller can be divided into two major categories:

- fast random access and control functions of preferably digitalized mass information; and
- data output channel functions.

It has to be mentioned that such an "ideal" videodisc system is not on the market yet, but present trends show that this will be the very likely way.

4.2.1. *Fast Random- Access Control of Digitalized Mass Information*

As mentioned earlier, all information on the tracks of the videodisc device can be addressed separately. If coded textual information is stored, an additional subdivision of the entities of information might be carried out by defining a number of information blocks and recording each on a separate information track as done by Philips in their DOR. The random access process on videodisc is very similar to the well-known random access method on moving head magnetic discs. The mode of access control can be one of the following:

- by direct manual ("physical") addressing by the operator of the videodisc
- by indirect addressing by the operator through an appropriate videodisc data base management program stored by the videodisc controller
- by downloading an access-control program from predefined tracks of the videodisc into the videodisc controller
- by downloading an access control program from external data sources (e.g., interactive videotex channels) through hardware interfaces.

a) *Manual direct access:* An operator knowing the physical address of the required frame initiates access to the videodisc by typing in on operator panel/keyboard all the information necessary for access. He may access individual frames, which might be information frames or videodisc control programs to be downloaded, or he may initiate the output of frame sequences to be played back, etc.

b) *Indirect addressing through a videodisc data base management program:* The user of the videodisc player may interact with the system through an internal database management system tailored to the functions of the videodisc controller and drive. Such a system could be used to retrieve information recorded on videodisc records from a databank, such as an encyclopedia. The language used would, in a simplified fashion, be similar to the database languages now used in computer information retrieval systems.

c) *Downloading of access control program from videodisc:* Each frame of the videodisc can contain a different type of information. It can contain output data (textual, video, audio), or data required for specific videodisc control functions, such as index information (thesaurus) for the videodisc database management program or executable programs for the videodisc controller itself. These would be fed into the core memory of the controller for immediate execution.

d) *Downloading of access control program from external data sources:* This category is identical in nature to the category mentioned in paragraph c. The only difference is that the access-control program is fed into the videodisc controller from outside data sources through an external interface. In this fashion access control information may come from local or remote external computers or from videotex and other computer network nodes, etc.

The modes of access listed above are summarized in Figure 14. It should be noted that the access control functions can be linked in many ways, making the access system extremely flexible. For example by direct manual access, an access program can be downloaded to perform a complicated chain of access functions to other videodisc frames.

4.2.2 Data- Output Channels and Their Functions

Any of the following types of data can be stored on videodisc:

a) frames with video information
b) frames with audio information (sound)
c) coded textual information (e.g., videotex frames)
d) coded data information for data processing programs
e) data processing source and object code (excluding the videodisc control program codes mentioned in the previous chapter).

Since all information is stored in the same physical (preferably digital) form, a separate identifier must be placed at the beginning of each videodisc frame stating the type of information it contains.

The output channels for information can also differ; their selection depends mainly on the type of information to be channeled from the videodisc and on the category of application.

The data-output channels for videodisc are the following:

a) channel to an attached television set for displaying video frames
b) channel to a hi-fi amplifier for reproduction of audio information
c) channel to a textual data (e.g., videotex) decoder for decoding stored textual (videotex-like) frame information
d) channel to an external interface for local (e.g., printer, local computer) and remote (e.g., to the videotex network, remote terminals) connections for transmission of coded textual information, data for computer programs, and computer program source and object codes.

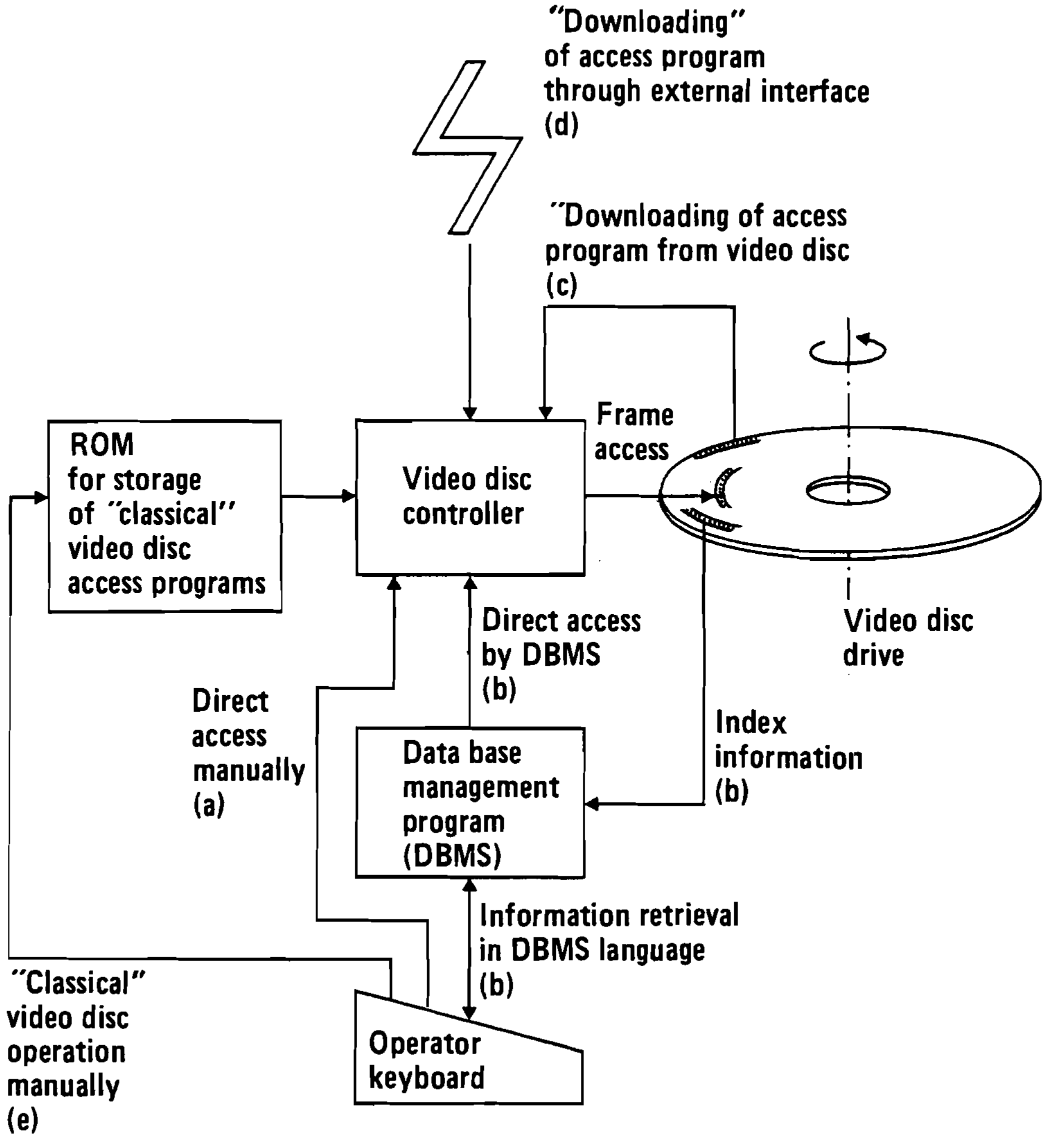


Figure 14. Access-control paths for videodisc drives: (e) represents the "classical" videodisc player functions, such as "play forward," as discussed in Chapter 4.1.

e) channel to the built-in core memory of the videodisc player (e.g., information of a videodisc record thesaurus) for internal usage.

These data-output channels are summarized in Figure 15.

5. VIDEODISC APPLICATIONS

In this chapter an attempt is made to describe some possible videodisc applications as they are presently seen. It should be pointed out that the list is by no means complete. It is difficult at present to predict all of the suitable types of videodisc usage, just as it would have been hardly possible in Gutenberg's time some five hundred years ago to classify all of the applications for printed information.

The major classes of videodisc application are:

- Videodisc as an entertainment medium (5.1)
- Videodisc as an information and reference medium (5.2)
- Videodisc as a tool for education (5.3)
- Videodisc for mass storage and for data and program archives (5.4)
- Videodisc in office automation and document filing (5.5).

5.1 Videodisc as an Entertainment Medium

5.1.1 The "Classical" Type of Entertainment

The primary purpose for developing videodiscs was to create a machine for reproducing motion pictures, on the analogy: "videodisc should be in the video field what the well-known gramophone is in the audio field." From the industry's point of view, these disc techniques have a great advantage over the taperecording technologies (both video and audio) in that the copyright law cannot be got round. Videodisc and gramophone are "read only" devices: a reproduction of the stored program onto other records can only be carried out through a complicated manufacturing process. Thus those interested in protecting copyrights hope that a wide distribution of videodisc players will promote the sale of stored video programs, such as films, in a fully controlled way.

At present, however, videodiscs have certain disadvantages in comparison with videotapes, which may hinder the acceptance of the videodisc technology by the public, should it be used solely for entertainment purposes.

First of all there are technical problems. Because videodisc technology is still in its early infancy, there are still technical difficulties due to the limited lifetime of the disc's read laser head (about 1000 hours), which, moreover, can presently be produced only at relatively high costs. Also, the microscopically sized pits, which are the actual carriers of digital information, place fearsome demands on the servo system, which must keep the laser beam in focus and in alignment with spiral turns, despite inevitable eccentricity and warpage of the disc [1]. As Barry Fox

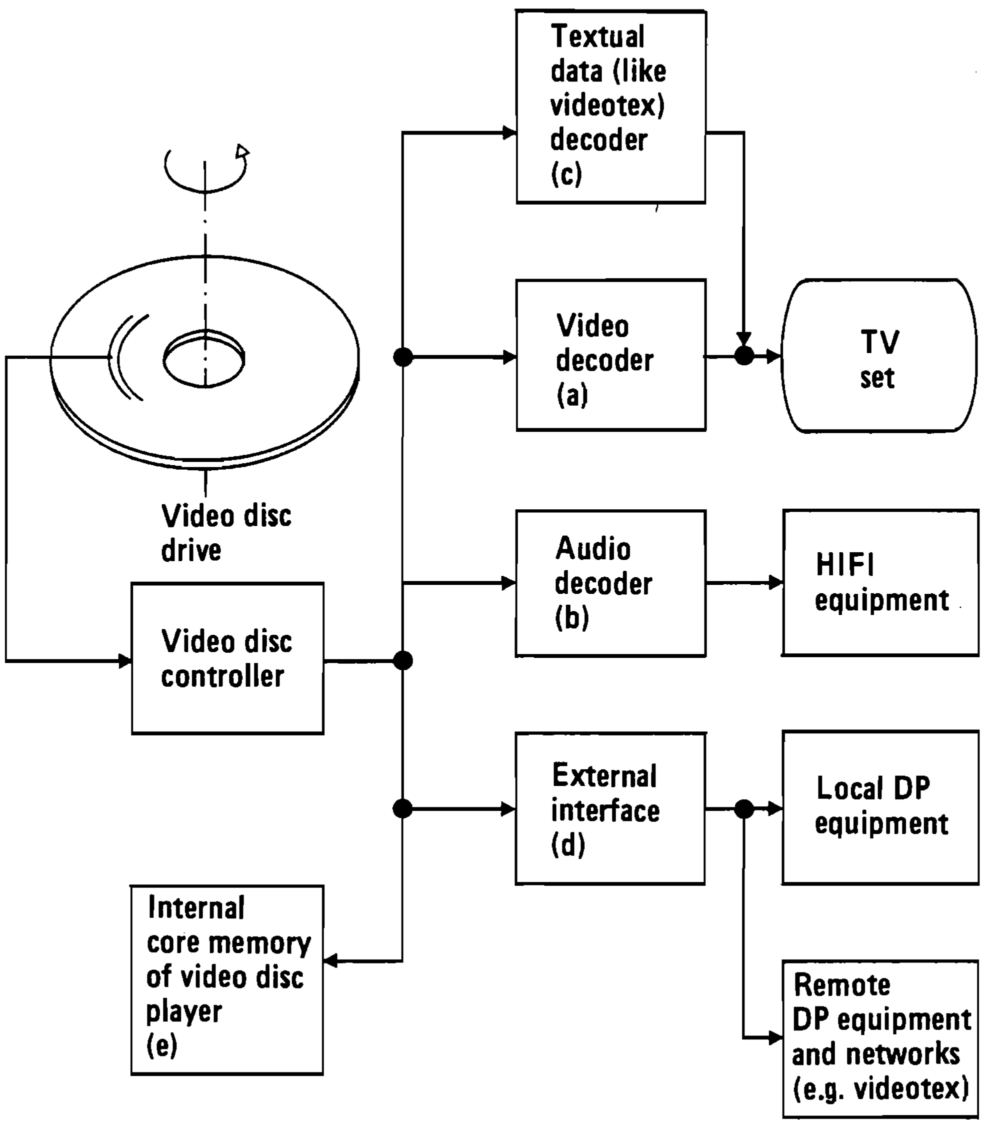


Figure 15. Data-output channel options of videodisc devices

[8] points out, with so little margin for error, making the discs becomes a nightmare. In one system now on the market the laser beam must accurately follow a spiral of pits 1/30th the width of a human hair apart that are traveling at over 60 kilometers an hour!

The next hindering factor is cost. Video tape recorders cost less than £400 (US $750) and four hours of continuous program can be taped on a single casette at or for less than £3 (US $5.7) per hour. In the entertainment category, videodisc recorders now cost about £500 (US $800-900) and the discs cost around £15 (US $25-30) for a full length film. Thus, at present, the videotape technology seems not only to be technically more advanced than videodisc, but it is also cheaper.

The next problem is the availability of programs. For this purpose new recording lines would have to be installed at high costs, whereas recording of videotapes, be it over TV or through a separate camera, is flexible, cheap, and simple. In addition, centralized production of videotape programs has already been developed.

Thus this classical application for the videodisc technology does not seem to justify its viability.

5.1.2 New Types of Entertainment

The variety of new types of videodisc entertainment is endless. Videogames stored on videodisc frames will add new flavor to the current "videogame bonanza." For example, a programmed labyrinth game stored on videodisc record frames may become a competitor to the labyrinth game installed on interactive videotex services [14]. In this game each displayed picture frame could offer alternative paths leading to other tracks which would be selected manually by the player. On some of the tracks a short frame-access program might be stored. Upon selection of such frame, a program would be downloaded into the videodisc controller and a movie scene would be suddenly triggered off (e.g., the "Wumpus" or a monster who "lives" in the labyrinth would appear to frighten the player and the game would be lost).

Another kind of videodisc entertainment might utilize the programming capability of the videodisc controller. For example, specially prepared videodisc frames might be programmed to combine a given color, graphics, and one of the constant tones of the musical scale to produce appealing melodies.

A similar application in the field of music would be the establishment of a database on videodisc containing musical notations of music written by famous composers. The Common Musical Notation (CMN), or staff notation, as it is also called, is one of the few graphical notations that is truly accepted internationally. It is well-known that in recent years, the cost of printing music has risen dramatically; one is now likely to pay well over $1 per sheet for printed sheet music. According to Cheek and Simpson [15], the storage of music on interactive videotex systems and its display on home TV screens might become an interesting application in the near future.

The storage of music notation on videodiscs—in its more advanced applications it might be accompanied by a sound recording of the music on hi-fi channels—might itself become an exciting entertainment and educational application.

In its simplest form, individual music notation frames would be organized by a music notation data bank and stored on separate videodisc tracks. Using the retrieval program of the videodisc controller, compositions may then be retrieved and displayed on the screen, or hard copies may be taken, if an appropriate interface and output device is connected to the videodisc player through its external interface. Another form of musical notation application would be to play the music stored on hi-fi equipment while showing the corresponding musical notation frames simultaneously on the screen. In this fashion, up to one hour of music and notation can be stored on each record. An excellent educational tool and means of performing home exercises would be to store the recorded music on the two separate audio channels (which as we know, is indeed possible) and to have the user switch off that channel playing the music from the instrument he wants to play himself. In this case, the other audio channel would accompany the player while the corresponding frames with the musical notation would be displayed on his home TV. By recording his own "performance" with a tape recorder, the player could directly compare his "playing art" with of the style of the artist whose performance is stored on the first sound channel. A similar application might be particularly useful for singers.

Interesting opportunities are offered for analog videodisc with "color TV-like" short motion picture programs and "hidden" alphanumerical lines in teletext mode. In such manner, for example, "quiz" programs can be stored on the videodisc and the solution to the questions would be given on the appropriate teletext lines belonging to the motion picture session containing the given question. In such a way, an analog videodisc equipped with standard teletext decoder would be able to show the replay on the TV screen on pressing the teletext button on the remote controller keypad. This type of application could also be most interesting in educational applications.

The potential for gaming with videodisc is endless; if the reader regards the above forms of entertainment as rather boring and simple minded, he should accept the author's apologies, but the aim of this passage is simply to point out the vast gaming potential of this rather universal machine.

5.2 Videodisc Applications in the Field of Information Storage and Retrieval

5.2.1 Videodisc as an Information Medium

The use of videodisc for information storage is probably the most important type of application in view of the impressively large amounts of information that can be stored and randomly accessed, and this at extremely low cost.

The total storage capacity of videodisc records varies considerably: As referred to in the previous chapter, on one Discovision videodisc record nearly 30 billion, on a Philips DOR disc, 10 billion, bits of information are stored. According to Predicast Inc. [28], a high-density/laser-encoded disc storage system patented by RCA stores 100 billion bits of information on a 12 inch (30 cm) disc.

Before going into details special attention should be given here again to Table 4, where the storage capacities of different types of present and future videodisc systems are listed according to different "media" categories such as audio, video, freeze-frame, coded alphanumerical, "atomic" information unit, etc. The information for most of the applications that will follow could be put on different types of videodiscs—first of all, in the form of different types of "media." This is primarily up to the author and the electronic publisher. For example, in the design of a videodisc encyclopedia one can go several ways. One alternative is to follow the pattern of the classical printed encyclopedia. In this case mainly alphanumerical and standing picture types of information should be stored—hence a digital videodisc seems to be optimal. The second alternative could be to provide as many motion picture scenes complemented by audio information as possible; in this case, an analog videodisc such as of Discovision Association should be applied. A third way might be the so-called "talking" encyclopedia as suggested by Barrett [23]; in this case, the majority of the information should be audio, complemented by freeze-frame and motion pictures. Here the "future analog or digital videodisc system" should be used.

The exact videodisc storage needs and technical requirements thus very much depend on the outlay of the encyclopedia and will be determined when the detailed design of such system is performed. Therefore, in what follows all the figures given in this paper with regard to applications should be looked at from that angle. In actual design, figures can differ considerably; here, with a few examples, only some rough major characteristics should be outlined to provide the right feeling to the readers about the orders of magnitudes involved in different applications.

In our first example we have taken some typical figures for different types of storage "media" which can be stored on one of the present or future videodisc players. Since the types of stored information can be mixed on any videodisc record, the total amount of actual information varies according to the type and amount of stored information entities. Examples of storage capacities for typical—not mixed—applications are shown in Table 7.

Looking at Table 7, we find that an enormous amount of information can be stored on a single videodisc record. If the capacity to store a 60-minute movie (first entry) does not seem particularly outstanding, one should imagine that all of the major paintings of the world, the contents of a large personal library, or all of the references in one of the biggest bibliographical databases such as NTIS, INSPEC, or PREDICAST can easily be stored on a single videodisc record.

Table 7. Examples of data stored on videodisc records

Type of information storage	Examples for total amount of information entities	Example
Moving picture program (video and audio storage)	Scenes in total of a 60-minute program at normal speed	Disc containing all scores of the national football championship of last year
Standing pictures -TV quality	108,000 picture	All pages of a larger encyclopedia of twenty odd volumes on two records
-Facsimile III quality	25,000 pictures	All famous etchings of the world
Coded information on videotex-type frames (960 characters per frame using the CCITT/ISO standard 7-bit code)	Over 3 million frames information	300,000 encyclopedia pages of information (The Encyclopedia Brittanica has "only" about 24,000)
		15 bilingual dictionaries with each approximately 270,000 entries (words, expressions)
		Over 3 million references inclusive abstracts of database information (the largest database "Chemical Abstracts" has over 4 million references)
Coded data (detailed discussion in 5.4)	Over 3 billion bytes	E.g., over 750 million figures (Fortran Real 4 bytes) for archive of statistical data
Computer programs –source code –object code (detailed discussion in 5.4)	Over 3 billion bytes	E.g., 100 million lines of source code (a larger program system has 10,000 lines of source program)
		E.g., storage of 100,000 object program of 30 Kbyte size

The high storage density is also amazing, not only in comparison with other disc storage technologies but also in comparison with the traditional printing technology: the 300,000 "encyclopedia-pages" contained on a videodisc record would occupy a library shelf 18m long. The amount of physical storage needed for a video disc record is about 4,000(!) times less than the amount needed for an equivalent amount printed matters. If all of the material in the IIASA Library—an average research institute library—could be put on videodisc records, the resulting discs would easily fit into a small cabinet with a few drawers.

The number of computer programs that could be stored on a single videodisc record is also immense. Assuming that an average programmer writes between 3 and 25 fully-tested source statements per day (average about 14 statements/day or 3,500 statements/year), then the 100 million lines or source code that could be stored on a single videodisc record would be equal to the work of about 28,500 programmer man-years; this amount of development work would take some 2,600 full-time programmers in Hungary more than 10 years to code!

The following chapter gives a short overview of types of information applications for videodisc technology.

5.2.2 Use of Videodisc for Old and New Types of "Reference Books"

As already pointed out in previous chapters, the use of videodisc as "reference books" is one of the optimal types of usage for this medium. Similar to the extremely numerous categories of possible classical reference books, their "videodisc equivalents" represent a large family as well. No attempt can be made in this paper to map out all the possible reference types for which videodisc would be ideal; only a few are mentioned and discussed here.

5.2.2.1 Videodisc as "encyclopedia"

The Encyclopedia Brittanica has 23 volumes (approximately 1,000 pages each) of text containing approximately 20,000 figures and a separate volume containing indexes and a geographical atlas. A single page of full text might contain a maximum of 9,600 text characters.

If we use a digital videodisc with storage characteristics according to the new DOR disc (2 GBytes/disc), assuming that there are 23 volumes of full text and 20,000 black and white pictures of standard resolution, with data compression a videodisc capacity of 7.2×10^8 Bytes would be needed, which represents approximately 36% of a single DOR capacity. If an analog videodisc such as DVA's 7820 model 3 was used, the 23 volumes of full text in TV mode and the 20,000 pictures of color TV quality (according 1 track per picture) could be put on 2-3 videodisc records.

Greenagel [25] describes the first trial along this line, a Channel 2000 videotex experiment currently taking place in Columbus, Ohio in the USA, in which a new general encyclopedia for secondary school and university students, the "Academic American Encyclopedia," is being recorded on videodisc records. Just the text of the encyclopedia would fit on two sides of a videodisc, but it will occupy three or four discs because of the sound and motion sequences illustrating the material.

> With such a videodisc (the DVA 7820 model 3—N.B., an analog videodisc model—was used because of the more sophisticated programming facilities) one is able to call up the article on "hydrofoil," read the text, see a full-color cut-away illustration, switch to a 29-second film clip of the hydrofoil rising up and skimming across the water, check the bibliography for further references and finally, cut quickly to the article on "air conditioned vehicles" to compare the advantages and physics of these two new water-crossing technologies.

It is planned to make the entire encyclopedia available via two-way interactive cable TV in six American cities. It is estimated that the cost of this videodisc encyclopedia to the customers would be less than half of the cost of the printed version.

Barrett's "talking Encyclopedia Brittanica" [23] is estimated to have a volume of 10 videodiscs which would additionally have a capacity of 270,000 color television frames and it would take 750 hours to listen.

As explained previously, there are two "extreme directions" in which a product can evolve: either its cost will be reduced while performance is kept constant, or the cost kept constant at increased performance (see Figure 9). Of course, a mixed strategy between the two extremes is also possible. Falling prices for the same performance would mean that the present price of the Encyclopedia Brittanica could drop by a factor of around 50-100, provided that the drop in price would result in the mass purchase of encyclopedias, which would allow coverage of the extremely high intellectual costs of collecting and updating its contents.

The other "extreme direction" would be to keep the cost the same (e.g., AS 25,000 in Austria for a complete encyclopedia) and increase its performance. As suggested earlier, this could be done by including "motion picture" encyclopedia entries whenever the information to be provided to the user is less of a descriptive and more of a visual or audio nature. If this new type of encyclopedia were made up of about twenty records—similar to the number of volumes in printed encyclopedias—it might contain about 2500 half-minute or one-minute moving picture or audio screens. Such a "mixed media" encyclopedia could still be sold at about half the price of the present printed version. An encyclopedia with voice and motion in addition to text would be a qualitatively improved new medium, in the author's view.

To keep the price level constant, especially during the introductory period, it can be expected that dedicated videodisc players will be offered with the records. Later, however, when the videodisc technology (hardware, software, stored data) is standardized, the encyclopedia records could be played on any videodisc player. The first videodisc based encyclopedias will appear in libraries and on computer networks—this includes videotex networks as third party data centers—but eventually they will find their ways into most households.

5.2.2.2 Videodisc as an "automated dictionary"

An automated dictionary is a computer based device—in our case realized on a videodisc record player—that holds all the information of a dictionary and allows dictionary entries to be accessed and displayed. The dictionary might contain entries of a single language, such as a standard dictionary in English, German, or Hungarian, or it could be bilingual (e.g., English-German, German-English). In special cases, for example for a "dictionary of computer techniques," it might be multi-lingual. There are many advantages to the use of an automated dictionary instead of a dictionary in book form:

- the user-interface will provide a simpler means of accessing dictionary entries;
- the device will provide a set of search capabilities enhancing the usability of the dictionary;
- it will allow sophisticated new applications, such as spelling correction, synonym and antonym search, voiced word pronunciation, games such as picture naming, and in more advanced systems perhaps grammar correction and sentence building capabilities.

A detailed description of a similar system is provided by Fox, Bebel and Parker [8]. While one can fully agree with their definition of the functions of the automated directory, their assessments concerning physical realization of such systems do not take into account the potential storage and retrieval capacities offered by videodisc technology, which is perhaps the only cheap mass storage technology presently known that could provide a sound basis for this type of application. The limit of the system they describe would be around 30,000 entries stored on approximately 120,000 frames. However, using videodisc storage technology, up to a few million frames can be stored per videodisc record: enough space for the largest of the presently known printed dictionaries. So even the complete Oxford English Dictionary, with its 12 volumes and three supplement any volumes (price approximately £300 ≈ US $570) and approximately 300 million characters, would fit easily onto a single videodisc record. A typical dictionary entry is shown in Table 8; a list of the most important automated dictionary functions are presented in Table 9. Figure 16 shows the same dictionary entry given in Table 8 implemented on the experimental—not based on videodisc—Zog System of the Carnegie-Mellon University team [8].

Figure 9 shows the two "extreme directions" in which the automated dictionary can evolve. Following a "learning curve," the simplest versions of automatic directories stored on videodisc records will become cheaper and cheaper; it can be expected that they will be sold at average videodisc record prices of approximately US $25-50 per record, which is considerably cheaper than an equivalent printed version (for example, by a factor between 10 and 25 in case of the full Oxford English Dictionary). If one follows the "performance curve" however, more sophisticated automated dictionaries will be available offering in addition to the

Table 8. A classical language dictionary entry and how it is used in an automated dictionary entry according to [8]

The dictionary entry. The primary purpose of the automated dictionary is to store and allow access to a dictionary data base. Consider the definition of the word "flag" taken from *Webster's New Twentieth Century Dictionary of the English Language:*

> **flag**[1]:(flag) n. [LME. ***flagge***<?Flag[4], in Obs. sense "to flutter"] 1. A piece of cloth or bunting, often attached to a staff, with distinctive colors, patterns, or symbolic devices, used as a national or state symbol, to signal, etc.; standard; ensign. 2. [pl.] [Now Rare] Long feathers or quills as on a hawk. 3. The tail of a deer. 4. The bushy tail of certain dogs, as setters and some hounds. 5. ***Music*** any of the lines extending from a stem, indicating whether the note is an eighth, sixteenth, etc. ***–vt.*** **flagged, flag'ging** 1. to decorate or mark with flags. 2. to signal with or as with a flag; esp. to signal to stop (often with ***down***). 3. to send (a message) by signaling **–dip the flag** to salute by lowering a flag briefly **–strike the** (or one's) **flag** 1. to lower the flag. 2. to give up; surrender
>
> 3flag[2]: (flag) n. [ME. ***flagge***< ON. ***flaga***, slab of stone<IE. base ***plak-*** , to spread out, flat, whence L. ***plasidus***, flat] ***same as*** FLAGSTONE ***–vt.*** **flagged, flag'ging** to pave with flagstones

We list two separate entries for the word "flag," although the dictionary actually contains four separate entries. The rationale for separate entries is that each entry represents a conceptually ***different*** definition of the word. Notice that each entry contains multiple definitions which are not necessarily related.

Each definition also contains a variety of information, including correct spelling, syntactic category, pronunciation (written), etymology, synonyms, and syntactic variations. Information such as antonyms, examples of usage, hyponyms, and pictures can also be found.

---

standard dictionary functions, "value added applications," such as voiced word pronunciation (another revolutionary step forward!), spelling corrections, games, etc.

It is expected that automated dictionaries will be offered on the market relatively soon. The first version will probably be accompanied by dedicated videodisc record player devices. The first devices will be placed either in libraries and educational institutions and on computer networks including videotex networks. Thus, in the first phase, the principle of resource sharing would apply. Later, when videodisc prices have come down, the standardization problem has been settled, and videodiscs have found their ways into homes, videodisc records containing automated dictionaries will be found in the storage cabinet of every videodisc device owner.

Table 9. The most important functions of automated dictionaries (Source: Fox et al. [8])

Word retrieval:	The user types in a word, and the corresponding dictionary information is displayed.
Spelling test:	The model presents to the user, by voice output, a word at a level of difficulty chosen by the user. The word is then typed in by the user. If spelled correctly, a positive response is given to the user. Functions that gather statistics on user performance could also be provided.
Word recognition:	A word is randomly chosen and permuted according to standard spelling errors. The user must confirm or deny its legality as a word.
Anagrams:	A list of letters is provided to the user, who then tries to compose as many legal words as possible from them.
Word search:	A definition is displayed, and the user must provide the corresponding word.
Picture naming:	A picture is displayed, and the user must name it or parts of it.
Synonym search:	By following synonym paths, the user must determine whether two words are related.
Voiced word pronunciation:	A displayed word will be accompanied by voiced word pronunciation.
Grammar correction, sentence building:	This capability would be dependent upon more sophisticated processor and software becoming available.

5.2.2.3 Videodisc as on- line information bank

Videodisc technology is likely to have a major impact on on-line information retrieval. At present, on-line information services such as Lockheed, SDC, or ESA/IRS offer huge amounts of information over private and public computer networks to some ten thousand of users. There are three major characteristics of the present technology: 1) frequent centralized update (daily, weekly, monthly, quarterly) of the data bases; 2) the principle of on-line ordering and off-line delivery of primary documents; and 3) the aspect of cost and resource sharing by a large user population. The videodisc technology will have major impacts on the presently-known, on-line databank technology (based on large central mainframes and special database management programs—suitable for fast retrieval from large stores of information on large magnetic disc devices). First, the amount of stored information can be multiplied. For example, the 17 million on-line references of a present large database

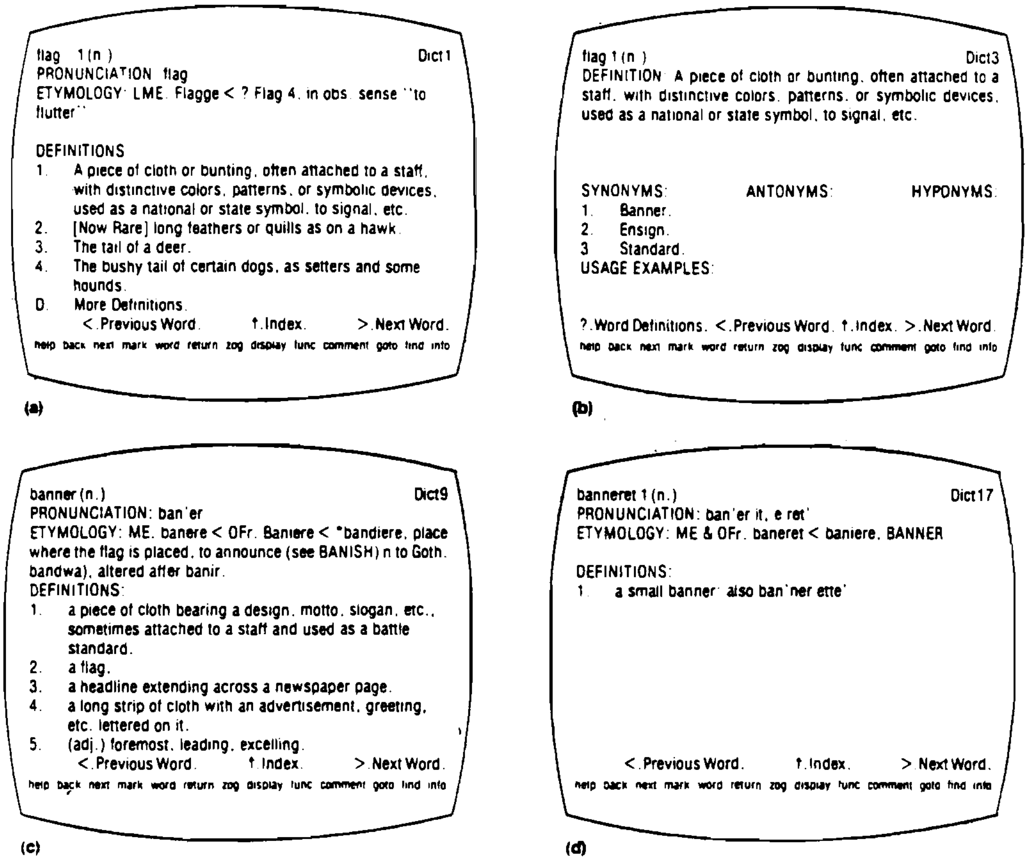
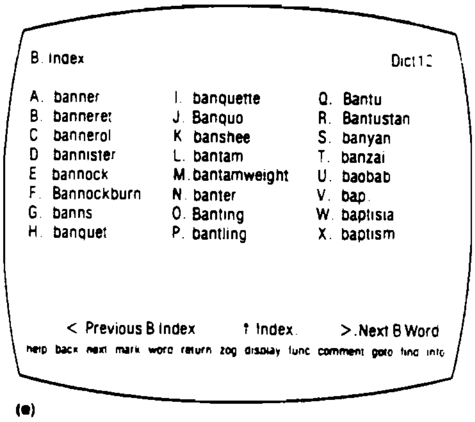


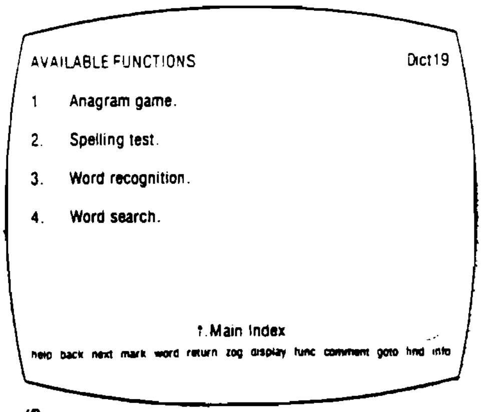
Figure 16(Part I). Example of automated dictionary entry.

service center can easily be stored on twelve parallel working videodisc devices controlled by one central processor ("head computer").

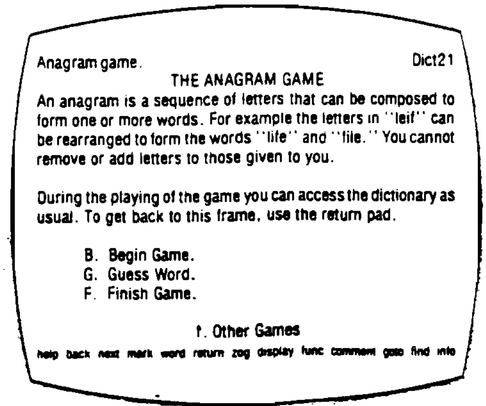
The installation cost of the videodisc-based data center configuration is considerably lower—about one sixth the cost of an equivalent traditional database center [9] (see Table 10). Comparing total operating costs, the videodisc-based, large on-line information bank center is cheaper than an equivalent center based on the magnetic disc storage technology by a factor of approximately three. A possible configuration of a videodisc technology based center of the size of an ESA/IRS (about 30 on-line databases, 18 million references) is shown in Figure 17. The fifty videodisc units are grouped according to the usage of the individual databases. More frequently used databases, such as INSPEC, BIOSIS, or CHEMICAL ABSTRACTS would be operated separately on two to three parallel disc installations separately, allowing parallel searches by different users. The configuration shown in Figure 17 could serve at least 50 users simultaneously. Let us assume that we use a videodisc model which can store 1.5 GByte of information. About 50 percent of the total on-line disc capacity of 75 billion bytes (an approximately 75 million references) would be used to store all on-line references at least twice for simultaneous access during multiple usage, and another 50% would be used to store the latest on-



(e)



(f)



(g)

Each dictionary entry is represented by a primary frame (a) that provides pronunciation and etymology as text and definitions as options. Selecting a definition option causes transfer to a secondary frame (b) containing synonyms, antonyms, hyponyms, and usage examples that go with that definition. This frame is reached by selecting the option text on the screen or by hitting the "1" on the keyboard. The frame for the synonym "banner" (c) is reached by selecting item "1" in frame (b). Two options—NEXT WORD and PREVIOUS WORD—allow sequential movement through words in the dictionary. For example, the frame for "banneret" (d) is reached by selecting the NEXT WORD option while in the "benner" frame (c). The INDEX option transfers to a frame where the current word is indexed (e). The last line on the page contains global commands—special options for manipulating the network of frames. To play games, the FUNC option is selected, and the FUNC frame (f) displays the available functions in menu form. Selecting the "anagram game" option from this frame calls up the anagram freme (g).

Figure 16(Part II). Example of automated dictionary entry.

line primary documents. In this way, about five million one-page, on-line documents size A4 can be stored, the equivalent of a library shelf 300 m in length or 500,000 papers with an average of 10 pages each. This amount of on-line primary information is approximately equal to the total of referenced primary documents over the last 12 months.

On-line document delivery of primary information might become an attractive service for centralized information data bank centers; however, to this end, the data transmission capabilities of the telecommunication networks has to be improved considerably and the cost of telecommunication has to come down. Perhaps the introduction of advanced computer networks and new hardware technologies (such as fiber optics networks and telecommunication satellites) will remedy the present situation.

The cost of telecommunication is still very high: as a rule of thumb for on-line retrieval, one can say that one-third of user costs is spent on telecommunications, one third, on databank center usage charges, and one third goes through the data spinner (operators of databank centers) in the form of database royalties to the database suppliers. Only the operating costs of the center could be reduced through the introduction

Table 10. Comparison of service costs of "classical" and videodisc-based data centers

	Yearly cost of on-line service centers	
	Based on a "classical" data base configuration (US$)	Based on a distributed videodisc-based configuration* (US$)
Hardware	430,000	90,000
Software	145,000	10,000
Office expenses	25,000	20,000
Operating staff salaries	100,000	100,000
Total	700,000	220,000

* calculated on 50(!) parallel working videodisc (2-3 years lifetime) with a total on-line capacity of 75 billion(!) bytes attached to a "head" minicomputer

of videodisc technology to on-line information bank centers. Royalties and telecommunication charges would reman the same. This will probably lead to the establishment of local databank centers based on videodisc technology on the premises of major users, e.g., libraries, which might negatively influence the revenue growth of the centralized databank centers. In the long run it can be expected that the database suppliers will start to supply their subscribers with the most up-dated videodisc versions of their databases on a regular basis. Thus there will be separate videodisc records for a BIOSIS, an NTIS or a CHEMABS database. In most cases, each of the present databases could be put on to a single videodisc record. Only the largest databases such as CHEMABS or PASCAL would need more space. Eventually—once standardization is achieved—all these records could be put on any more sophisticated videodisc player.

In the field of information retrieval, the impact of videodisc on videotex systems will be twofold. First, it will be beneficial from the viewpoint of information suppliers and videotex data center operators since it will allow the storage of large amount of information frames at considerably lower costs. A configuration similar to the one shown in Figure 17 can be imagined for videotex data centers as well. However, if the videodisc technology finds its way into every household, there will be limited need for special types of centralized information to be stored at videotex data centers; for example, a database for a railway timetable or even an electronic directory could be stored on home videodiscs. Only information requiring frequent up-date (e.g., daily) and the "umbrella" type of information, when many information providers put their information under a common "umbrella" (as commonly used in the interactive videotex type systems such as PRESTEL) are unsuitable for videodisc

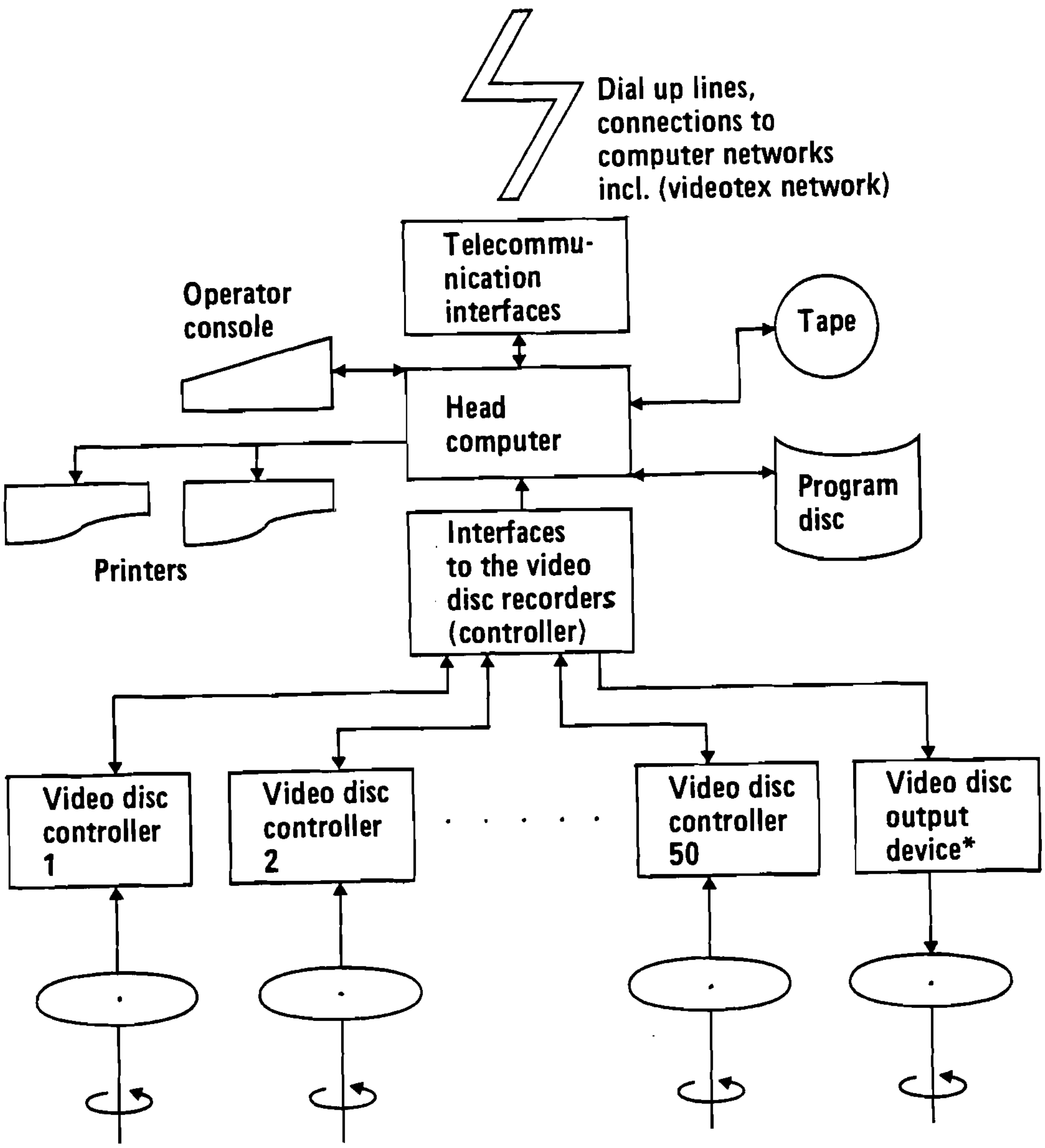


Figure 17. Example of an on-line data service center based on videodisc storage devices (* such as the Philips DOR system).

application. These categories are better suited for videotex type of services.

Last but not least it should be mentioned in this chapter that a special (new) database for patent drawings that is based on videodisc has been demonstrated by Pergamon International Information Corporation. The new service called Videopatsearch [13], offers microcomputer-microcomputer access to the Pergamon Patsearch file (U.S. patents from 1971 to date) as mounted on Bibliographic Retrieval Services (BRS) in the US with the facility for two-second *retrieval of* patent *drawings* using a Discovision videodisc player. The 700,000 drawings are stored on 14 discs (each disc side providing 26,000 frames for drawings). The microcomputer terminal/videoplayer link permits automatic retrieval of selected drawings; discs will be updated quarterly by Pergamon. There are plans to use two parallel screens to allow text and drawing to be viewed simultaneously. The price of the system will be US $6,000 per year (including terminal end, videodisc player, and videodisc subscription).

The novelty in the Videopatsearch system lies in its capacity to retrieve pictures. Similar applications in the past were mainly based on micro-fiche; videodisc will probably bring another real breakthrough in this field.

5.2.2.4 Videodisc as an "electronic directory"

The first Electronic Directory System is presently being developed for 250,000 telephone subscribers in the Ille and Vilaine region of Western France. It will be implemented on a videotex-type computer network using simple CRT terminals [10]. It is hoped that by replacing the paper telephone directories issued yearly, that not only will more up-to-date information be provided, but significant savings in resources (paper, distribution, etc) can be achieved.

The videodisc technology might have a two-fold impact on the "electronic directory." First, if one keeps to videotex-system based on the central "electronic directory" philosophy, then the storage and retrieval function of the central "electronic directory" center—which is basically an on-line information bank center—can be fulfilled by means of videodisc players working in parallel (similar to Figure 17) enabling simultaneous usage of the system by many users. In this example, let us assume that we use a videodisc model with a storage capacity of 1.5 million frames of information. If data on all telephone subscriber were stored on one frame each, then an on-line videodisc record could contain information on about 1.5 million subscribers, a large telephone user population. If the videodisc units were stand-alone devices and each subscriber had its own videodisc player at home, then twice this amount of information storage would be at his disposal, since the other side of the record could be used as well. Table 11 gives a rough overview of the number of videodisc records needed in selected countries according to 1980 AT&T statistics [21] on their telephone populations.

Table 11. Number of videodisc records needed to store "electronic directories" for selected countries (source [11]).

Country	Telephone population (January 1980) (million)	Number of videodisc records containing "electronic directory"	
		through videotex	stand alone
Austria	2.812	2	1
Bulgaria*	0.946	1	1
Czechoslovakia	3.073	3	2
Finland	2.244	2	1
FRG	26.632	18	9
GDR	3.071	3	2
Hungary	1.186	1	1
Italy	10.085	12	7
Netherlands	6.853	5	3
Sweden	6.407	5	3
UK	26.651	18	9
USA	175.505	117	59
USSR	22.464	15	8
Japan	55.422	37	19
Canada	15.560	11	6

* data in 1977.

The number of videodisc players installed on videotex-type networks to be in the on-line version of "electronic directory" would depend on the telephone subscriber population of the country. With the appearance of the home videodisc version of the "electronic directory," every owner of a videodisc player who is also telephone subscriber would get yearly "electronic directory" records from the PTTs. Since videodisc players are multi-purpose devices, this would not require any major hardware installation at the user's site or on the telephone network—again provided that videodisc standardization is achieved. In countries with under-developed telephone infrastructures, the concept of an on-line telephone directory might be arguable since its usage would add unnecessarily to an already overloaded telephone network. This would also have a negative impact on the quality of the on-line "electronic directory" service itself.

However, whether the concept of an electronic dictionary were to come about through videotex network or by videodisc, there would remain open one basic question: would the user accept the concept or would he prefer to continue to use paper telephone directories and ask the central information for any unknown number?

5.2.2.5 Videodisc as a tool for "electronic publishing"

Videodisc can be used to store image pages of any printed publication. The huge storage capacity of videodiscs would allow, say, all the novels of Thomas Mann to be put on a single disc record. The contents of the record could then be shown page by page on any videodisc recorder. The advantage of such usage would be its low cost, and the savings in paper and storage space. The disadvantage would be that reading from a TV screen would be far more tiring than reading a book.

Other sorts of electronic publications might better utilize the "value added services" offered by videodisc technology. Electronic publications such as a "Guiness Book of Records" with voice and motion scenes or an "electronic cookbook" would utilize the videodisc technology's sound and motion dimensions. Similarly, history books might include motion and voice scenes. An encyclopedia of animals on a videodisc record might be an excellent and useful educational and entertainment medium for children. The dimensions of random access, voice and motion are endless.

At this point, however, some thoughts should be given to the "electronic publishing" industry as a whole. The success of videodisc will depend on many factors. Important point will be the degree to which it can penetrate the mass market, which in turn will heavily depend on its usefulness and on user acceptance. The cost factor will be decisive in this process; both videodisc players and videodisc records have to be mass produced and distributed in order for costs to come down to a reasonable level. The production and broad selection of videodisc programs—be it video, audio, or text—is of basic importance. If the choice of information on videodisc records is not attractive to the users and is not available in all the major application categories—entertainment, movies, voice recordings, encyclopedias, automatic directories, educational programs, etc.—it cannot attract the necessary broad consumer population. Therefore, while building up videodisc player production sites, special attention has to be paid to the establishment of a videodisc record industry. A necessary precondition for the healthy growth of the record production industry will be the adoption of videodisc standards; otherwise the flexibility of the videodisc technology will not be exploited and we only will see a limited diffusion of dedicated videodisc systems (for example, a dedicated system for a CHEMICAL ABSTRACTS, separate automatic directory systems, etc.). If the development moves in that direction, then the mass market cannot be reached and both hardware, software, and videodisc record prices must remain high. It can be expected that the videodisc record manufacturing industry will appear in a concentrated form since the installation of videodisc record production lines are rather expensive (on an order of magnitude of some millions of dollars). In order to keep the production costs down, the records must be produced in large quantities.

In the audio area hard competition can be expected between the digital audio and ordinary LP producers. In the field of text publishing, competition with publishers of printed materials can be expected. In the field of on-line databanks, there will be competition among producers of videodisc records containing large databanks, and among database spinners who sell on-line services in the traditional way through networks and time-sharing computer centers. For the producers of databases, once they have made appropriate arrangements for record production, it will make no principle difference whether they provide their subscribers with magnetic tape or videodisc up-dates. In fact, it can be expected that they will be able to increase their revenues through reduced subscriber rates but increased user population.

The sharing of labor in electronic publishing will be similar to that in the classical publishing industry. There will be a separate videodisc record production industry on the analogy of printer's shops. There will be electronic publishing houses who will be responsible for the content of the videodisc records, similar to traditional publishers. There will be new type of authors with new type of skills: in addition to writing skills they will require skills in video, voice, and also in videodisc controller programming. The subject of videodisc authorship is obviously much broader than this, and requires more concentrated study.

A final thought here: videodisc is a new medium suitable for expressing ideas, feelings, and emotions. The emergence of a new medium is often accompanied by the emergence of a new type of art. The advent of the motion pictures triggered off the cinematic art, the development of radio broadcasting led to the emergence of radio plays, and the art of modern journalism was made possible by the development of new printing technologies. And the novels of T. Mann, W.S. Maugham and L. Tolstoi could not have been disseminated without printing. In a similar way it is likely that the videodisc technology will be the basis for a new type of creative art based on video, audio, and text information and exploiting the mixing and programming capability of the videodisc controller.

Selling videodisc records will be a specialized new business with strong resemblance to the selling of books, traditional records, films and games but requiring concentrated interdisciplinary marketing.

All in all the "electronic publishing" industry is an exciting new field offering new opportunities and challenges to producers and sellers of information as well as to buyers. While it might eliminate some jobs in traditional publishing it will open many others in the new field. The publishing industry has interesting times in sight...

5.2.2.6 Use of videodisc as timetables

Railway and flight timetables are similar in the nature to the previously discussed electronic directory. in that they are made up of masses represent reference information up-dated about twice a year, and printed in bulky books. If they could be stored electronically, large amounts of materials, especially paper, could be saved. One possibility would be to store timetables on interactive videotex frames. This approach already functions perfectly on a small scale with the existing videotex technology. However, similar to encyclopedias and electronic directories, the volume of information to be stored presents a major barrier for the presently-known videotex systems. Thus using videodisc players for this purpose, either linked on-line to videotex networks as third party computers or as stand-alone systems, would be a feasible solution. On-line access through the videotex network could have an additional provision for subsequent on-line reservations when a suitable train or flight is found and free places are still available. Obviously, this sort of interactive traffic could not be performed by stand-alone videodisc devices. Therefore, it seems as though that the information retrieval type of usage of interactive videotex systems—which is at present the main usage category of videotex-like systems—can be taken over in many cases: by teletext or cabletext if a full channel is put at the disposal of such services (around 100,000 videotex frames can be rotated) or by videodisc as shown here. The main strength of the interactive videotex lies in its interactive nature, and from the information retrieval point of view, in its capability for frequent and quick update.

5.3 Videodisc as Tool for Education

We have seen what an excellent tool for information transfer the videodisc player is. Education is also a sort of information transfer: in a structured way information is "fed" into the memory of a person being educated.

Theoretically, videodisc is an ideal tool for education. However, its acceptance in an educational environment depends upon user impressions: Is it easy to use? Does it provide new functions being those of devices used for similar purposes?

In order to "measure" the "interface quality" of videodisc, let us compare it with the seven interface performance factors as defined by Card et al. [12];

- Time: How long does it take a user to accomplish a given set of tasks?
- Errors: How many errors does the user make, and how serious they are?
- Learning: How long does it take a novice to learn how to use the system to do a given set of task?
- Functionality: What range of tasks can a user accomplish with the system?
- Recall: How easy is it for a user to recall how to use the system for a task that he has not done for some time?
- Concentration: How many things does a user have to keep in mind while using the system?
- How tired do users get when they use the system for extended periods?

Fox, et al. [8] name four additional factors that must be considered when evaluating interfaces of educational systems:

- Variety: Does the interface provide information in a variety of ways; for example, does it offer color rather than black and white, flashing images, speech output, motion pictures?

- Curiosity: Is the user's curiosity to explore piqued by the interface?
- Fun: Does the user find the device fun to use?
- Adaptability: Does the device adjust to the user's level of competence as the user becomes more experienced with the device?

Satisfying these demands can present a difficult design problem, but it seems that it can be done for videodiscs relatively easily. In an educational environment it is of special importance that the last four factors be relatively easily fulfilled. This indicates that videodiscs will be excellent educational devices. Many of the applications for videodiscs discussed in previous chapters could play major roles in education.

The automated dictionary, for instance, could do much to promote language training and education—perhaps more than any other device before it. It will help to enrich the users' vocabulary in the language, will promote spelling skills, word recognition, and aid in word search, synonym search and the like. Its capability for easy word retrieval could revolutionize the translating process.

So-called "programmed course books" have proved to be useful teaching tools for language training. On the analogy of programmed course books, programmed courses on videodiscs—so-called Computer Assisted Instructions (CAI)—could be made available, perhaps containing voice and motion picture scenes in addition to text. The flow of the course would be preprogrammed: the student learns a new chapter supported by text, video and audio information; a test then determines whether or not he has understood and mastered the material. If he has not, the material is repeated, this time in a more detail and perhaps from a different angle. Subsequently a new test decides whether or not the student may go on to the next chapter. Of course, the student satisfactorily passes the test first, he may immediately go on to the next chapter. Supplementary tests could be used to allow particularly advanced students to skip certain chapter.

Programmed courses (CAI courses) could be designed for practically any field: mathematics, language, biology, engineering, programming, art, geography, and so on. The principle of Computer Aided Instruction is described by James Martin in *The Wired Society* [20]:

> Computer-assisted instruction has been used for a wide variety of people and a wide angle of subject matter. It has been used at most levels of education, from very small children to graduate students and professionals. When the system is well designed, the pupils are captivated by the terminals; they learn at a fast rate with a high level of retention and finish each session with a sense of accomplishment. The computer is programmed to respond to them sensibly, with infinite patience, and with timing designed to maximize the reinforcement of the information in their minds. The pupils leave the terminals stimulated and often mentally fatigued. However, a badly designed system can be immensely tedious and can leave the pupils with their patience strained to the breaking point, thinking that it is a worthless gimmick and that they can learn much

better from a book. To write well for this medium requires considerable care and talent. The writer must understand the subtle psychology of the medium.

Some topics lend themselves well to computerized teaching, but others do not. Subjects involving large amounts of routine details or facts are natural for computers, as are subjects with elaborate but standardized logical procedures. It is ideal for teaching spelling, simple mathematical techniques, the mechanics of foreign language, statistics, computer programming, electronics, and so on. It would have more difficulty teaching philosophy, carpentry, basic principles of calculus, or appreciation of music, although even here it could assist a human teacher.

. . .

Given a suitable subject and skillful programming, computer teaching can have significant advantages over conventional classroom teaching. Teaching in a classroom is almost always instructor-centered. The students have to proceed at the speed and level of complexity that is dictated by the instructor. The brighter students, finding the pace too slow, are bored; those who are not so bright often become lost or fail to understand part of what is said. Any student, bright or dull, can miss sections through lapses in attention. With computers, the process is pupil-centered, not instructor-centered, and the machine adapts its pace to that of the student. Dull students can ask for endless repetitions without embarrassment. Quick students or those who already partially know the material can skip a segment—with the machine questioning them to check that they do in fact know it. Students who want more practice in a certain area can obtain it.

. . .

Writing these elaborately structured teaching programs requires much time and considerable skill.

. . .

An outstanding program for computer-assisted instruction is a work of great art. A strong sense of style is needed. This is a new medium quite different from any that have preceded it, and needs its own rules concerning style. No doubt a style guide will be developed in time, and it will probably change with time just as style in other media, such as movies, has changed. Computer-assisted instruction may be much more susceptible to change because of the intimate two-way interaction, which no other medium has.

. . .

There are three levels at which computer-assisted instruction can operate, differing in channel requirements.

The lowest level displays alphabetic text on the terminal. This, like all uses of computer dialogues with text, letters, and numbers, has low bit transmission requirements compared with digitized telephone transmission.

The medium can be more effective and stimulating when pictures are used. The second level can display still color pictures on the screen. Some systems have used two screens, one for text and one for pictures. Substantially more bits are required to store or transmit pictures, but the requirement is low compared with the transmission capability of cable television.

The third level uses movies. An educational movie will stop at intervals to show still frames and ask the student questions. The response to the questions will determine what frames are shown next and whether the machine repeats or skips segments of movie. The selection of the next movie segment may take ten or twenty seconds, and this selection delays is hidden by showing still frames.

The lowest level can be achieved by any interactive computer system: interactive videotex systems such as PRESTEL, for example, would be ideal for this. The second level, additionally showing high quality freeze frame pictures, will be attained in the next years by PICTURE PRESTEL. The third level, at least on a long-term basis, will only be possible through stand-alone videodisc systems. Perhaps sometime in the future fiber optic link based interactive videotex systems will be able to compete with the videodisc in this field.

It cannot be stressed too strongly that the production of good computer-assisted instruction is a highly skilled, professional operation. One day a substantial industry will grow up to produce such programs. It may become an industry the size of Hollywood and just as professional. More than one thousand manhours of work will go into preparing one hour of top-quality instruction.

A glimpse of this can now be seen with non-interactive education in the Open University campus and the studios of video education companies. The best that is produced will exist for many decades, as do classic books, recordings, and films. it will be part of the cultural heritage of the satellite age.

Continuing the line of suitable videodisc applications in teaching and learning. reference books on videodisc could serve educational purposes as well, although this was not the in primary purpose.

An analysis of movement—e.g., when learning ballet or skiing—can be made easily using videodiscs. No other type of video device presently in use would allow such a full analysis of movement (normal motion, slow motion, picture by picture, forward motion, reverse motion, etc.).

The variety of videodisc applications for educational purposes is endless and here an attempt is made only to point out some of its potentials; a comprehensive mapping of all educational applications cannot be given.

5.4 Videodisc for Mass Storage and Archives of Data and Programs

The fact that a videodisc record can contain such vast amounts of coded data, it being the most condensed form of mass information storage developed to date, and the fact that it does not wear out, its lifetime being practically unlimited, make this technology particularly suitable for use in archives. The major hindering factor at present is the requirement for a high degree of production precision and a clean atmosphere of an "operating theater."

As pointed out previously, the fact that videodisc cannot be deleted and re-used is hardly a disadvantage for this application, in light of the low costs of producing records and the fact that the final goal is to archive data which normally should not be deleted.

In many case large amounts of data need to be archived. Statistical data for countries, firms, towns, factories, etc. can be stored and archived by this medium on a monthly or yearly basis. Mass measurement data gathered during experiments, such as during a flight to the planet Saturn, must be archived, duplicated, and distributed as well. Moreover, they must be protected from being overwritten. For this and similar purposes videodisc is a suitable medium.

Source and object code programs are also ideally suitable for storage on videodisc records.

Using a videodisc output device working in computer centers with the digital optical recording techniques as described in Chapter 3 and shown in Figure 14, it will be possible to save the content of the system and of library magnetic discs on videodisc on a regular basis. At present system and library disc savings are mostly made on magnetic tapes—usually according to the grandfather-father-son principle; i.e., three subsequent generations are stored at the same time. By using space-saving videodiscs one could build up a system and library savings archive containing snapshots of the computer center system over many years. Where this is required, videodisc technology could be extremely useful.

5.5 Videodisc in Office Automation and Document Filing

In the view of Barrett [23], ideally *an optimum mass storage and document filing system* should have the following characteristics:

a) non-erasable archival medium;
b) fast access time;
c) high data rate (for input, processing, retrieval and output);
d) low cost;
e) volumetric efficiency;
f) data and/or image storage;
g) expandability to at least 10^{15} bits capacity.

The requirement for an non-erasable archivable medium would exclude, magnetic tapes because of their sensitivity to temperature, humidity, and electrical/magnetic interference. (Annual re-copying is often resorted too.) From this point of view, microfilm, holograms, and any other inexpensive write-once, read-often media are preferable. (Microfilmed evidence is now acceptable in a court of law, whereas magnetic tape is not.) Magnetic tape was originally intended for short-term data capture and manipulation; however, its erasability is undesirable where long-term integrity is sought.

A typical access time for magnetic tape mass memories is 15 seconds, the few microform retrieval systems available can achieve 5 seconds, depending on capacity. Requirements vary with the application, but 5 seconds would probably be adequate for document-retrieval systems; a requirement easily met with the videodisc technology.

In discussing the storage potential of videodisc Harrier Collier [22] points out that

one videodisc record= 35 magnetic tapes
= 500 microfiches
= 182.5 feet of microfilm
= 50,000 A4 pages in image format
= 500,000 A4 pages in coded alphanumerical format.

Office automation systems require the following basic functions in addition to document filing:

a) Recording—the acquisition and input of information
b) Storage—temporary or permanent retention,
c) Retrieval—recall based on various attributes of the data;
d) Composition—changing form, appearance, and structure of the data as and when required;
e) Distribution—recognizing multiple needs or group actions;
f) Communication with geographically dispersed users and sources.

Of course computers and word processing machines do the lion's share of above work: Communication can be carried out either via on-line telecommunication channels or off-line (e.g., by sending diskettes or videodisc records by mail). However, for office automation functions such as permanent storage, analog or digital optical recording systems seem to be extremely useful. Systems like the previously described Philips DOR system or the Document Filing systems announced by Toshiba (DF-2000) could play an important role here.

The Toshiba DF-2000 image recorder/laser file system which will soon be available on the US and Japanese markets, will be the first videodisc technology office system on sale in the US. It will consist of a high resolution laser scanner input device (8.5 seconds input time per document), a high quality laser printer (14 seconds for printing a single document), a central computer (4.5 seconds for retrieving a given document and calling it up on screen) and an analog optical disc storage device (capacity of 10,000 document pages per record). The system is expected to cost only around US $50,000. A record will be cost $140. This cost level will make these systems highly competitive with other systems, such as those based on microforms.

6. SUMMARY AND CONCLUSIONS

(1) Optical disc technology is a revolutionary new technique that will have a major impact on both information technology and the consumers electronics industry. We see at present the emergence of analog storage technology for videodiscs with the tendency of storing growing amount of digital information in a "pseudo" digital form. Videodisc with digital storage technology will also be entering the market soon. Digital systems based on the PCM (Pulse Code Modulation) technique allow sound and video signals to be recorded in high quality at a relatively cheap cost. Also, another digital technique is used to store vast amounts of coded digital information, such as of coded text, data, and computer programs. These two digital coding techniques will be used in digital videodisc systems, allowing flexible mixing of audio, freeze-frame video and coded textual information. In principle, mixing of media will also be possible on analog videodisc. The memory unit price for optical storage systems—which we believe will be the basic technology to be used in videodisc—is far below that of all other presently known and used techniques especially on the mass produced (pressed) videodisc records. However this very positive cost factor might be negatively influenced if data accuracy problems with the mass produced videodisc records cannot be solved cost effectively.

(2) The videodisc revolution will be triggered off by the following main factors:

- low costs for information storage and data handling;
- easy random access and retrieval of information;
- high flexibility in mixing voice, video, text, and data;
- the information processing capability of the videodisc controller;
- flexibility in handling videodisc output alternatives (local display, remote data termination equipment, computer networks, etc.)

- the convergence of information and video technology
- revolutionary new applications

(3) These factors could mean that the videodisc technology will reach the mass market within the next few years. It is hoped that videodiscs will become for secondary information storage what the Ford Model T was for the automotive industry, making mass storage technologies a part of everybody's daily life. Despite reduced prices for secondary storage devices, increased revenues could be collected through mass marketing.

The following can be said about market penetration by videodiscs. At present we see only the tip of the iceberg. Videodiscs have already begun to penetrate the entertainment market; whether or not they will is an open question. Educational, training, television look up, and image data base, systems such as those of Discovision Associates are already on the market and there can be hardly any doubt that they will successfully penetrate the market. Optical Recording Systems—such as the Philips DOR System—will soon enter the market. However, their impact on document filing, mass storage, archiving will probably not be felt until the second half of the decade. Cheap digital optical videodisc systems using mass-produced replicated videodisc records that could be employed for most new applications (complete, multimedia encyclopedia, automated dictionary, large information banks, etc.) have not yet reached the market and thus it is too soon to predict their success.

(4) Videodiscs as we presently know them are "read-only" devices. However, this will not narrow their scope of application. Indeed, for archiving purposes the non-erasable characteristic is of major advantage. Videodisc can store in appropriate form the huge amount of information needed for information retrieval in an appropriate form.

However, resembling mass information for this application is a complex task and should be carried out by specialists on a labor sharing basis. To meet this need, it is likely that an increasing number of electronic publishing firms will evolve. Electronic publishing will influence the traditional paper-based printing and publishing industry.

(5) Market penetration and the overall success of the videodisc technology will depend on the availability of appropriate videodisc programs. Present difficulties lie in production technology of records. It is hoped, however, that as experience is gained, the technical difficulties can be overcome. Another problem is that the production of the laser technology-based videodisc records requires a completely new technology and new record production lines and tools. Accumulation of the capital needed to begin production might be a prohibitive factor in a time of economical recession. Industrial policy factors, i.e., "who is backing or not backing what" might be crucial to the success of this new medium.

(6) The development of uniform videodisc standards is urgently needed. There are already a few different systems, although the technology is still in its infancy. The elaboration and approval of standards will be a long and painful process, perhaps taking years. But without standards the production of videodisc records cannot fully exploit its potential; for instance, the inter-changeability of records from different systems could not be assured. Standardization is needed not only in the physical characteristics of videodisc records, but also in content, programming methods, coding of information, error recovery, and so on.

(7) The videodisc technology will be applied in revolutionary new ways: interactive TV, an electronic encyclopedia containing textual, audio, and video information, automated dictionaries, on-line information banks, electronic timetables, electronic directories, and other types of electronic reference devices.

(8) The videodisc technology has great potential in the area of entertainment and education. It can be expected that this technology will considerably change classical teaching methods. Also, videodisc record may become as new medium in art, too.

(9) Videodisc could have a significant impact on on-line information banks. On-line information service centers as we presently know them could lose their biggest customers, who might install their own videodisc data centers at low cost. On the other hand, service costs for on-line information service centers operating videodisc storage devices will drop.

(10) Videodisc will have a major impact on videotex technologies as we presently know them. The information retrieval function of videotex will be particularly affected. Some applications, such as encyclopedias, are better suited to videodisc. As we have pointed out in other studies ([17], [18]), the success of videotex-like systems will depend on the scope of their application. At present however, videotex systems primarily support information retrieval, an application type which might be especially affected by videodisc technology. Where frequent information update is required, videotex technology will continue to play a leading role; where huge amounts of information needing relatively infrequent update are required, videodisc technology is preferable. Videodisc storage devices will be particularly useful for replacing magnetic disc storage devices in videotex information centers.

(11) Videodisc technology has a "dualistic nature" with both consumers electronics and information technology aspects. A convergence of video and information technology will form a solid base for the emerging "videomatics" era.

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