Holographic Filing: An Industry on the Verge of Birth

Information flow is the life blood of American industry and government. Astounding amounts of data are transmitted around the nation and around the world every day. Eventually, though, most data must stop flowing and come to rest in a reservoir of some sort. Conventional storage techniques are beginning to show their deficiencies, and it has become clear that new ways are necessary to increase the amount of information that can be stored in a given space. Many people think that storage of the data in the form of holograms might be the best solution available now.

Examples of the growth of information flow are easy to cite. Satellites and space probes of the National Aeronautics and Space Administration, for example, transmit to earth 1000 trillion bits of data each year; a bit is the smallest unit into which data can be divided and is stored electronically as either a 1 or a 0. Of that total, 10 trillion bits (10×10^{12} bits or 10 terabits) will be stored for 50 years or longer, says former astronaut David C. Scott, now with Scott Preyss Associates of Los Angeles. Private industry now stores some 265 billion financial documents, he says, and the government stores some 20 million cubic feet of records. Information storage systems are a \$1-billion-a-year business that should double in size by 1980.

Documents Least Desirable

The least desirable way to store information is in the form of documents. These require vast amounts of storage space, and retrieval of specific items is laborious and time consuming. A slight improvement is the use of machine-readable punched cards, each of which contains about 800 bits of information; these cards are typically stored in boxes of 2000. Punched cards provide little or no increase in density, but they render the data accessible to computers. One terabit of information filed on punched cards would fill a string of boxes 123 miles long.

The most common way to store data now is on magnetic media, in the form of discs, spools, or reels. These provide substantial increases in information density and quicker retrieval of data. One reel of magnetic tape contains the equivalent of 677 boxes of punched cards; discs and spools contain less. Magnetic media are also less than satisfactory. The most important shortcomings are the short lifetimes of tapes and their vulnerability to environmental changes. Tapes must be cleaned frequently, kept under exacting conditions of temperature and humidity, and recorded over again every 10 to 15 years as the medium deteriorates. The cost of this care averages about \$10 per reel per year, or about \$1 million per year for a terabit library.

A more satisfactory storage life is obtained with film, which is impervious to a wide range of environmental insults. A 4- by 6-inch sheet of film, called a microfiche, can store 88 pages of data, or as much as 1.5 million bits (1.5 megabits); these pages can be photographs, written or typed pages, or electronically produced data pages in which the binary bits are represented by opaque and transparent squares arrayed in crossword puzzle fashion. A box of microfiche the same size as a box of punched cards contains 1560 times as much information. A terabit library on microfiche would be 777 feet long.

Microfiche has not been particularly successful for storage of binary data, however. Each image is so small that dust, fingerprints, scratches, and the like can destroy a portion of the recorded data. To overcome this problem, some companies have investigated storage in the form of holograms. This technique has the potential both to eliminate the problem of data loss and to provide a further increase in storage density.

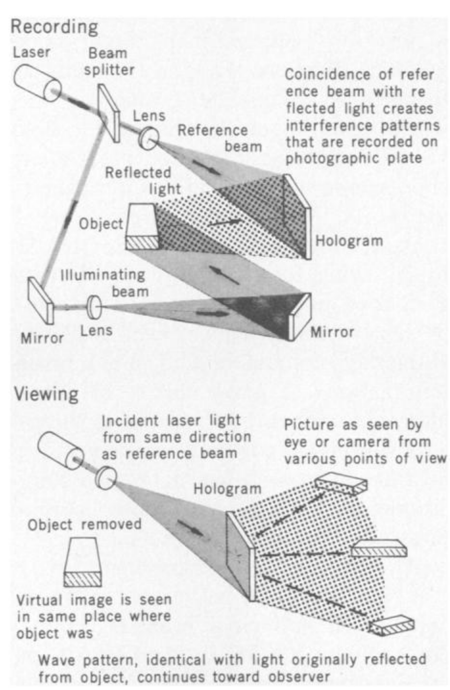

Fig. 1. A hologram is a record of the interference pattern produced by the reference beam and the illuminating beam. When the hologram is illuminated with coherent light, a three-dimensional image is produced. The three blocks on the right represent the image as seen by the eye from three points of view.

Holograms are produced (Fig. 1) by splitting coherent light from a laser into two beams. One beam, the reference beam, illuminates the film directly. The second beam illuminates, by means of mirrors, the object to be recorded. Light reflected from the object mixes with light from the reference beam to form an interference pattern on the film; this pattern is called the hologram. When the hologram is illuminated with laser light from the same direction as the reference beam, it yields a three-dimensional virtual image of the original object.

For archival storage of data, the most important aspect of the hologram is its redundancy. Light from each point on the recorded object is spread across the entire hologram. If a photograph, for example, is cut in half, each portion contains only half the recorded information. If a hologram is cut in half, however, the complete image can be reproduced from either half, albeit with a slight decrease in the signal-to-noise ratio; only when most of the hologram has been destroyed does the signal-to-noise ratio become so small that data are obscured. Binary data can thus be stored in a hologram without any of the problems associated with conventional microfiche. Also because of this redundancy, a hologram on a microfiche can be substantially smaller than a microphotographed page. A 4- by 6-inch holofiche can store as much as 200 megabits of information in 20,000 individual holograms, and a file of holofiche can contain as much as 208,000 times as much data as an equal volume of punched cards.

Technology from Three Companies

Technology for holographic storage of data has been developed by three companies: Siemens AG, of Munich, West Germany; the Government Communications Systems Division of Harris Corporation in Melbourne, Florida; and the Defense and Space Systems Group of TRW Inc. in Los Angeles. The TRW technology has been licensed to and refined by Holofile Industries Ltd. of Los Angeles, with assistance from Scott Preyss Associates.

Holofile hopes to be the first on the commercial market with a complete holographic memory system. Their system, says Holofile president Leslie L. Cahan, has two main parts, a recorder and a reader. In the recorder, electronic data

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are converted into an optical data page with a conventional page composer that has been specially adapted for recording at high speed. The data page, identical to that used with conventional microfiche, is then recorded on the fiche as a hologram. This unit records at a rate of 5 to 12 megabits per second. The cost of the fiche is about 50 cents, Cahan says, compared to a cost of about $10 for an equivalent storage capacity on magnetic tape.

The reader contains a second low-power laser that can be focused on each hologram. The resulting image is focused on a photodetector array which converts the image to an electronic form that is compatible with conventional data processing equipment. This unit can read the holofiche at a rate of 5 megabits per second. The reader will be available in three formats. The simplest format will be a manually operated unit that accepts one fiche at a time. A second format would have 780 holofiche in a carousel unit; the maximum time for selection and reading of any fiche, Cahan says, would be 4 seconds. The third version would use not fiche, but scrolls contained in cartridges 2 inches square and 4.5 inches wide; each scroll would be the equivalent of 275 fiche. Cahan says 100 scrolls could be placed in a fully automated rack that would fit on a desk top. This unit could contain a terabit library from which any fiche could be selected within 6 seconds; it would be equivalent in storage capacity to a 96-foot-long magnetic tape library costing about $1.1 million.

A Wide Price Range

Individual readers are expected to sell at prices ranging from $5,000 for the simplest one to $75,000 for the desk-top scroll unit. A recorder will probably market for less than $300,000. Cahan speculates that service bureaus might be established to provide recording services so that only the largest users would require their own recorders. Holofile has constructed prototypes of each element of the system, but has not begun production because of a lack of financing. The number of inquiries has been so large though, argues Cahan, that he expects few problems in arranging financing, and production should begin within a year.

Harris has developed a similar system on a contract basis for the Rome Air Development Center (RADC) at Griffiss Air Force Base in Rome, New York. Their system is named HRMR because each fiche can contain data in both human-readable and machine-readable form. Because holograms in this system are generated synthetically by a computer rather than interferometrically, and because the Harris engineers are more conservative than those at Holofile, each holofiche contains only 30 megabits of data. The HRMR system also features automated storage and retrieval of holofiche; the storage system is built in modules that contain 0.2 terabits of data on 6750 fiche. Any fiche in the system can be retrieved in 4 to 15 seconds. Harris has already produced a prototype of the system, and its performance, according to Albert Jamberdino of RADC, meets all the claims made for it.

Harris is also developing for RADC a holographic recorder for high-speed accumulation of data. It records interferometrically on reels of 35-mm film. Engineers at Harris have demonstrated storage and retrieval of data on this system at the rate of 600 megabits per second. In comparison, a high-speed magnetic tape recorder operates at a rate of about 80 megabits per second. Using 70-mm film, it should be possible to record at a rate of 1 billion bits (1 gigabit) per second. This system is still at an early stage of development, according to Jamberdino, but there appear to be no major impediments to its completion. The ultimate application of the recorder is classified.

Harris is also working for the U.S. Army's Engineering Topographic Laboratories at Ft. Belvoir, Virginia, in an effort to develop holographic storage techniques for pictures, maps, and other graphics. Because the Army is required to be able to operate throughout the world, says Robert Leighty of Ft. Belvoir, it is necessary to have information about the terrain at locations throughout the world. Most of this information is contained in maps ranging in size from 22 by 30 inches to as large as 4 by 6 feet. Each map may have as many as four color-separated negatives, as well as several overlays containing tactical and other information. Original copies of these maps must be stored in central locations as a source for copies when necessary; field headquarters units must also store sizable numbers for their own operations. Holographic systems, Leighty hopes, might solve both problems.

Progress in this area has not come as readily. The principal problem, points out Anthony Vander Lugt of Harris, is that increases in storage density become more difficult as the resolution required increases. Since binary data and textual material require only low resolution, significant increases in storage density can be achieved. Resolution is more of a problem for engineering drawings and the like, and is a major problem for photographs and high-quality maps, where resolution is all important. It may not be possible to achieve an increase in density for storage of the latter materials.

In a central repository, Leighty says, images from a hologram would be used for direct production of printing plates to make other copies. Several problems now prevent this, including dimensional instabilities at the edges of the enlarged holograms, noise introduced during the enlargement, misregistration of colors, and nonuniformity of illumination over the image. It will take at least another 2 years to solve these problems, he estimates. Resolution problems are not so crucial for simple storage and display of maps, however, and this use may be developed more quickly.

Less Activity at Siemens

In contrast to this American work, work at Siemens has not produced any significant commercial applications. Hartwig Rull and his colleagues at Siemens have been exploring the use of erasable holograms on thermoplastic and manganese-bismuth films, but the company, unlike its American peers, seems to have concluded that storage might be better achieved with semiconductor and magnetic bubble systems. It has thus deemphasized work on holography.

Siemens' one commercial application of holography, which does not strictly involve data storage, is an identity verification system called Holocheque. With the Holocheque system, credit and identity cards would have a small window containing a film with an imprinted hologram. This hologram might contain an image of the card itself, the signature of the card's bearer, digital information about the bearer's account, and so forth. By placing the card in a special viewer, it would be possible to check the card against its image to see whether there were, for example, any alterations and to compare signatures. False cards would be difficult to manufacture. To date, however, Siemens has been unable to market the system.

Comparisons among the different systems are difficult to make because there do not appear to be any knowledgeable observers who are familiar with more than one system. In general, the systems seem to be an appealing way to handle one important aspect of the information explosion. Given the many apparent advantages of holographic filing, it seems to be only a matter of time before this technique becomes widely used.

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