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AUTHOR	Smith, Merrill W.; And Others
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ABSTRACT

Designed to examine the potential for delivering images stored on videodisc and other optical media from the library to the classroom, the pilot project described in this report has focused on ways to transmit still color or black and white images from the library's collection to a constituent academic unit. This report discusses analog and digital formats for electronic image storage and modes of image transmission; presents the results of work using the different configurations; and describes the design of a remote Image Delivery System that has been designed and implemented at the Massachusetts Institute of Technology. This system contains a network of independent computer nodes which are linked by a digital fiber-optic network as well as by a cable television system. A glossary of terms, a discussion of related work, and an 11-item reference list are included. (RP)

Visual Image Transmission

An examination of electronic delivery of visual images and text from the library to the academic community

Massachusetts Institute of Technology
Rotch Visual Collections
September 1986

Merrill W. Smith
Patrick A. Purcell
Christopher P. Thorman

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Abstract

A variety of means exist for storing and transmitting images in digital and analog storage formats. Analog storage is generally more space-efficient, while digital storage is generally more adaptable to data processing needs. At present, it is most efficient to use an analog distribution system, such as a cable television network to transmit high-quality high-resolution images. An Image Delivery System (IDS) has been designed and implemented which allows the interactive distribution of image databases. This paper describes a network of independent computer nodes which are linked by a digital fiber-optic network, and also by a cable television system. A review of other projects examining visual image transmission is presented.

Contents

1 Introduction

The purpose of this pilot project was to examine the potential for delivering images stored on videodisc and other optical media from the library to the classroom. Rotch Visual Collections, a branch library in the MIT Libraries system, is a repository for over 300,000 slides, photographs, and architectural drawings. Over the past several years, portions of its collections have been stored on videodisc projects developed at the Institute. Visual access to those parts of the collections has expanded through the use of the discs. This study was seen, in part, as an extension to local access of optical storage and retrieval systems. It tested transmission of those images over the electronic delivery systems available at MIT.

Image transmission is actively under consideration at several libraries and in a number of fields. Both at the Library of Congress Optical Disk Pilot Project and at Lister Hill, National Library of Medicine, systems have been developed for scanning and digitizing journals including illustrations and sending them as black and white images to remote user display. News companies such as the Associated Press and the Gannett publication *USA Today* have developed methods for dispersal of images needed over their coverage area. The academic institutions University of Pittsburgh and University of California, Berkeley are investigating or implementing means for transmission, especially video transmission for teaching and research. MITRE Corporation and others are investigating digital storage and transmission of images. A summary of some of the work being done is in Appendix A.

The particular scope of this project has been an exploration of the ways to transmit still color or black and white images from the library's collection to a constituent academic unit. During summer 1986 a number of experiments were designed to examine the potential for transmission of images using the electronic means available at the Institute. These include the campus cable TV (broadband) system, the Project Athena network infrastructure, and the direct microwave link between MIT and Harvard University.

The results of the work using the different configurations are contained in this report; and a suggested design for a remote Image Delivery System follows in the body of the report. It is interesting to note that, as a result of the work described here, the system proposed is now under development by Project Athena for use as a campus-wide delivery system for video based images.

Applications of image transmission techniques to libraries in general are promising. Libraries collect materials in a variety of formats including photographs, slides, drawings, as well as pages of text. For the past few years high capacity storage vehicles such as videodisc, optical digital disks, and compact disks (CD ROM's) have been under investigation as options for storing large collections. Increasingly, it will be possible, and viable to use optical compact storage for parts or whole large collections, or for access to large collections.

At MIT as at other universities, (U. of Michigan, U. of California at Berkeley, Carnegie Mellon, Brown, etc.) a campus-wide digital network is being implemented. The network provides a telecommunications/computer link with shared communications and access to common computer software, general files and databases. As network systems expand, remote bibliographic searching of library on-line catalogues possible over the network. In addition to bibliographic information, interactive visual access to visual formats in a library collection could be available to the student or researcher at a network workstation.

Significant limitations exist before experiments such as these can be translated into a large scale working system. A digital network requires images to be translated into digital form, which occupies considerable storage space. A single full-color NTSC image uses over 450 Kilobytes of space – nearly 1/2 megabyte – without data compression. Storage devices of limited capacity restrict the number of images which can be accomodated and adversely affect the retrieval time. Bandwidth restrictions and high demand for a shared digitial transmission medium (network) can slow or prevent successful transmission of images. Other problems with efficiency exist. A packet-switched network such as Ethernet has sufficient speed for networking multiple hosts, 10 megabits/second. However, transmission of large amounts of data such as digital images is slowed at the interface to the network by encoding and error-checking steps built into the transmission protocol.

Future work on this topic will center on the optimization of digital processing of images. Digital image compression techniques are being investigated by a number of firms for commercial and military applications. Digital packet-radio transmission and the problem of interfacing networks with massive storage devices such as optical laser discs are the subject of ongoing investigation at several institutions and at MIT's Media Laboratory, at Project Athena, and at the Computer Resource Laboratory.

2 Electronic Image Storage

Electronic storage of images can be divided into analog and digital formats.

2.1 Analog Storage formats

In analog storage, the shape of the waveform used to reproduce an image is stored. Retrieving an image stored in analog format involves reconstructing the waveform from its representation on the storage medium. There exist different analog formats for the storage of video images. In the United States, nearly all analog storage devices and media store NTSC format video signals.

Two familiar types of analog image devices are videotape and videodisc. These are primarily designed to store a particular type of analog signal, such as NTSC or PAL formats.

Some storage methods can provide only *linear access* to the images which they store. For example, a magnetic videotape must be searched in a linear fashion in order to locate a desired segment. Linear access devices such as videotape are commonly used for the purposes of storing large amounts of analog data. However, for automated storage and/or retrieval, linear access storage methods are generally not adequate. *Random access* devices are better suited.

Because random access devices allow direct access to any single frame of a sequence of video frames, they are useful for large-scale storage and interactive retrieval. Laser videodisc players are the most common type of random access storage devices. A laser videodisc is randomly accessible because any particular frame of the video signal stored on the disc may be individually retrieved by specifying its unique frame number.

2.2 Digital Storage Formats

Digital storage differs greatly from analog storage. To store an image digitally, it is first necessary to convert it to a series of numbers which contain information about all of the parts of the image. These numbers are in turn represented as a stream of ones and zeros, and thus form a digital data stream. Since computers and many related devices are designed to work with digital data, digital image formats work well for storing and manipulating images.

Digital storage devices are designed store any kind of digital information. Images stored in digital formats can usually be manipulated in the same ways as can any other digitally-stored information.

Because the information in a digital image must be broken down into many pieces of information, digital images typically require very large amounts of storage space in comparison to other types of digital data. The greater the resolution of an image, the greater the number of discrete pieces of information that must be stored.

Magnetic disks are common storage media for digital data. They are made of metal or plastic, and are coated with a material capable of being magnetized by a disk drive. They exist in many forms, and have varying storage capacities. A floppy diskette used with a small computer may have a capacity of 1 Megabyte of data, while a disk pack used on a large computer system may have a capacity of 1000 Megabytes or more.

Read-only optical disks are also an effective means of storing large amounts of data. Read-only disks must be produced in quantity by a manufacturer of optical media, and are therefore best used as means of distributing large databases of information.

Write-once optical disks are used increasingly for storing digital data. Such disks may hold 170 Megabytes to as much as 2000 Megabytes of data apiece. Their extremely large capacity suits them to the storage of large amounts of data.

An important feature of most digital storage media is that they provide random access to the data which they store. That is, information can be retrieved on demand without regard to its physical location on the storage medium. Hence, most large capacity digital storage devices work well for the interactive storage and retrieval of images encoded in digital formats.

3 Modes of Image Transmission

Here three important means of electronic image transmission are discussed.

3.1 Electromagnetic Broadcast

At present, most television broadcasts in the United States are of analog video. Electromagnetic waves are emitted by a single transmitter, and are received by any number of local receivers. A signal may also be beamed to a satellite and then broadcast directly to receivers on the ground.

Broadcast signals travel by electromagnetic waves. The electromagnetic frequency spectrum is divided into many *channels*, each of which carries one analog video signal. The amount of information that each channel can carry is called its *bandwidth*.

Digital signals require a much higher bandwidth than analog signals. That is, they require a greater share of the electromagnetic frequency spectrum than analog signals containing an equivalent amount of information. As a result, when transmitting images by means of electromagnetic broadcast, it is more efficient to transmit analog signals.

Another method for transmission of analog video signals is point-to-point microwave link. Microwaves are electromagnetic waves with shorter wavelengths than those used for conventional television broadcast. A special receiving station is needed to pick up a microwave broadcast. Since microwaves do not propagate well, transmitter and receiver must be placed in a direct line of sight.

Microwave transmission works well for communication between two locations, over relatively short distances. Standard electromagnetic broadcasts are generally intended for public use, and are therefore not well suited to the uses of interactive image access. Microwave broadcast systems, however, are generally closed, and intended for communication between two specific points. A microwave link connects MIT to Harvard University.

3.2 Cable Television

In the same way as electromagnetic waves can be used to transmit more than one video signal, a cable link may also carry multiple signals. Just as the airwaves can carry several video signals at once, the frequency spectrum of a cable is also divided into a number of channels.

Cable television systems use a cable to connect remote receiving sites. An advantage of a cable system is that it does not use public airwaves, and is therefore well-suited to the purpose of transmitting images in a local context. Many such systems exist commercially in the United States. At MIT, a cable television system spans the entire campus, allowing campus-wide access to several video channels.

3.3 Digital Data Network

A digital data network is used for transmitting digital information. It allows many users and many computers to communicate simultaneously. For a network in which several computers are linked, each computer may use the network for only a fraction of a second at a time. To allow smooth use of such a network, a *packet-switched* concept is used. In a packet-switched network, computers send small "packets" of digital data. Large data transmissions are broken up into many packets. Packets on a data network typically have a maximum size of approximately .5 Kilobytes – equal to 500 characters of data. Although the transmission of individual packets occurs extremely quickly, the rate at which packets may be sent varies with the number of computers competing for the use of the network. A network is said to be "slow" if enough computers are using it at once to cause noticeable difficulty in sending packets of data.

To transmit an image over a digital network, the image must first be converted to a digital format. There are many formats and algorithms for the digital storage of images, but each format results in a simple digital data file. The size of digital image files typically varies between 50K (Kilobytes) and 500K. Thus, transmitting a single digital image requires sending between 100 and 1000 separate packets on the network.

Fiber-Optic Cable

A fiber-optic cable system uses laser light to carry signals through extremely fine glass threads. An advantage to a fiber-optic link is that it has an extremely high bandwidth. That is, it can be used to transmit information at a higher rate than an equivalent electromagnetic or metallic medium. Its high bandwidth makes it ideal for both analog and digital data transmission. It is especially well suited for use as part of a packet-switched data network.

At MIT, the data network which ties together the computers on campus uses a fiber-optic cable as its "spine". This cable runs the entire length of the campus, and allows high-speed digital communication between computers through the use of a packet-switched system.

4 Experiments and Test Scenarios

4.1 Storage, Retrieval, and Transmission of Digital Images

Several time tests were done to analyze the speed of various modes of storing, retrieving, and transmitting digital image files. Digital files were obtained by using two different commercially available hardware products to digitize standard video images. The smaller size digital image file was obtained by using an Image Capture Board (ICB) from American Telephone and Telegraph, Inc. to digitize a still-frame video signal. The larger file was produced in the same way using a Truevision Advanced Research Graphics Adaptor (TARGA 16) board, manufactured by the same company. Sample file sizes representative of different digital storage formats were chosen for study. Few digital image files are smaller than 50K in size, while no more than 500K of space is needed to store the amount of information in one frame of NTSC video.

The image storage times were significantly better for the hard disk drive than for the floppy disk. Hard disk drive access time was never longer than 2 seconds for any operation. Storage times on the write-once optical disk were slightly longer than those for hard disk, but never exceeded 3 seconds. Overall, retrieval time for an image was always shorter than the storage time for that image.

The storage and retrieval of the 50K image files always required less than half the time required for the 500K files, and usually less than one third of the time.

The next phase of this experiment involved transmitting the digital files over a digital packet-switched network. The Unix ftp (file transfer protocol) program was used to transfer the files over the fiber-optic data network. The experiment was performed between 10:00 am and 11:00 am, since the network load at this time is representative of average usage levels.

The test showed that a 500K file was too large to transmit reliably on a packet-switched network that is being used by multiple hosts. [1] The transmission times for the smaller (50K) file were still quite long – averaging 12 seconds.[2]

Lastly, the same files were stored on a Remote Virtual Disk (RVD) system, and timings were taken for RVD access to the files. The larger file required 30 seconds to transmit to the hard disk of an IBM Personal Computer. The smaller file required only 1 second. It is interesting that the RVD method, which uses the same data network as the `ftp` method, performed as well as it did in comparison with `ftp`. RVD uses a different protocol and different software from `ftp` and therefore encountered fewer errors during the file transfer process. Despite the successful transfer of the larger file using RVD, that method of image storage would still prove to be prohibitively slow in the context of an interactive Image Delivery System.

The results of all time tests are presented in Table 1.

4.2 Remote Access to Still Images Using Cable Television

To test the analog transmission of video signals using a direct cable-television link, the MIT cable television system was used. The connection of a videodisc to the input for cable television Channel 8 allowed the transmission of still NTSC video images to any place on campus.

Transmitted image quality was excellent; in general it was indistinguishable from the pre-broadcast signal. Because the cable system is designed to

[1] In work at the National Library of Medicine, G. Thoma has demonstrated that transmission of files on the order of 500K in size can occur in less than 3 seconds on a network which is dedicated exclusively to the transfer of data between two machines. Here, the problem was caused by the error rates encountered when the network is being used by many more than two machines.

[2] Times for network transfer are generally the same for transfer in either direction (from a PC to a mainframe, or vice versa). This is because the speed of the network is the limiting factor, not the disk access time required to retrieve the image to be transmitted.

Experiment	File Size	Average Time
Writing to floppy	500 K	7 sec
	50 K	1 sec
Reading from floppy	500 K	7 sec
	50 K	2 sec
Writing to Hard Disk	500 K	2 sec
	50 K	.5 sec
Reading from Hard Disk	500 K	1.5 sec
	50 K	.5 sec
Writing to WORM Drive	500 K	3 sec
	50 K	2 sec
Reading from WORM Drive	500 K	3 sec
	50 K	1 sec
Network TCP/IP Transfer	500 K	N.S.
	50 K	12 sec
Network RVD Transfer	500 K	30 sec
	50 K	1 sec

N.S. = Not Successful.

Table 1: Digital File Transmission Time Tests

transmit video signals at a rate of 30-frames per second, the transmission time for an analog signal was instantaneous.

The experiment used various images of library architecture including views, drawings and plans. While these images were being transmitted and broadcast, an experiment was set up to test the effectiveness of locally digitizing images from the cable broadcast. The cable television signal was connected directly to the appropriate digitizing hardware (described above). This allowed for the digital storage of images that were received from the cable system. In this way, 40 images were captured and stored digitally on a WORM Optical Drive.

During the next phase of the experiment, requests for images were made using the digital data network that links MIT's campus. The videodisc player was connected to an image server workstation. [3] This server allowed a user to operate the videodisc player from across campus, viewing the results by way of the cable link. The images could then be digitized and manipulated in the same way as before.

From this experiment, the concept of an Image Delivery System (IDS) was developed. This system was implemented and is described in detail in Section 5 of this report.

4.3 Microwave Transmission as an Analog Alternative

A point-to-point direct microwave broadcast link operates between the campuses of MIT and Harvard University. Its primarily use is transmitting live programs between the two campuses. Such programs may be broadcast on the cable network of the campus at the receiving end of the transmission.

A videodisc player provided an analog signal of a still architectural image for use in testing the transmission of still frame video images between the two campuses.

For the first experiment, an image was transmitted from MIT to the remote station at the Harvard campus. The signal was looped back and transmitted again in the other direction, to be received at MIT. It was then broadcast on MIT cable television channel 13.

[3] see Section 5: A Delivery System for Still Images.

The quality of the image was extremely good; the received signal was indistinguishable from the original signal from the videodisc player.

For the second experiment, an IDS workstation[4] was set up at Harvard with a connection to MIT's digital data network. From the workstation, requests were made for videodisc images by typing frame numbers of desired frames. As each request was typed, the images were broadcast from MIT to Harvard, where they appeared on a nearby monitor. The time involved was minimal; transmission to the site 2 miles away was instantaneous.

Use of a closed point-to-point microwave link to transmit single still images could extend the reach of the analog component of an Image Delivery System.

5 A Delivery System for Still Images

A system proposed here is one which allows any number of users at individual workstations to access, interactively and simultaneously, the same database of stored images. Such a system could be used by students whose assignments include visual familiarity with a set of images, professors who wish to present images to their students in a classroom environment, speakers who wish to illustrate a lecture with visual images, or researchers whose work requires interactive access to databases of stored images. User-end workstations could be located in classrooms, offices, research laboratories, libraries, lecture halls, or wherever such access is desired. Additionally, portable workstations could be moved to any location which has links to the appropriate networks.

During the experimentation phase of this project, an Image Delivery System (IDS) was designed and implemented which allows interactive remote access to a database of images. Here, the description of such a system is presented.

5.1 Design Overview

The IDS makes use of two data distribution systems: one for digital data, and another for analog video signals.

[4]see Section 5: A Delivery System for Still Images

Requests for images are communicated from system workstations using the digital data network. The workstations are linked to a cable television system which is used to access images that have been retrieved from a laser videodisc player.

The heart of the system is its image server. The server's job is to listen to the data network, waiting for a request for an image. When such a request is received, the server causes the videodisc player to retrieve the appropriate image. The image is then broadcast over the cable television system.

When the appropriate images appear on the analog line, they can be displayed to the user, stored digitally, or manipulated by the software that is running on the workstation.

5.2 An Prototype Image Delivery System at MIT

The Image Delivery System as it is implemented at MIT uses the campus-wide fiber-optic data network for the communications link between the local workstations and the image server.

For analog transmission of retrieved images, a dedicated channel on the MIT cable television system is used. This system, which already extends broadly throughout the campus, proves ideal for use by the IDS.

5.3 An Image Server Daemon

The physical link between the fiber-optic network and the videodisc player is a MicroVAX II, running the UNIX operating system.

The multi-process capability of the MicroVAX allows it to run programs which will operate without disrupting other activities of the machine. Such a program, called a *daemon*, runs without being noticed by users of the machine, but performs a desired function when needed.

The image server daemon is a simple program which receives an instruction packet from the data network, and communicates instructions to the videodisc player. The player in turn broadcasts an image over the cable television system. When the image server daemon is running, the IDS is ready for use by any workstation on the network.

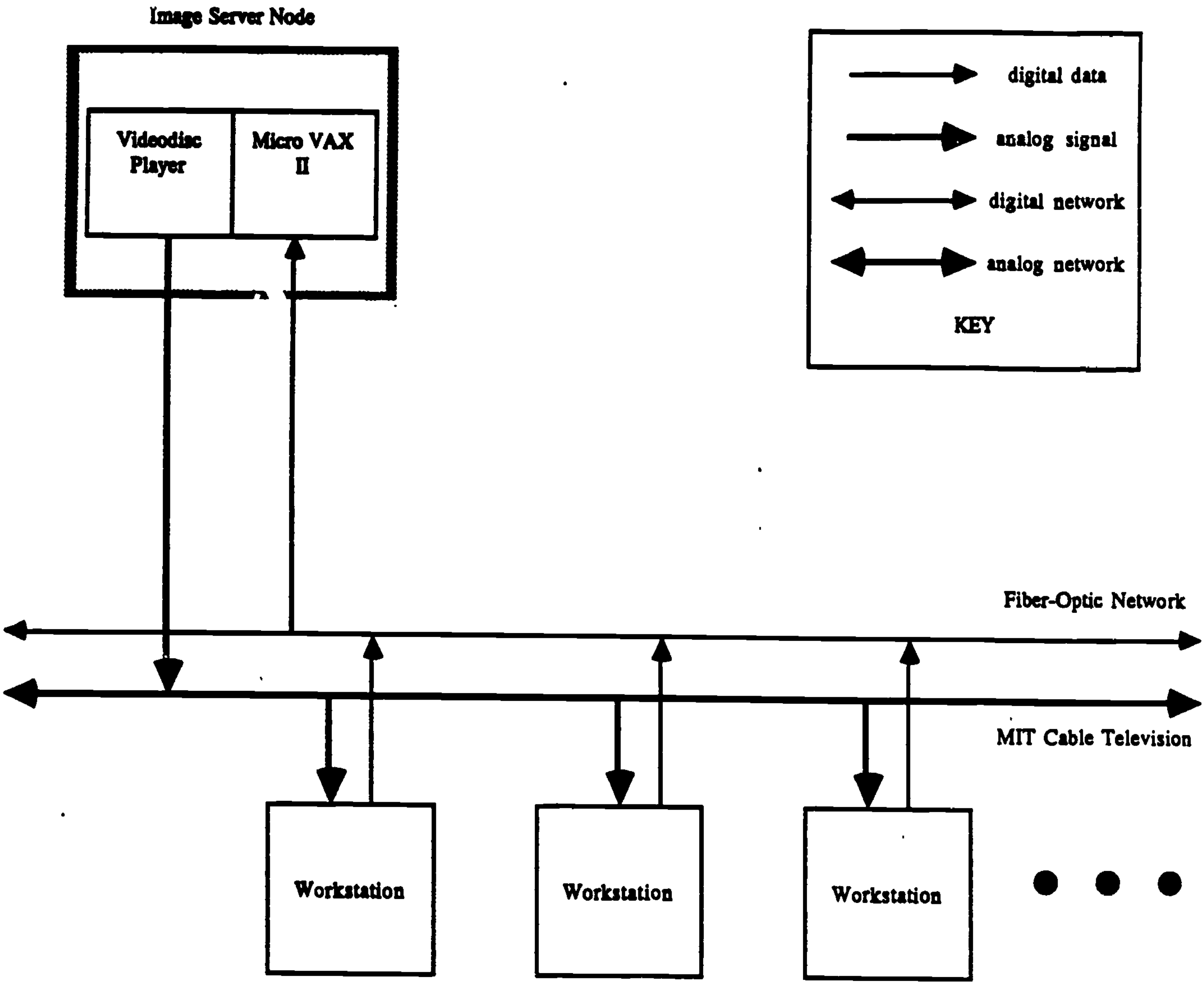

Figure 1: MIT Image Delivery System

5.4 Providing a Visual Database on Videodisc

The IDS functions by accessing a database of video images. An analog videodisc, with the capacity to store over 54,000 separate full-resolution NTSC images, provides a bank of video images for use by the system.

Each of the images on such a disc is identified by an index known as its *frame number*. Videodisc players can search and retrieve any such image on a disc. Sending the videodisc player a five-digit frame number will cause the player to select that frame on the videodisc and provide a continuous NTSC signal of the frame.

For the IDS, a Sony LDP-1000A videodisc player was linked to a computer using a standard RS232 communications port. Computer commands were sent directly to the player to retrieve images stored on a videodisc. The output from the videodisc player was connected to the cable system, with the resulting video signal from the player broadcast campus-wide.

5.5 A Typical Workstation

A workstation using the IDS may be simple: for example, the simplest workstation would allow the user to type frame numbers and view the corresponding images by watching cable television. A more complex workstation might request an image, verify its arrival over the cable system, and then digitize it, store it, and display it for the user.

The latter configuration is necessary when many users will be using a single videodisc database simultaneously. Because the workstation maintains its own copy of an image, the delivery system remains free to field requests from other workstations without interfering with a user's viewing of a retrieved image.

Depending upon the software and hardware capabilites of the workstation, a digitized ("captured") copy of an image could be manipulated by the user or by the software running on the workstation.

5.6 An Application Program Using the Image Database

An Image Delivery System proves useful for study in fields such as architecture and urban planning, for which visual images are an important resource.

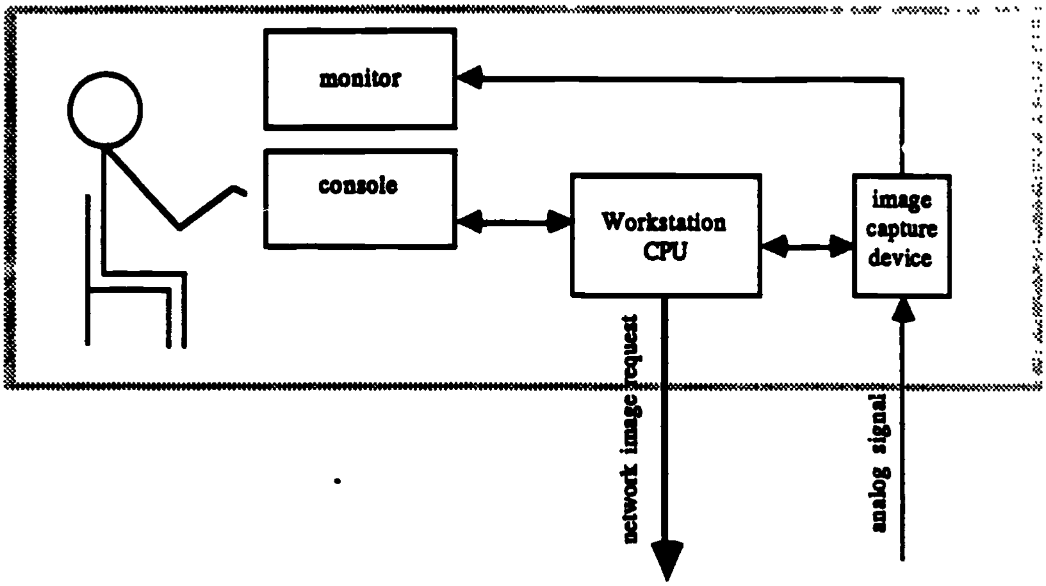

Figure 2: IDS Workstation Diagram

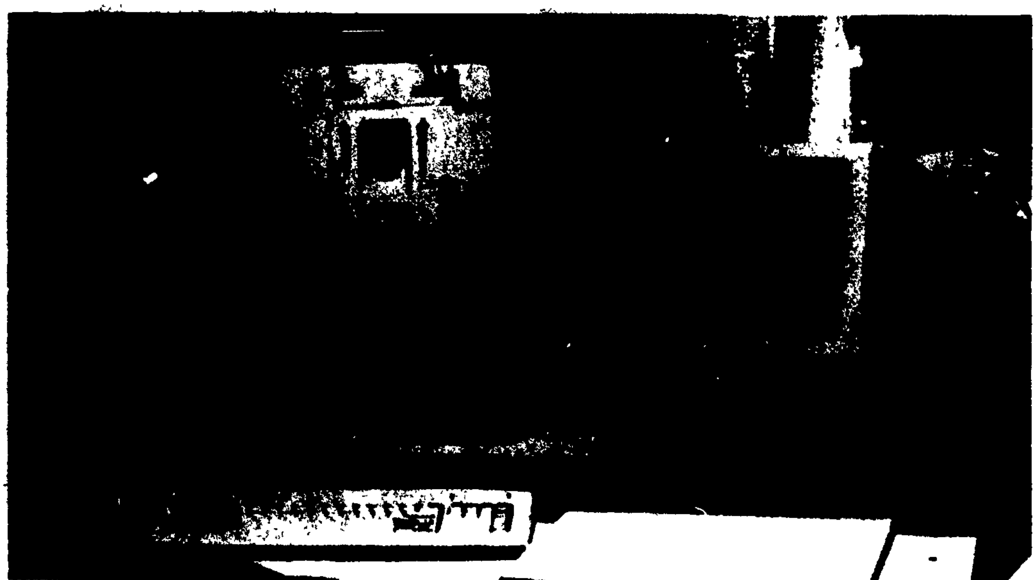

Figure 3: Photograph of typical IDS workstation

Figure 4: Detail of monitor showing retrieved image

Applications of laser videodisc technology to the needs of these two fields have been researched at MIT.

The Boston Project, a research project of the MIT Rotch Visual Collections, provided an architectural database which has a strong visual component. The database for the project consists of over 7,000 data records for architectural works in the city of Boston. Each record in the database indexes a visual image of Boston architecture and urbanism. The visual portion of the collection is stored in analog format on a laser videodisc; the textual record for each image is maintained in a digital database.

The Boston Project database was adapted for use in a UNIX environment, operating under the database management system Ingres. Through interactive commands, the user queries the database and selects a record with its associated image.

Workstation software then sends the image request over the network. Almost instantly, the image appears on the video monitor at the workstation. The user is presented with a live video image of a still frame.

Currently, this simple program does not digitally capture or store the retrieved image. However, as noted above, the use of a commercially available Image Capture Board would provide this capability.

Using the Boston Project image database in conjunction with the IDS, campus-wide access to architectural images has become a reality.

6 Conclusion

Several modes of storing and transmitting images have been explored.

As large-scale digital data storage becomes more readily available, digital storage of image databases will become increasingly practical and more commonplace. Currently for visual image storage, especially for full-color images, systems that store conventional analog video signals are more available than digital storage systems, and are more compatible with existing technology.

In this study, analog image transmission has proved more efficient than digital transmission for two reasons. First, the technology of digital image broadcast is still young, although various methods of efficient digital broadcast are currently being explored. Second, the transmission of image files over non-dedicated digital data networks is significantly slower than transmission of the same images using analog methods. The advantage to be gained by using analog transmission is speed: faster retrieval of images allows greater possibility of user interaction with image databases.

An Image Delivery System (IDS) has been proposed which makes use of a digital data network for inter-host communication and an analog network for the transmission of images. An image server handles requests for images, which are stored on a laser videodisc. The images are distributed by being broadcast over the analog network.

A scenario is envisioned in which many local computer workstations use the Image Delivery System. Each would have the capability to store an image retrieved by the system, and to present that image to the user in any of several ways. The workstations could be located wherever needed, and could be used simultaneously by independent users.

A Glossary

amplitude – the magnitude of a waveform signal.

analog signal – a signal which consists of a waveform which can vary subtly both in amplitude and frequency.

bandwidth – an expression that corresponds roughly to the amount of information which can be transmitted over a channel. For example, to transmit a digital signal at a high baud rate requires a high bandwidth. Transmitting an analog NTSC video signal requires a much smaller bandwidth than transmitting a digital signal.

baud – bits per second. (data transmission rate) *see also:* Mbps,Kbps.

bit – the smallest piece of digital data. Usually represented as a 1 or a 0. *see also:* byte.

byte – a piece of digital data usually composed of 8 bits. Common unit for the size of a set of digital data. *see also:* kilobyte, megabyte.

digital data – data which is represented as a series of ones and zeros.

digital signal – a signal consisting of discreet values representing digital data.

disk drive – electronic equipment which allows the retrieval of data stored on a magnetic disk.

disk pack – a stack of large metal magnetic disks. Most often used with large computer systems.

DRAW disc – Direct Read After Write laser videodisc. An analog videodisc which may be written once, and only read thereafter. *see also:* WORM disc.

Ethernet – The brand name for a 10 mbps packet-switched network system marketed by 3COM Incorporated.

fiber optic cable – a thin strand of optically pure glass which can be used for communication by transmitting signals of laser light

floppy diskette – a magnetic disk for small computers. Consists of a mylar (plastic) sheet which is coated with a magnetic material. Typical capacities for floppy diskettes range from .3M to 1.3M.

frequency – (of a waveform) the number of wave crests arriving per unit time.

frame – a single still video image. Motion video is composed of many still frames being played quickly in succession. *see also:* frame number.

frame number – the unique number of any single frame on a videodisc.

frame rate – the rate at which single frames are played in order to produce motion video. For NTSC, the frame rate is 30 frames per second.

IBM DOS – a Disk Operating System created by International Business Machines Coroporation for use with IBM Personal Computers. *see also:* UNIX.

IDS – Image Delivery System.

Kbps – KiloBits Per Second. (data transmission rate) *see also:* baud,Mbps.

ekilobyte – one thousand bytes of digital data. Abbreviation: K. *see also:* megabyte.

LAN – Local Area Network. A packet-switched network which allows a group of computers to communicate with one another via high-bandwidth cables over a small geographic distance.

LDP-1000A – Model of videodisc player produced by Sony Corporation. Can be controlled by a computer via an RS232 cable.

linear access – a mode of storage in which stored data must be accessed by passing over all preceding data on a storage device until the desired data is found. *see also:* random access

Mbps – MegaBits Per Second. (data transmission rate) *see also:* baud,Kbps.

megabyte – one million bytes of digital data. Abbreviation: M. *see also:* byte, kilobyte

NTSC – National Television Standards Committee format for analog video transmission. This is the standard that is used in the United States.

operating system – the program which allows a computer to run. *see also:* UNIX, IBM DOS.

optical storage – use of data storage devices which record information that can be read using a laser.

packet-switched network – a data communication network which operates by allowing the sending of small "packets" of data from one machine on the network to another.

pels – picture elements. The smallest piece of information in an image. Corresponds to a single "dot" on a display device.

random access – a mode of data storage which allows direct access of a particular segment of data without reading or accessing other data also stored on the same medium. *see also:* linear access

resolution – a measure of the number of pels in an image. The approximate resolution of an NTSC image is 500 pels by 500 pels.

RS232 port – communications device allowing one machine to communicate to another. For example, a computer might communicate commands to a videodisc player via the player's RS232 port.

RVD – Remote Virtual Disk. A magnetic data storage disk which may be used by machines other than the one to which it is attached. To the machines which use it, the remote disk appears to behave in the same way as local disk drives. Often implemented in a networked environment.

server – general term for a device which is responsible for fielding requests for various services to be performed. An *image server* delivers images from a database by processing user requests.

TCP/IP – one common protocol for communications between computers that are connected to a single network.

UNIX – an operating system for multi-user machines that was developed by Bell Laboratories. *see also:* IBM DOS.

videodisc – format for analog video storage. An analog signal is encoded by means of tiny impressions in the surface of a metallic disc, and is reproduced by a videodisc player.

workstation – a terminal or computer which interacts with a user in order to provide access to a particular application program.

WORM disk – Write-Once Read-Mainly optical laser disk. An optical storage device that may be written once and read many times. Used to store digital signals. *see also:* DRAW disc.

WORM drive – Write-Once Read-Mainly optical laser disk storage device.

B Related Work

Associated Press Research and Development Division – The Associated Press transmits hundreds of black-and-white or color-separated photographs around the world on a daily basis. Images are generally selected by a central office and then transmitted to regional offices. The images are scanned at approximately 200 lines per inch, and require about 3 Megabytes of storage space. These images require about 8 minutes to transmit over conventional leased telephone lines using an analog signal. In most cases, the signal is converted directly to hard-copy as it comes over the line. Current research involves re-digitizing an image once it is received, manipulating that digital image, and storing it using optical storage devices. Work is also being done to study the direct transmission of images via satellite; however this method is not currently widely used to reach many remote sites because the technology to allow these sites to receive such a transmission is too expensive to become standard.

National Bureau of Standards – The Computer Storage Media Group is investigating the development of standards for optical image storage methods, including optical laser disk and microfilm. Interactive CD ROM disks provide interactive access to databases of digitized images. Additionally, interactive computerized storage and retrieval systems for microfilm are being developed. Microfilm systems will be able to store upwards of one million images, and transmit them on demand. Also under investigation are standards for digital data interchange and methods for the digital scanning of images. Currently there exist several international standards for facsimile transmission of images. Work is being done to develop new facsimile standards which will take advantage of advances in storage and transmission technology.

MITRE Corporation – Under study are electronic workstations that allow a user to manipulate text and images in a highly interactive fashion. Because of the many types of images that these systems will need to manipulate, including video, and high-quality medical images, the workstations have been developed to store and transmit images digitally. These images have been high-quality high-resolution images, often from the medical field. The transmission times for these large image files has proven to be quite long – on the order of ten seconds per image in some cases, although current work is aimed at improving transmission times by exploring data compression and other techniques.

University of Pittsburgh – As part of the Univeristy's "Campus of the Future" project, a system has been set up in which single still images are made interactively accessible from remote sites. Images are stored in analog format on videodisc or NTSC videotape, transmitted digitally via a campus-wide fiber-optic data transmission network, reconverted to analog signals, and displayed to the user. A user with a keypad may request images by specifying their videodisc frame number or NTSC time code. Currently twenty-one classroom sites are equipped with the system, and more sites will be added within the year.

Library of Congress Optical Disk Pilot Program – The Optical Disk Program studies the use of optical disk technology for large scale storage of images. Both analog disc and digital disk storage of text with images are considered. High-speed scanners digitize pages of journals and books at a resolution of 300 lines per inch. The resulting data is compressed and stored first on magnetic disk and then transferred to twelve-inch optical DRAW disks. Each disk holds 10,000 black-and-white images of pages of text and associated photographs or diagrams. A "jukebox" capable of storing and accessing 100 disks serves as the player to provide access to more than 300,000 documents. Since January 1986, 6 public user stations throughout the library are linked directly to the main video system controller. Library users can search a bibliographic database and retrieve full-resolution black-and-white images of scanned documents. Access time varies from about 25 seconds for an initial search while a disk is selected and spun up on the jukebox to 2 seconds per page as a user reads through an article. A "Non-Print" Project tested analog videodisc storage for visual images such as photographs, drawings, and music. The transmission of these analog images was not investigated.

Gannett – The Gannett Newspaper Group provides an interesting example of the way in which the newspaper publisher is availing of the technology of image transmission, as an integral part of both distribution and printing operations. The entire daily edition of USA TODAY is transmitted via satellite from Arlington VA to thirty printing plants serving major market clusters across the USA and to two printing plants located in Europe and Asia.

The transmission of images is handled by an advanced facsimile/satellite network. The facsimile equipment is capable of extremely high resolution with scanning lasers that slice up the page into a grid having a resolution of 1.68 million picture elements per square inch, (1,200 lines horizontally and 1,400 scan lines vertically). This precision provides color half tones of magazine quality, with screens up to 150 lines per inch.

Black and white pages are are sent in one transmission, taking about three and one half minutes. Color pages require four seperate transmissions; one each for red, blue, yellow, black. Each of the individual color transmission takes from seven to fifteen minutes. As the image is being scanned at the transmit site the electronic signal carrying the page data is being sent to the satellite and broadcast back simultaneously to the individual printing sites.

Apart from transmission, computers are used extensively to monitor the entire process, including quality control.

USA TODAY was designed around computerized image creation, processing, production and transmission technologies.

National Library of Medicine – The Library has built a prototype system for electronic scanning, digitization, storage, retrieval, and display of images of biomedical documents. Journal articles are scanned, the resulting signals processed for storage on magnetic or optical disk. Access to the images is by means of searching a conventional bibliographic database. A CATLINE (MEDLARS) database system is used. Retrieval and display of the digitized pages corresponding to the citations is rapid, requiring only 3 seconds for black-and-white images at a resolution of 200 lines per inch. The file size for a single image is 500 Kilobytes. The prototype point-to-point system is controlled by a PDP-11/44 processor with specially written compression software. A recent configuration uses an Ethernet data network to retrieve images from the disc and display to a video monitor.

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