DIGITAL IMAGING TECHNOLOGY ASSESSMENT

Digital Document Storage Project

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1. INTRODUCTION AND EXECUTIVE SUMMARY

An ongoing technical assessment and requirements definition project is examining the potential role of digital imaging technology at NASA's Scientific and Technical Information (STI) Facility. Produced as part of that effort, this report focuses on the basic components of imaging technology in today's marketplace as well as the components anticipated in the near future. It contains a requirements specification for a prototype project, an initial examination of current image processing at the STI Facility, and an initial summary of image processing projects at other sites.

A number of projects to implement document imaging technology have encountered serious difficulties, received press attention, and defined document imaging as a risky endeavor. As will be seen from a reading of the detailed sections, this reputation is deserved. There are many opportunities for poor requirements or design specification of an imaging application to lead directly to a dysfunctional system. This danger is particularly acute for the STI Facility, because some of the STI Facility's requirements involve features not addressed directly by the mainstreams of today's marketplace.

Operational imaging systems incorporate scanners, optical storage, high-resolution monitors, processing nodes, magnetic storage, jukeboxes, specialized boards, optical character recognition (OCR) gear, pixel-addressable printers, communications, and complex software processes. The best way to ensure that specifications for the STI Facility are succinct, accurate, *and verifiable* is to proceed with a prototype implementation. Many complex interactions can be effectively tested and specified operationally in a prototype mode that would otherwise require extensive mathematical modeling and analysis. STI Facility processes that are revealed by prototyping to be critical can then be thoroughly quantified. The prototype can be used to extract formal requirements for a production installation of image technology at the STI Facility. Prototyping experience will be invaluable to assist a more detailed consideration of and a data interchange with related projects within NASA, other government agencies, and related organizations. Based on effective prototyping, a production implementation can be specified and pursued confidently and efficiently.

Several fundamental attributes must be present in any successful implementation of imaging at the STI Facility:

- *Image quality*, when the STI Facility's system results are delivered to users, must be perceived by them as an acceptable approximation of original document quality.
- Both *system throughput* and total *system capacity* must be appropriate for the scale of operations at the STI Facility.
- The *stochastic properties* of requests arriving at the STI Facility must be met by an imaging system with appropriate response timing and throughput.
- A *seamless integration* between imaging technology and existing Facility processes must be achieved.

In the case of *image quality*, difficulty is manifested primarily by the numerous halftone originals in NASA's scientific and technical literature. When most digital scanners record halftone originals using typical parameters, optical phenomena cause the introduction of periodic distortions (moirè patterns) to the digitized images. In many cases, these distortions make it difficult to perceive original image details. Given NASA's policy that images included in technical reports must contribute to the technical content of the document, this degradation has potentially serious consequences for the quality of imaging products from the STI Facility. The typical response to aliased halftones[1] in today's marketplace is to ignore them, because the predominant demand for imaging systems comes from processing office documents—and *they* contain very few halftone originals (see section *3.2.2.5.3. Halftone*).

System throughput and *system capacity* requirements can be met by configuring larger units or by interconnecting a larger number of smaller ones. It is comparatively straightforward to ensure *system throughput* under these circumstances, but *caveat emptor*—let the buyer beware—image processing requires multiple processing steps and vendor and integrator specifications typically address only a few of them (see the throughput comments in each section). Often, the steps omitted from specifications require more time than those included.

Stochastic properties represent a major challenge to image system designers. Most existing imaging applications fail to accommodate stochastic behavior well, and several projects have been configured to eliminate them altogether through very expensive equipment configurations. Vendors virtually never provide complete enough specifications to assess responses to stochastic variations; in fact, they concentrate heavily on selling products based exclusively on stationary attributes where imaging products *appear* to offer competitive advantages over alternative technologies. One of the most striking examples of this behavior is the selling of optical disks on capacity and cost per gigabyte of the storage media alone; initial equipment investments are not figured into the cost estimates, and data access is addressed, if at all, through the wholly inadequate notion of *average* response time. Another is the relative silence in the marketplace on the comparative inability of today's LAN technology to address imaging applications (see section *3.2.4.4. Optical Disk Drives* and section *3.2.7.5. LAN Technology*.)

The overwhelming impression from surveying the marketplace is that the basic technology required to provide a *seamless integration* to meet the STI Facility's requirements is currently available, but not from one source. The desktop publishing arena emphasizes image quality. The office imaging community addresses throughput. A wide variety of capacity and response alternatives can be purchased, but buyers must be able to assess the alternatives themselves; the marketplace competes elsewhere. Scientific imaging specialists have developed algorithms that, if properly configured, promise to tie the other system components into a functional

1 Aliasing, in imaging technology, refers to the ability of optical systems to see and record phenomena that do not exist in the objective world; thus, aliasing is somewhat akin to an optical illusion or mirage. An aliased halftone is a digital representation of an original halftone that contains features, the moirè pattern, that were not present in the original image, but that were perceived by the optical recording system as though they were present in the original.

whole. Communications technology requires special attention; it appears to be the only technology with intrinsic weaknesses in the support of imaging applications. Here, the most viable strategy is a carefully studied reliance on open systems concepts to achieve a well engineered positioning of currently available components designed in advance to absorb new alternatives as they emerge.

The *cost* of a complete imaging system will not be available until the detailed requirements are determined later in the project. The component costs given in this report indicate that cost-effective alternatives are available.

The remaining sections of this report address the salient aspects of the STI Facility's consideration of imaging technology. Essential conclusions and the relationship between the sections and the attributes discussed above are presented in the introductions preceding each section. The sections have been sequenced to place the most substantive recommendations and findings first. A more tutorial presentation of subject matter may be achieved by reading the sections in reverse order.

Section 2, **Requirements Specification**, discusses image processing in general and presents recommendations on how to proceed with a prototype digital imaging installation at the STI Facility.

Section 3, **Imaging Technology**, addresses the major equipment and functional components of imaging systems and describes how each should contribute towards the system attributes needed for a successful implementation at the STI Facility.

Section 4, **Image Processing at the STI Facility**, analyzes the Facility's production flows as they relate to image processing. This section provides the underlying quantification of STI Facility operations against which candidate image solutions will be judged.

Section 5, **Image Processing at Other Sites**, characterizes the potential for identifying relevant successes with imaging technology and applying their solutions at the STI Facility. Projects are included on which details sufficient for an architectural characterization have been published.

2. REQUIREMENTS SPECIFICATION

2.1. Introduction and Summary

On the surface, the creation of a digital image management system does not seem overly complex: combine state-of-the-art graphics, text, scanning, database, and networking technologies with on-line magnetic and optical disk media. Such systems allow for the storing of all documents as images—even those documents with nontext information, such as photographs and line drawings. Stored on either optical disk or magnetic media, these images can then be automatically retrieved in a matter of seconds. Such systems allow documents to be:

- stored at high densities to reduce space and storage retrieval costs
- permanently and securely archived
- retrieved rapidly
- filed using cross-indexing
- always available for use
- made more secure.

To achieve such a system, however, the critical issue of network topology design must be solved. Though choosing the specific equipment components (such as a scanner, optical disk drive, and high-resolution workstations) may be relatively straightforward, taking into account the factors of peak load times, specific device characteristics, image management, and the user's expectation of the system is not.

A prototype implementation leading to an open-architecture production system is recommended. Operational specifications can be developed by executing or modeling real portions of production processes. The time-consuming applications of detailed analysis and mathematical modeling can be focused on precisely those portions of the intended system that demonstrably require such effort.

2.2. Functional Model

Regardless of the actual configuration of the digital image management system, an open-architecture system approach should be used. Open-architecture systems are designed for flexibility and future modification. They allow for a wide choice of various hardware and software components and use standardized communication protocols. Access to internal components is usually provided so specialized circuitry can be added. Software is usually well documented so changes can be made easily in the future.

On the other hand, closed-architecture systems are usually sold as a complete unit without providing for modification and offer little documentation for end-user alteration of software. Even though such systems are usually less expensive initially, one must consider the lifetime of the system. Because closed-architecture systems do not provide for future needs of expansion and modification, they usually must be replaced when requirements change. The degree to which a system truly has an open architecture depends on the ability of the end user to provide for modifications and budget considerations. For example, adding a new hardware component on one system may require the addition of a new interface card and device driver, while another system may only require the modification of existing driver software.

Some vendors have suggested using a centralized processing system. Such approaches have a control computer monitor or perform all data processing tasks while peripherals have little or no processing power of their own. Stand-alone turn-key workstation systems usually adopt this strategy. They consist of a scanner, printer, and optical disk drive all to be controlled by a single PC. This approach is not recommended for the STI Facility. Such configurations are good only for small office environments and offer little room for expansion or modification. Furthermore, multitasking is not easy to implement, thereby reducing the potential for full simultaneous use of individual peripherals.

Another configuration based on central processing involves the use of the existing IBM 4381 mainframe at the STI Facility. Such a system would have all workstations and peripherals attached directly to the mainframe or to a LAN connected to the mainframe, using 3270-type emulation. This approach has the benefits of central access, security, application integrity through central control, and a large, shared database. The mainframe, however, will be required to service the workstations in addition to its regular activities. It will also handle the communication processing power for the entire imaging application, which contain very large files. Peak workloads on the imaging system will severely degrade mainframe performance. Therefore, this approach is also not recommended for use at the STI Facility.

The suggested approach for use at the STI Facility centers on the use of a *distributed processing system*. Also known as *network computing* or *cooperative processing*, distributed processing uses peripherals that contain their own processor and are relatively independent from a control computer. Such an approach uses an open architecture and offers a superior price/performance ratio over a mainframe-based system. Since each peripheral can operate independently, multitasking is easier to implement, allowing simultaneous applications to take place. Furthermore, such configurations are flexible and expandable to meet future needs.

2.3. Detailed Requirements

The suggested configuration of the STI Facility's prototype image system distributes functions among multipurpose nodes connected to each other through a LAN (see figure 1). Most nodes of the LAN will be based around a microcomputer built upon an Intel 80286 (PC/AT models) microprocessor or a 80386 microprocessor. The quality-control station must be able to execute specialized image processing software, and a RISC (reduced instruction set computer, see *3.2.6 Processors*) processor is recommended. The functionality of each node will be determined by the specific combination of software, add-in boards, and peripheral devices it uses. The original implementation will contain three such multipurpose nodes: (1) input and OCR processing station, (2) quality-control station, and (3) combination database manager, file server, and output station.

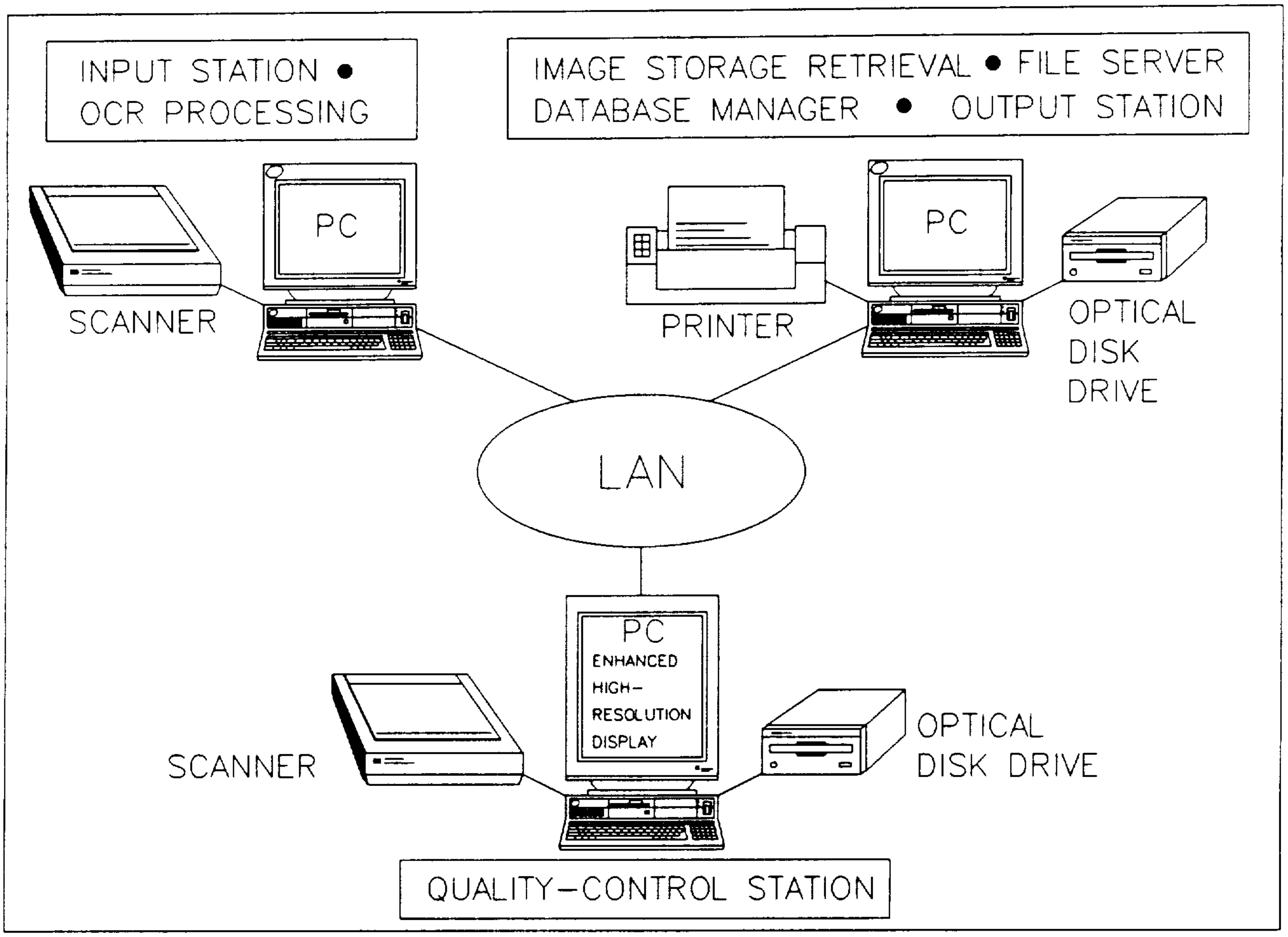

Figure 1. *Suggested Prototype Configuration*

2.3.1. Input and OCR Processing Station

The input station is the front-end station of a digital imaging system. It consists of a PC control computer and a scanner to convert hardcopy paper images into an electronic form that can be stored, displayed, and printed. A scanning resolution of 200 dpi may be sufficient for business applications, but the nature of the NASA Technical Reports—which contain a relatively high proportion of halftone photographs—requires a scanning resolution in the range of 300 to 400 dpi. This higher resolution reduces moirè patterns and loss of detail. Scanning at resolutions higher than 400 dpi is not recommended due to the large amount of disk storage required, as well as the large increase in transfer rate times.[2] Furthermore, affordable monitors and printers to take advantage of higher resolution than 400 dpi are currently not available.

It is also recommended that the scanner have true gray-scale capture ability to later perform any image processing functions that may be necessary to improve the quality of the scanned image. The suggested gray-scale capability of the scanner should be 64 levels to avoid problems of false contours, as well as minimize the image file size as much as possible. A color scanner is not recommended at this time due to their generally higher cost and larger file size (three times larger than gray scale). Color scanners also require color monitors and printers to display the images. Due to alignment and paper-feed problems that are common with edgefeed scanners (see section *5.3.3. Federal Drug Administration*), a flatbed scanner is recommended. Flatbed scanners also offer the advantage of scanning from books without removing the binding.

To increase scanning speed and automate the scanning process, an automatic paper feed device, capable of holding between 50 to 100 sheets of paper, is recommended. To decrease the file size for storage and communication purposes, CCITT Group 3 or Group 4 compression techniques are recommended. These techniques are based upon run-length encoding and the Huffman algorithm. Although software compression is available and less expensive, hardware-based compression consisting of very large scale integrated (VLSI) chips is recommended because of the fast speed of the chips. Once captured, image files are usually stored in formats that include descriptions of the file's characteristics, such as its compression format, size, and resolution. TIFF is the recommended file format due to its emergence as a de facto standard for interchange of digital images.

To provide an alternative method of retrieval other than the document number, full-text search and retrieval may be able to be supported using character recognition devices. Because documents will be scanned using a standard format, such as TIFF, high-cost optical character recognition (OCR) devices will not be needed. Instead, recognition can be accomplished using Calera's TrueScan or Caere's OmniPage. Both of these devices come in the form of a full-length PC plug-in board containing a 68020 accelerator and 2 to 4MB of RAM. The ASCII output of these devices can form inverted indexes on which searches can be performed. To increase speed, an alternative to performing character recognition on every page is to perform recognition and indexing in conformance with MIL-M-29532, Master Library Indexing Elements for Technical Publications as was implemented as part of the Navy Automated Information Logistic System (NAILS) initiative. This standard only requires the recognition of a few key pages, such as the table of contents or index pages, from which searches can be performed

2 One available strategy to deal with aliased halftones is to scan original page images at very high, 1600–2000 dots per inch, resolutions and immediately to reduce the resulting bit map (using specialized scaling algorithms) to 300–400 dpi for database storage.

to locate specific pages. Functional requirements for enhanced search and retrieval must be determined and translated into technical and equipment requirements in order to recommend a specific approach and estimate its implementation requirements.

2.3.2. Quality-control Station

The quality-control station is responsible for the quality of the image capture. It will require the use of a high-resolution monochrome screen to display the image, as well as provide for the interactive viewing and manipulation of stored images. This screen should use standard CRT (cathode-ray tube) technology but should be capable of displaying roughly 1700 by 2200 pixels, resulting in an image with approximately a 200-dpi resolution. Display screens with higher resolutions are currently much more expensive because they require the CRT to be more precise. In addition, larger memory storage and faster transfer rates would be required. It is also suggested that this display monitor have a minimum capability to display 16 gray-scale levels to take advantage of the gray-scale capture of the image. A portrait-oriented display screen (also called a full-page display) is recommended for this workstation so the entire image can be viewed at once and so that no scaling of images will be required. Since monitor clarity is very dependent on the relationship between resolution and monitor size, both of these factors should be carefully considered.

The primary purpose of this station is to ensure that the digitized image is a close reproduction of the original before committing the image to optical disk. Because the scanning will proceed at a faster rate than the quality-control station, this station's control computer must contain a minimum of 300MB of expanded memory and/or hard disks for the buffering of incoming images from the scanner station, in addition to the standard 40MB hard disk and 640KB of RAM. This station will also require compression/decompression boards to view and store the image. If the image is determined to have been captured with good quality, it will be committed to optical disk at this station in order to reduce passing the images across the LAN. (See section *2.3.3. Image Storage and Retrieval/File Server/Database Manager/Output Station* for the requirements of optical disks and disk drives.)

If the digitized image is not of good quality, image-enhancement techniques (such as contrast control and low-pass filters) can be applied to the gray-scale bitmap image. Sophisticated gray-scale software, such as Microtek's Picture Publisher or Moniterm's Picasso, or scanning software, such as Xerox's PC Image, IBM's ImagEdit, or ZSoft's PC Paintbrush, may also be required. Because of the many computations and operations these software algorithms perform, it is recommended that this station use a RISC (reduced instruction set computer) processor because of their fast speed. This station should also contain another scanner with the same capabilities as the scanner at the input station. This scanner will serve as backup for the first scanner, as well as allow the rescanning of an image to which enhancement algorithms cannot improve the quality. To reduce the image size and increase transfer rates before storing the image on optical disk, it is suggested that various thresholding techniques and improved dithering methods[3] be applied to convert the gray scale image file to bitonal form.

2.3.3. Image Storage and Retrieval/File Server/Database Manager/Output Station

Due to the lack of full utilization of the prototype image system during its initial stage, it is suggested that the third node perform multipurpose functions, such as image storage, image retrieval, and output functions. The recommended storage media and devices are Write Once Read Many (WORM) optical disks and drives. These products are suited for document storage and retrieval because of their high-density storage, rapid access times, and their preservation of data by not allowing modification of images once they are written. In addition, their lifetime expectancy has been estimated to be a minimum of 10 years. Because of the trade-off between fast access CAV (constant angular velocity) disks and high-density CLV (constant linear velocity) disks (see the table in section *3.2.4. Optical Storage*), it is recommended that hybrid CAV/CLV disks, known as Modified CAV (MCAV), be used. Such disks are currently offered by several vendors and are in production by many others. Because the Small Computer System Interface (SCSI) is emerging as a standard series of commands regardless of the manufacturer or model of the storage device, it is the recommended interface for the optical disk drive.

The speed at which data can be transferred from disk to the control computer depends on the access time, latency, and data transfer rates of the controller and drive. Typical rates are about 100 ms for access speed, the time it takes for the disk to make half a revolution for latency time, and around 1MB per second for data transfer rates. Though standards currently exist for 5.25-inch disks, 12-inch disks are recommended because of their increased storage density per cubic inch of equipment space. Current 12-inch disks hold 1 to 3GB and cost $200 to $600 each. Drives (including controllers) cost between $8,000 to $35,000. Both the price of the drives and media are expected to decrease and even higher storage capacities per disk are expected to be announced soon.

For images to be retrieved, database management software is required to store and manage indexes to the locations of images and other descriptive information about images, such as the image size. In addition to being a retrieval station itself, this node will also serve as the network file server and will therefore provide multiuser/multitasking capabilities and allow for sharing of resources and network communications. Specifically, this node should contain software to process user requests for images, send images to the display screen or printer queue, optimize performance using a read-ahead image cache, provide for configuration and queue management, and provide document/user security. To store all the database information, utility software, and provide buffering functions, this node will require a large magnetic hard disk ranging from 100 to 300MB in capacity. As with the other nodes, compression/decompression chips will be necessary for the retrieval and transfer of images. A

3 Dithering is a technique of using rectangular arrays of pixels to simulate the effect of halftone dots (see 3.2.2.5.3 Halftone).

high-resolution monochrome graphic monitor capable of displaying 1280 by 960 pixels should be used to display manipulations, such as zoom in/out, scrolling, windowing, rotation, and panning.

In the initial configuration, this node will also serve as the output node and thus manage the output queue spooling function. A laser nonimpact printer will serve as the primary output device because of its high-speed and high-quality printing of text and graphics on the same page. To gain speed, it is suggested that the digital-to-analog (D/A) conversion required by the printer be done in the control computer and not the printer controller. Although 400- to 600-dpi laser printers are becoming increasingly available, a 300-dpi resolution printer is sufficient for the initial configuration because the scanner resolution will likely be the same, and thus scaling algorithms, which often cause distortions, can be avoided. The standard laser printer currently holds 200 sheets of 8.5-by-11-inch paper and prints at a maximum of eight pages per minute (ppm). Such a printer will probably be sufficient for an initial imaging system. Part of the control computer's magnetic disk will be used as temporary storage for images queued for output. In addition, any status messages or diagnostics will be displayed on the control computer screen.

2.3.4. Local Area Network

To interconnect these three nodes and form an imaging system, the use of a LAN is suggested. Because of the high data-transmission capacity needed for document images and because LANs were created for the transmissions of small files, the communications area is one of the hardest to configure for an imaging system. Although no single topology or network is best for images, with the proper design, a network can be made to handle images satisfactorily. The recommended LAN configuration is either a token-passing ring (such as IBM's Token Ring), token-passing bus (such as Datapoint's ARCnet), or a bus using carrier sense and collision detection (such as 3Com's Ethernet). Studies by the IEEE have shown that Token Ring is the least sensitive to workload, offers short delay under light load, and offers controlled delay under heavy load. ARCnet has the greatest delay under light load, carries less traffic than Token Ring under heavy load, and is sensitive to the bus length. Ethernet offers the shortest delay under light load, performs well with long transmissions, and is sensitive to a heavy workload and bus length.

The actual configuration to be used by the STI Facility imaging system will depend upon results of further study of workload, average image file size, number of nodes, and projected amount of usage. Because of their low cost and widespread use, shielded twisted-pair or coaxial cable will be used to as the transmission medium. As prices continue to drop, fiber-optic cable may be considered for high-traffic areas, such as the interface between the disk drive and file server. Each control computer attached to the LAN will require a network interface board to allow for communication with the file server and to access software applications. In addition to the network hardware, network software, such as the network operating system and network management software, will also be required. Database application software must also be able to accommodate network use, such as multitasking operations and simultaneous use of document files.

2.3.5. Software

For all the hardware to work in harmony, one must not overlook the importance of software to an imaging system. Most important is the choice of an operating system to provide the low-level interface between the hardware and application software in a control computer. The two leading candidates are the widely accepted, but single-tasking, MS-DOS or the multitasking, but less widely used, Unix. MS-DOS had some inherent limitations (such as a 32MB limitation file and disk size, a 640KB limit on RAM, no prevision for write once devices, lack of multi-tasking abilities, and weak network capabilities), but all these problems have been solved in recent years. It is therefore likely that the initial configuration will be based on MS-DOS.

Device driver software is another important area requiring software. Device drivers provide the interface between peripheral equipment and the control computer's processor to perform jobs for which the control computer was not originally designed. These drivers are customized for each peripheral and usually take the form of file system emulation or application utilities. They are also usually written in assembly language for maximum performance.

Database software is required to keep track of all the documents in the system, coordinate the operations of peripherals, and act as the user's primary interface. The actual structure of the database is likely to be a hybrid between a hierarchical tree and a network database using pointers to establish links among data items. B-tree structures are commonly used because they provide guaranteed space use, rapid searching, expansion limited only by disk space, and rapid insertion and deletion times. Further analysis is necessary, however, before a making a final decision on a database implementation.

Besides database management functions, database application software is required for basic storage and retrieval functions. Many imaging systems also include document processing software that manages the handling of documents by several people. This software can maintain an audit trail on each document, provide document/user security functions, and track work on the system to optimize system performance. Imaging systems also include standard off-the-shelf utility software, such as word processing and backup utilities. In general, all software will be menu driven so that functions are performed by selecting an option from a menu or pressing a function key. On-line help will be available and messages will be displayed when problems arise.

2.3.6. Operational Flow

The operational flow of the prototype imaging system is expected to be as follows: documents enter the imaging system by being scanned at the input station. This station will be automated as much as possible by using preset scanner settings and an automatic document feeder. The image will be processed using optical character recognition, producing an ASCII data stream that will be separated from the bitmap image and used to support creation of full-text indexes. Subsequently, the image will then be compressed, formatted, and transmitted on the LAN to the quality-control station. This second station will decompress the image, check the quality of the image capture, and will apply image processing or enhancement techniques as needed. If necessary, a rescan can be performed at this station. Images will then be compressed and written to optical disk on the drive at this location.

During off hours, information on this disk will be transferred to a third node which serves as the primary storage area. Indexing will also be applied at this time using the LAN. The third node will be the primary retrieval station for this initial system. Images will be searched and retrieved by document or accession numbers. In addition to retrieval, this third node will also act as file server, database manager, and output source. The multitasking structure of this system will allow the input and quality-control nodes to serve as additional retrieval stations during times of peak use. The addition of a scanner and optical disk drive at the quality-control station provides a backup device in case these devices fail at the other locations.

2.4. Pilot Production System

A pilot production system is suggested in figure 2. The objectives of the pilot production system include scanning, digitizing, storing, and reproducing in paper media approximately 5,000 NASA technical reports annually. The volume of reproductions processed will be limited by the system's capacity. Further evaluation of enhanced search and retrieval capabilities as well as remote communications will be conducted using the pilot system.

One of the benefits of a distributed open architecture configuration is the flexibility it offers for upgrading and expansion. Many of the functions that were carried out in the prototype by multipurpose nodes can now be configured in the pilot system to be accomplished by special-purpose dedicated nodes. The output, database management, and retrieval functions can each have a dedicated PC in the pilot configuration. Thus, the newly configured pilot system can consist of two types of nodes: workstations and servers. Workstation nodes provide the user interface for storing, retrieving, viewing, and manipulating images. Server nodes provide services that can be shared by all the workstations, such as database management, file serving, output, and gateway functions.

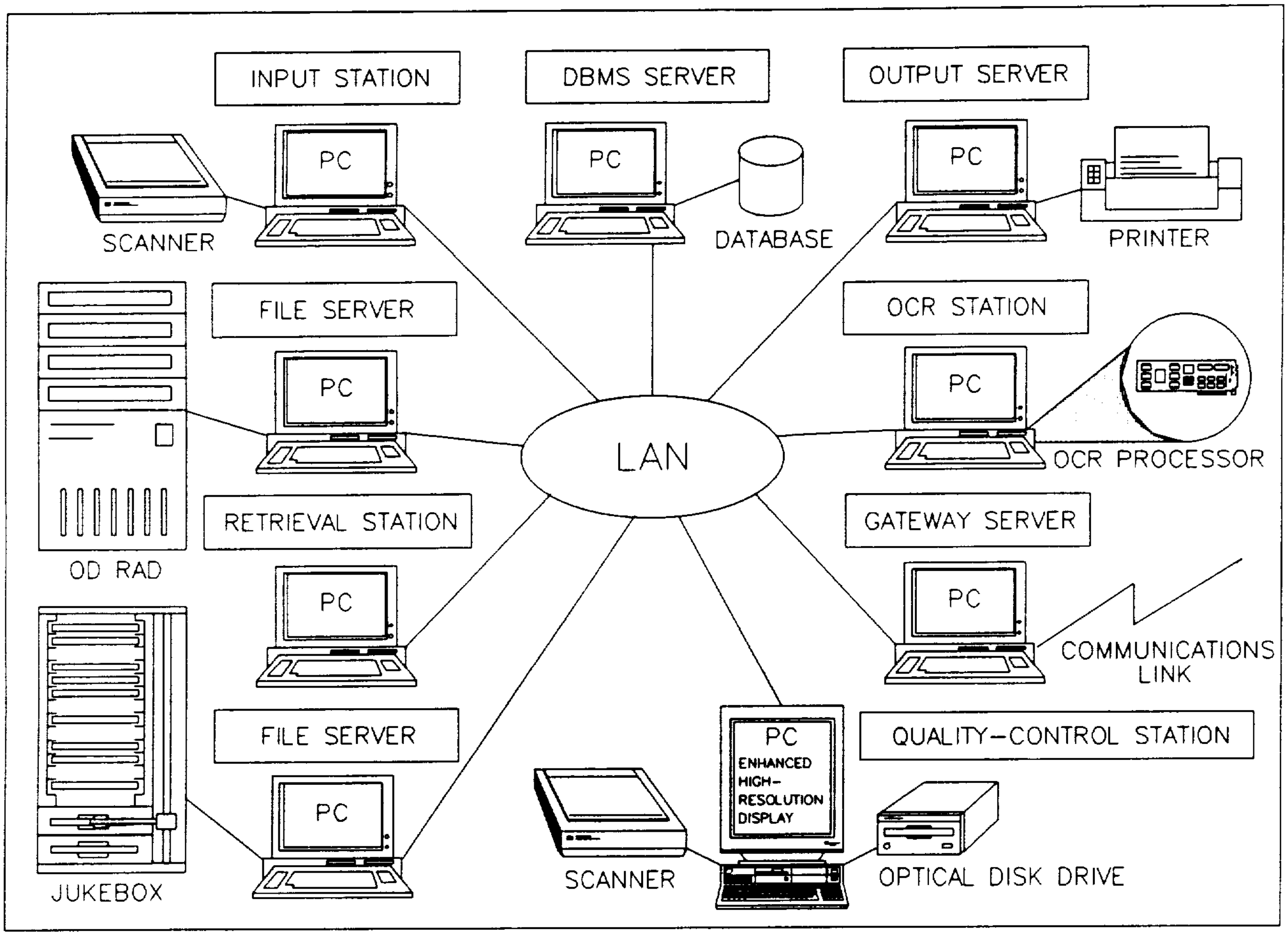

Figure 2. *Suggested Pilot Production Configuration*

As needs expand and the system grows, two approaches that can increase the on-line storage capacity of optical disks are possible. The first approach is to have multiple disk drives attached to one file server. This can be done either through the purchase of separate disk drives or the use of rapid access devices (RAD) which contain four one-sided optical disks. The U.S. Patent and Trademark Office currently uses 48 RADs as the primary storage location for images to achieve fast on-line retrieval. If the system will require more than five or six disk drives, the second approach of using jukeboxes (automatic disk changers) as the storage device is more economical. Jukeboxes can be configured to hold between 64 and 204 12-inch optical disks. A 204-disk jukebox can hold about 8.16 million pages (each page being 50KB) and access a page on an unmounted disk in about 15 seconds.

The imaging system can be attached via a network server to the present IBM mainframe. With such a configuration, database information could be kept on the mainframe. This would allow any end user with access to RECON to also search for and request a specific image from the imaging system. Such imaging systems with a mainframe based database are being used by the

Library of Congress and the Federal Drug Administration. The dedicated gateway node provides the necessary hardware/software interface to the mainframe and will perform all necessary protocol conversions. Communication of images to a remote end user is possible through T-1 lines or packet switching networks, but the cost effectiveness of transmitting such large image files must be studied further.

The suggested configurations discussed above are based upon a preliminary assessment of the STI Facility's functional requirements for a digital image management system initially servicing a limited set of technical reports such as 5,000 NASA technical reports annually. Much work remains to be accomplished to properly address throughput requirements and resultant queuing issues. Such effort is necessary to determine an approach and support requirements, and to estimate costs for actual implementation of an initial configuration or an expanded configuration.

3. IMAGING TECHNOLOGY

3.1. Introduction and Summary

The necessary technology to produce an effective imaging system at the STI Facility is present in the marketplace. Unfortunately, the overwhelming emphasis in commercially available systems and integrations is on the office document sector of imaging users—and this sector does not face all of the demanding requirements that must be met by imaging applications at the STI Facility. The recommended prototyping strategy can effectively address the differences.

The components of imaging technology are reviewed in the following sections. The section on equipment components addresses those units, such as scanners, disk drives, and CPUs, which are typically recognized and acquired as separate pieces of equipment. The section on imaging processes addresses imaging system components which are more functional in nature. They may be encountered as freestanding software, or they may be found embedded within equipment components.

3.2. Equipment Components

3.2.1. Introduction and Summary

The basic equipment components of an imaging system are scanners, display devices, optical storage devices, printers, processors, and communications gear. Each of these is discussed in the following sections. A synonymity between optical storage and imaging systems is frequently encountered in the trade literature and in the marketplace, and this equivalence is somewhat in error. The focus of the STI Facility's requirements is on an imaging system, not on storage devices. Optical storage devices are intrinsically associated with imaging systems only because they offer the least expensive storage architecture available for large files—and images certainly qualify as large files.

3.2.2. Scanners

3.2.2.1. Introduction and Summary

Scanners are electromechanical optical devices that digitize data from hardcopy, microfilm, microfiche, slides, transparencies, or aperture cards. Scanners convert these source representations to digital form so the data can be communicated, processed, modified, stored, and retrieved by computers.

In each case, an original image exists in the real world on a planar surface. The digital conversion process involves modeling this surface as a discrete set of rectilinearly arranged points—each of which (depending on whether the digitized image is to be bilevel, gray scale, or color) has an associated digital value: zero or one in the bilevel case of a black and white image, an integer value to represent a position in the spectrum between black and white in the case of a gray scale image, or a set of integers representing positions in the red, green, and blue spectra[4] in the case of a color image.

Much of the present interest in scanners stems from technological advancements seen in a related image technology—fascimile (fax) machines. Since the early 1980s, the demands of fax transmission have produced such developments in image technology as raster scanning, support for both gray-scale and color images, increased resolution, data-compression techniques, improved paper-handling mechanisms, and better overall machine reliability.[5]

Optical character recognition (OCR) devices use scanners to convert characters into digital form; OCR devices then interpret, recognize, and convert these characters into an editable format. According to Dataquest, a market research firm in San Jose, California, 25 percent of all scanners sold have OCR capability.[6]

Graphic scanners enable users to make electronic copies of text, drawings, or photographs, which they can later edit with a paint program. Presently, scanners are popular for desktop-publishing applications because they allow publishers to take existing material and use it in electronic format without having to retype, redraw, or rephotograph it.[7] According to Datek Information Systems, another market research firm, scanners that are used for publishing brought in revenues of 30 million dollars in 1987 and is projected to have revenues of more than 120 million by 1992.

Early nonfax applications of scanners were limited to professions that produce technical drawings and use computer-aided design (CAD), such as engineering and architecture, and businesses that handle a large volume of paper, such as banks and insurance companies. Since then, however, the speed, reliability, and decreasing cost of scanning has drawn the interest of others, ranging from professionals in the medical and pharmaceutical communities to officials in all levels of government.[8] Two growing markets for scanning technology are image storage-and-retrieval systems and combination scanner/fax systems. According to Dataquest, scanner sales have increased an average of 250 percent annually from 1984 to 1987, with a 200 percent increase in 1988.[9] The Gartner Group, another market research firm, predicts scanner sales will top 400 million dollars by the end of this year.

Although technology is constantly changing, scanners will be relatively stable for the next few years.[10] Scanners with high resolutions of 800, 900, or even 1,000 dpi are available, but most single CCD scanners have a resolution between 300 and 400 dpi. This range will remain until

4 Alternatively, but less frequently encountered, color images can be encoded with integer values reprenting luminance and chrominance levels.

5 Helgerson [87], p. 4

6 Stanton [89], p. 188

7 Mueller [89], p. 14

8 Kalthoff [88], p. 14

9 Stanton [87], p. 186

10 Stanton [87], p. 196

PCs can effectively process and store the large amounts of data that result from a high-resolution scan. Price is also a factor: higher resolution scanners cost four to eight times more than lower resolution scanners.[11]

Much of the recent improvements in scanning have been in software dealing with better image manipulation and the handling of gray scale and color.[12] In January and February of 1989, vendors announced the development of hardware and software that will allow PC-based gray-scale editing, manipulation, and printing. These advancements will allow a user with only a laser printer to exploit a true gray-scale scanner to its fullest capability. The trend is toward third-party developers to use the scanner as a platform for their independent application software.[13] In fact, according to Micro Publishing Report, independent applications are the key to growth for the scanner market.

The more than 150 scanners on the market vary greatly with the amount of image processing that can be done and the available options. Often choosing a scanner involves picking among three desirable traits: high speed, high quality, and low cost. While it is possible to get a scanner that offers two of the three traits, no product presently has all three.[14]

3.2.2.2. Types of Scanners

Since many applications require specialized functions, manufacturers have created specialized scanners instead of attempting to create a standard one that does everything. Scanners can be classified by their configuration—*edgefeed, flatbed, overhead, drum, handheld, printer*, or *micrographics*—each using a different method to transport documents through the scanner. Throughput and the minimum and maximum allowable paper size and thickness vary widely among scanners. For example, the Scan-Graphics Inc. CF500 uses an edgefeed mechanism that allows the scanning of paper originals as wide as 44 inches.[15] Some scanners work with opaque paper originals, others work with transparencies.

3.2.2.2.1. Edgefeed

The edgefeed scanners accept one page at a time and use a *roller-platen* mechanism to move the paper past the scan head (that is, paper is fed through a path and held in place by two rollers). The edgefeed scanner can automatically feed itself with loose pages from a bin that typically holds from 30 to 50 pages. This method, however, can cause paper to jam or misfeed, which lowers the scanner's effective throughput. This method can also fail to align the paper properly and can cause stair-stepping—the jagged-edge distortions of long, straight lines.

11 McNaul [88], p. 29

12 Mueller [89], pp. 17–19

13 Stanton [89], pp. 187–188

14 Brown [88], p. 56

15 Scan-Graphics [n.d.]

Recent enhancements to the microstepping motor in some newer edgefeed scanners allows them to move a source document in precise, minute increments past the scanning mechanism.[16] Because of their precision and reliability, these newer roller-feed mechanisms are commonly used for large engineering drawings. These same qualities make the newer edgefeed scanners a good candidate for STI Facility applications.

3.2.2.2.2. Flatbed

The flatbed scanner avoids any alignment or paper-feed problems by not moving the page through the scanner. Rather, the scanner operator places the paper on a flat glass surface that is on top of the light source. The scanner moves the light source across the page automatically, similar to the operation of a photocopying machine. Because it has a movable light source, however, the flatbed scanner can take a little longer to scan a page than an edgefeed scanner.[17]

Some flatbed models, such as the IBM 3119 PageScanner, improve scan time by using a movable flat bed that advances the page past a stationary light source. Most flatbed scanners now come with optional automatic sheet feeders to scan a stack of individual pages while retaining the ability to scan pages directly from a book without having to remove the binding. This flexibility makes the flatbed scanner the most likely candidate for STI Facility needs.

3.2.2.2.3. Overhead

The overhead scanner can scan three-dimensional (3-D) objects in addition to regular pages. Its operation is similar to an overhead transparency projector. The overhead scanner has two fluorescent lights (usually mounted at 45-degree angles) shining on the page or object and a scan head containing the camera positioned above.[18] The disadvantage of the overhead scanner is its lack of preciseness in scanning flat artwork when compared with the other desktop models.[19] This lack of precision makes the overhead scanner ill-suited for STI Facility needs. In addition, the STI Facility does not need the overhead scanner's ability to scan 3-D objects.

3.2.2.2.4. Drum

Another scanner that can handle letter-size pages uses a drum as the document holder. The document is attached to a cylinder that rotates the page in front of a scanning mechanism, which, in turn, moves across the document face along the length of the cylinder.[20] Such mechanisms are usually used for large color photo images or maps because of their high quality and accuracy, but they are very expensive. For example, the $200,000 Intergraph 5040 can scan a

16 Helgerson [87], p. 8

17 Brown [88], p. 55

18 Truvel [n.d.]

19 Robinson [88], p. 166

20 Helgerson [87], p. 8

50-by-40-inch document with up to 2000 dots per inch (dpi) scanning resolution.[21] Some smaller page scanners also use a drum mechanism, but these cheaper models can be awkward to use and can breakdown easily.[22] Drum scanners are ill-suited for STI Facility needs.

3.2.2.2.5. Handheld

Inexpensive, compact, handheld scanners are entering the mainstream scanner market. Though their scan mechanism is similar to that of a desktop scanner, they can only scan a narrow strip at a time (between 2 and 4.5 inches). Handheld scanners are useful, however, for character recognition of short pieces of text and numbers or for scanning small illustrations or spot graphics. Because the scanner is moved across the page manually instead of mechanically, the output quality is much poorer than the edgefeed or flatbed scanner and contains much image and character distortion.[23] Handheld scanners are unsuitable for STI Facility needs.

3.2.2.2.6. Printer

Another inexpensive type of scanner uses a dot-matrix or plotter printer as the scanner engine. The print head is replaced by a scan head that scans the document as it goes through the printer.[24] ThunderScan by Thunderware Inc. pioneered this method for the Macintosh ImageWriter and costs only $249. Although they are inexpensive machines with full-page scanning capability, printer-based scanners do not typically deliver the sharp scans of flatbed or edgefeed scanners.[25] They require a serial interface to send data from the printer to the host (instead of the standard parallel interface). Printer-based scanners also require operator skill to precisely position the scan head to focus on the paper.

3.2.2.2.7. Micrographics

A breed apart from the scanners that accept paper input, micrographics scanners come in versions to handle microfiche, microfilm, or aperture cards.[26] Micrographics scanners can be used for back-file conversions, current daily input to image systems, or for input to character recognition processors. These scanners use the same technology as paper scanners and have enhancement features to transform micrographics into high-quality digital image output. Table 1 is a list of micrographics scanners. All information in this table is derived from phone conversations with the vendors or from vendor-supplied specification sheets.

21 Intergraph [n.d.]
22 Helgerson [87], p. 8
23 Robinson [88], pp. 166, 171
24 Robinson [88], p. 166
25 Stanton [87], p. 196
26 TDC [n.d.]

COMPANY	MODEL	INPUT MATERIAL	SCAN MODE	LEVELS OF GRAY	RESOLUTION (dpi)	FILE FORMAT	INTERFACE	PRICE
Bell & Howell	Jacketscan	4" ×6" jacket microfilm; 24:1–48:1	—[a]	—[a]	200	—[a]	25-pin delta connector	—[a]
Merkel Engineering	M400[b]	microfilm (16 or 35mm; roll or cartridge)	bitonal, gray scale	64	400	raw bitmap	RS422	$49,000[c]
TDC	IS-3000	microfiche (24:1) (98 or 60 frame)	bitonal, dither	64	300	raw bitmap	RS422	$39,950

[a] Information not available at press time [b] Prototype microfiche scanner will be available by December 1989 [c] Software is an additional $750

Table 1. *Micrographics Scanners*

The TDC ImageScan IS-3000 is an example of a microfiche image scanner that can convert microfiche documents to digital images. Built for high-volume production, the IS-3000 only requires an operator to load the fiche on the platen and key-in the frame coordinates; the IS-3000 will scan each image without further operator intervention (like the micrographics dry-paper printer already used at the STI Facility). It uses an automatic image edge detection and trim function to locate images precisely and produce a borderless digital image. Based on a 98-frame microfiche (24 : 1 image reduction), the average throughput is 33 images per minute. This time includes microfiche-loading time, prescan time, and row retrace time. These scanners are not in widespread use, however, because of their limited applications. The STI Facility will require a micrographics scanner if the back-file of material currently maintained on microfiche is to be converted to digital format.

3.2.2.3. Scanning Mechanics

Although many vendors sell raster scanners, only a few manufactures build the scanner engines.[27] Scanner engine manufacturers include Canon, Ricoh, Microtek Lab, Panasonic, and Fujitsu. Scanners have two basic subsystems—one to capture the data and one to process it.[28] Scanners mainly use hardware to capture the data and software to process it.

3.2.2.3.1. Scanner Engines

Scanner engines have three main components: *document-transport mechanisms*, which hold and transport the document while the capture process takes place; *light sources*, which illuminate the document; and *light detectors*, which translate the reflected light into a voltage level.

Document-transport mechanisms. These mechanisms are one of the fundamental configuration attributes by which scanners can be classified. Section *3.2.2.2. Types of Scanners* contains descriptions of the various document-transport mechanisms.

27 Stanton [87], p. 186
28 Helgerson [87], p. 5

Light sources. Raster scanner engines operate on the physical principle that black absorbs light and white reflects it.[29] When a page is scanned, the scanner engine illuminates a portion of the page. Using mirrors, prisms, and lenses, the scanner directs the reflected light to a photocell that measures the percentage of reflection. Depending on the application, one of the following sources of light are used for illumination: cathode-ray tubes (CRTs), lasers, incandescent lamps, florescent tubes, light-emitting diodes (LEDs).[30] With the advent of fiber-optic cables that transmit light uniformly, many scanners can use smaller lamps to illuminate documents.

Light detectors. Most scanners use a charge-coupled device (CCD) as the photocell.[31] The CCDs typically used for document scanning are rectangularly shaped solid-state chips that contain linear arrays of microscopic light sensors. Usually about an inch in length, these sensors convert light to electricity by delivering a voltage level proportional to incident light intensity and sending out the result as a voltage level. Though the actual number of cells in the CCD may vary between scanners, it usually has enough cells to capture the length of an entire line at once.[32] Since most CCDs are smaller than the scanning length of a line, a projection lens is normally used to project the scanning line into the CCD window. Although some scanners, like the Sharp JX-300 for example, use a movable CCD, it is more common for the CCD to remain stationary within the scanner, and either the paper passes in front of it, as in edgefeed scanners, or light is reflected on the CCD through the use of mirrors, as with flatbed scanners.[33] Some scanners have more than one CCD, especially when they are designed for use with large drawings, maps, or engineering diagrams. For example, the Scan-Graphics CF-1000, used for scanning engineering diagrams, can have up to nine separate scan lenses, each with its own CCD.[34]

Other types of detecting devices include charge-injection devices (CIDs) or change-state devices (CSDs).[35] Both of these are also solid-state chips that can capture the entire width of a document at once. However, CCDs are the most commonly used detectors because they are small, lightweight, precise and are very sensitive to small changes in light.

3.2.2.3.2. Data Capture Subsystem

The data capture subsystem uses the three hardware components of the scanner engine to capture the image. Scanners employ a variety of methods to accomplish this image capture. The

29 Robinson [88], p. 168
30 Helgerson [87], p. 6
31 Robinson [88], p. 168
32 Rothchild [88], p. 10
33 Wood [89], p. 66
34 Scan-Graphics [n.d.]
35 Helgerson [87], p. 7

most common way is to use the *flying aperture* method.[36] This method requires an area of the source document to be flooded with light so that the CCD, either by moving or by using mirrors, can perform the scan by having each of its elements record the amount of light reflected.

Another more recent (though less commonly used) method is called *flying spot*. This method requires either a movable light source or a combination of a stationary light source and mirrors to illuminate the document one spot at a time, while a single detector senses the amount of light reflected. This method uses lasers as the light source and therefore is mainly used by printers that double as scanners (see section *3.2.2.2.6. Printer*). The basic difference between these two methods is the location of the actual scanning mechanism. Flying-aperture scanners have the scanning mechanism attached to the detector (usually the CCD); flying-spot scanners have the scanning mechanism attached to the illumination source.

A third technique recently announced uses a 3000-element, 10-inch-long CCD that has a separate LED for each element.[37] It is a hybrid and thus uses a combination of both spot illumination and spot detection. This method, which is less expensive, is expected to become popular.

No matter which method is used, the reflection of light is converted to electricity.[38] Since white areas reflect the most light, they will generate the highest voltage, and conversely, totally black areas will generate no voltage. Shades in between will generate voltages that are proportionate to the amount of light reflected. Though a continuous-tone image, such as a photograph, may have an infinite range of tones, the CCD's signal-to-noise ratio limits the actual number of voltages it can measure. Thus no scanner presently exists that can produce an exact duplicate of the original image.

3.2.2.3.3. Image Processing Subsystem

The components of the image processing subsystem of the scanner are responsible for the analog-to-digital (A/D) conversion of the voltage level; optional data conditioning, such as enhancements or modifications; and data encoding into some specified format depending upon the application.

The analog voltage levels produced by the CCD correspond to the sampling spots of the scanner and are usually characterized as sine-like spatial frequency patterns.[39] These patterns are used to represent the two-dimensional (2-D) modulation transfer function (MTF) of each sampling spot. Through the use of algorithms, the analog signals are then translated into digital bit patterns called picture elements, or pixels for short. It is becoming common for a scanner to use multiple bits to represent one pixel to be able to distinguish among different levels of

36 Nagy [83], pp. 15–17

37 Rothchild [88], p. 10

38 Stanton [87], p. 187

39 Nagy [83], p. 17

gray.[40] The range of gray values that a scanner can measure and process is a geometric function of the number of bits assigned to each pixel. Thus a 4-bit pixel would have a gray scale of 16, ranging from 4 bits off to 4 bits on. Common gray-scale levels for a scanner are 16, 64, 128, and 256, with the scanner containing 4, 6, 7, or 8 bits per pixel, respectively.

Data conditioning algorithms, which are found in many image-editing software packages, enhance the digital bitmap image. Section *3.2.2.9. Optional Scanner Features* contains descriptions of various data conditioning features, such as controls for contrast, scaling, and threshold levels.

Before saving the image data, the scanner operator chooses a data-encoding scheme—bilevel, gray scale, halftone, or color—to store the image. The data-encoding scheme directly affects how much image detail is saved. Section *3.2.2.5. Types of Image Scanning* contains descriptions of each scheme as well as their advantages and disadvantages.

3.2.2.4. Resolution

The number of sample pixels taken for a given line measure, usually measured in dots per inch (dpi), is called resolution.[41] The higher the resolution, the more samples taken per inch. Higher resolution produces a more accurate and higher quality reproduction of the original, but requires more storage space for the larger number of pixels. Lower resolutions require less scanning and processing time. Storing high-resolution images requires that PCs (the de facto workstation standard) have large amounts of RAM and high-capacity hard disk drives to be able to process the data.[42] For example, scanning a color image at 300 dpi requires a minimum of 2 to 4MB of RAM.[43] At a recent product demonstration, Al Robins, scanner product manager for Ricoh Corporation, bluntly addressed the image storage issue by saying, "You try loading a 8 or 12MB image into a 25-MHz 386 and, even with a drive that has a 19-millisecond (ms) average access time and 8MB of memory in the system, you are dealing with a three- or four-minute wait. If you stick that in [Microsoft] Windows, you might as well go to lunch."[44]

Since storage requirements of an image file increase with the square of the resolution, the storage volume and processing time implications of higher resolutions can be serious.[45] Table 2 shows some common uncompressed settings.

40 McNaul [88], p. 28
41 Robinson [88], p. 166
42 Kalthoff [88], p. 17
43 Sharp [n.d.]
44 Mueller [89], p. 15
45 McNaul [88], p. 28

RESOLUTION (DPI)	GRAY-SCALE LEVELS 2	16	64	256
300	1.1	4.2	6.3	8.4
400	1.9	7.5	11.2	15.0
600	4.2	16.8	25.3	33.6
All file sizes are in megabytes and are for an 8.5-by-11-inch image.				

TABLE 2: *Files Sizes at Various Resolutions and Levels*

The number of cells in a CCD relates directly to the maximum scanner resolution. For example, the Ricoh RS312 and RS320 have a 2600-element CCD based upon a fixed scanning resolution of 300 dpi and a maximum width of 8.5 inches.[46] Containing a 3600-element CCD and a movable camera (which contains the CCD), the Truvel TZ-3BWC can scan at 900 dpi for a width of 4 inches or at 300 dpi for a maximum width of 12 inches.[47] New CCDs with 5000 elements, such as those in the Cannon CS-220 and the CS-240, are now available at low cost and allow a 400-dpi resolution scan on a document, provided one side is twelve inches or less.[48] Some scanners, however, contain only one CCD that can deliver a resolution of 1000 dpi, such as the handheld TransImage 1000 by Everex Systems Inc., but the scan area is limited.[49]

The output resolution of the scanner is not necessarily the same as the actual scanning resolution.[50] Software algorithms usually handle the conversions between the two resolutions by using bit averaging, decimation, or interpolation. The output resolution of the scanner is usually adjustable, and in some scanners, such as Hewlett-Packard's ScanJet Plus, the operator can adjust the resolution in 1-dpi increments.[51] Although not on the market yet, published technical papers have reported scanners that will allow different scanning resolutions within the same document.[52]

Scanning an image at 200-dpi resolution scan typically produces a clear copy. Using 300-dpi scanning resolution is becoming more common not only because it offers very high clarity, but it also matches the current maximum printing resolution of standard laser printers.[53] In addition, OCR processors perform noticeably better at 300 dpi than at 200 dpi, but gain little added performance at 400 dpi. To get the best quality image with the least processing time, the input resolution should be equal to the output resolution (provided the scanner is in the mode of only capturing a single bit per pixel). If the scanner is being used to capture gray-scale

46 Ricoh [n.d.]
47 Truvel [n.d.]
48 Canon [n.d.]
49 Stanton [87], p. 186
50 Wood [89], p. 66
51 Hewlett-Packard [n.d.]
52 Rothchild [88], p. 11
53 Aldus [8?], p. ?

images (multiple bits per pixel), the scanning resolution is best set lower than the printer resolution. For example, Panasonic suggests that when using its FX-RS506 to capture multiple bits per pixel, the operator should set the scanning resolution to 75 dpi when printing the output on a 300 dpi laser printer.[54] Such a setting allows room for a dithering algorithm to represent the gray-scale data (see section *3.2.2.5.2. Halftone*).

3.2.2.5. Types of Image Scanning

Once in digital form, the scanner processes the image to produce the *bitmap* (an array of bits that form the contents of an image file). Scanners offer the operator a choice of one or more of four formats: *bilevel, gray scale, halftone,* and *color.*

3.2.2.5.1. Bilevel

Bilevel or bitonal images, such as line art, contain only pure black and pure white—they have no gray-scale information. Their digital representations contain pixels that are either on (black) or off (white).[55] The scanner creates bilevel bitmaps using *thresholding*—the process of automatically or manually selecting a voltage-level cutoff above which voltages are considered to be on and below which voltages are considered to be off. A list of bitonal-only edgefeed scanners is given in table 3. All information in this table is derived from phone conversations with the vendors or from vendor-supplied specification sheets.

COMPANY	MODEL	MAX. SCAN SIZE (in.)	LEVELS OF GRAY	RESOLUTION (dpi)	FILE FORMAT	INTERFACE	PRICE
Calera Recognition Systems	CDP-3000XF	8.5 × 14	2	300	Group 3, Group 4, TIFF, PCX	RS232C, Ethernet	$14,950
	CDP-9000	8.5 × 14	2	300	Group 3, Group 4, TIFF, PCX	RS232C, Ethernet, SCSI	$29,950
CompuScan Inc.	CompuScan PCS	8.5 × 14	2	300	TIFF, CUT, IMG, PCX	Proprietary Parallel	$ 2,621 [a]
Taxon USA	Crystal Scan 300-I[b]	8.5 × 14	— [c]	300	TIFF, PCX, MSP	RS232C, RS422	$ 1,695

[a] Software is an additional $375 [b] Scanner engine made by Microtek Lab [c] Information not available at press time

Table 3. *Bitonal Edgefeed Scannners*

With the default thresholds, adaptive scanners can use different thresholds when imaging from a black area to a white area than when imaging from white to black.[56] A threshold is chosen based on the shade of the dark image areas, background shade, and the desired effect.[57] To produce straight lines, nonjagged edges, and smooth curves with bilevel imaging, the scanner

54 Panasonic [n.d.]
55 Stanton [87], pp. 187–188
56 IEEE [87]
57 McNaul [88], p. 29

must have an appropriate threshold, excellent alignment of the image, and at least a 300-dpi resolution.[58] Bilevel imaging is usually used for quick scanning of documents, pen-and-ink sketches, blueprints, engineering drawings, and text (for processing by OCR).

3.2.2.5.2. Halftone

True halftones, found in newspapers and magazines, create in print the illusion of continuous-tone images.[59] To make a halftone, the photographer places screens made of plastic or glass with a fixed number of dots per inch top of an image and photographs it to create a negative with a regular pattern of dots. These halftone dots vary in size corresponding to the level of darkness they represent: darker shades of gray have larger dots and lighter shades of gray have smaller dots. These variously sized dots create the illusion of different levels of gray because the brain blends the black dots seen by the eyes into the white background.

The quality of the halftone depends on how closely the dots are to each other.[60] This spacing of dots, known as *screen density* or halftone density, is measured in lines per inch (lpi). Usually, the higher the screen density, the finer the picture. Newspapers usually use a 65–75 lpi screen, while magazines use 120–133 lpi screens.

Since laser printers deliver dots of only one size, a scanner produces a dithered bitmap to create the halftone effect.[61] *Dithering* is the process of arranging pixels (usually multiple bit) that contain gray-scale information into patterns called *grains*. These patterns have various sizes and shapes to produce the illusion of large and small dots. The average gray scale of each grain is calculated, and a number of pixels (each now represented by one bit) are turned on (made black) in proportion to how dark the grain should be. The higher the average gray scale for the grain is, the darker the pattern will be. To determine how many levels of gray can be simulated, multiply the dimensions of the pattern and add one (for the case where all bits are off). For example, a four-by-four pattern can represent 17 levels of gray. See table 4 for a list of dithering edgefeed scanners and table 5 for a list of dithering flatbed scanners. Note that dithering scanners can also scan in bitonal mode. All information in these tables is derived from phone conversations with the vendors or from vendor-supplied specification sheets.

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58 Stanton [87], pp. 187–188

59 Stanton [87], p. 188

60 Mueller [89], p. 15

61 McNaul [88], p. 28-29

COMPANY	MODEL	MAX. SCAN SIZE (in.)	LEVELS OF GRAY	RESOLUTION (dpi)	FILE FORMAT	INTERFACE	PRICE
Bell & Howell	Copiscan 2115	8.5 × 14	—[a]	200	—[b]	—[a]	$ 9,195
	Copiscan 2118	8.5 × 14	—[a]	200	—[b]	—[a]	$10,995
	Copiscan 2315	8.5 × 14	—[a]	300	—[b]	—[a]	$10,995
	Copiscan 3115	11.8 × 17	—[a]	200	—[b]	—[a]	$12,995
Canon USA	IX-12	8.5 × 14	32	300	—[b]	Serial	$ 945[c]
IBM	3118	8.5 × 14	16	240	—[b]	cable/card	$ 1,702
Laser Connection[e]	IS-300	8.5 × 14	16	300	TIFF, PCX	RS232C	$ 895[d]
Microtek Lab	MS-300A	8.5 × 14	64	300	TIFF, PCX, MSP, IMG	RS232C, RS422, Bidirectional	$ 2,495
Mitsubishi Electronics	SP-MH216 AF	8.5 × 14	16	200	TIFF, PCX	Proprietary Interface	$ 995
Taxon USA	Crystal Scan 300-I[f]	8.5 × 14	—[a]	300	TIFF, PCX, MSP	RS232C, RS422	$ 1,695
The Complete PC	CPS	8.5 × 14	16	300	PCX, TIFF, MSP, IMG	Proprietary interface	$ 899

[a] Information not available at press time
[b] Dependent on controller
[c] Interface board is an additional $245
[d] Software is an additional $400
[e] Scanner engine made by Canon
[f] Scanner engine made by Microtek Lab

Table 4. *Dithering Edgefeed Scanners*

COMPANY	MODEL	MAX. SCAN SIZE (in.)	LEVELS OF GRAY	RESOLUTION (dpi)	FILE FORMAT	INTERFACE	PRICE
AVR	AVR-302	8.5×11.7	32	300	TIFF, PCX, IMG, CCITT3	Proprietary cable/card	$ 1,595[a]
Canon USA	IX-12F	8.5×14	32	300	—[b]	Serial	$ 945[c]
Chinon America	DS-3000	8.5×11	16	300	PCX, TIFF	Serial	$ 745
Fujitsu America	M3094-F	10.1×14.3	64	400	—[b]	RS-232C	$ 4,610
	M3096-F	11.7×17	64	400	—[b]	RS-232C	$ 5,520
	M3093-F[d]	8.3×11.7	64	400	—[b]	RS-232C	N/A
IBM	3117	8.5×11.7	16	240	—[b]	Serial, Parallel	$ 1,300
Kurzweil	Discover 7320-30[e]	8.5×14	16	300	TIFF, PCX, RES	Proprietary interface	$ 6,295
Microtek Lab	MSF-300C	8.5×14	64	300	TIFF, PCX, MSP, IMG	RS232C, RS422, Bidirectional	$ 1,995
NBI	803	8.5×11.5	16	300	PCX	Proprietary parallel	$ 2,445
Panasonic	FX-RS505	8.5×14	16	400	TIFF, PCX	Proprietary interface	$ 1,499
Ricoh	RS-320	8.5×14	16	240	TIFF, PCX, MSP	Bidirectional parallel	$ 1,100
Sharp	SS-300	8.5×14	16	300	PCX	Proprietary interface	$ 795
TDC	DS-2400	8.5×24	64	200	Raw bitmap	RS232C, RS422	$12,000
	DS-4200	8.5×24	64	200	Raw bitmap	SCSI	$55,000
	DS-4270	8.5×24	64	300	Raw bitmap	SCSI422	$55,000

a Software is an additional $1,100
b Dependent on controller
c Interface board is an additional $245
d Model to be released in fall 1989
e Scanner engine made by Ricoh

Table 5. *Dithering Flatbed Scanners*

A major quality aspect of digital scanning is the spatial sampling rate or resolution.[62] *Aliasing* is a phenomenon of data patterns that are added to a digital image even though they do not appear on the original image.[63] This phenomenon is caused by two adjacent spatial frequency periods (analog signals) that overlap optically and distort each other by giving the appearance of a higher voltage level than what really exists. To avoid aliasing, the sampling rate should be at least twice the maximum image frequency. By having a high enough sampling rate, aliasing is avoided, the sampling intervals decrease, and each frequency period becomes distinct so that no overlapping occurs. According to the Whittaker-Shannon sampling theorem, a band-limited function can be recovered completely from samples with the correct spacing.[64]

The following important relationship exists between resolution, screen density, and simulated gray scale:[65]

$$\text{number of simulated gray levels (dots/line)} = \left(\frac{\text{scanner resolution (dots/inch)}}{\text{screen density (lines/inch)}}\right)^2 + 1$$

FIGURE 3: *Levels of Gray Equation*

The formula in figure 3 states that as screen density increases (producing a finer image), the number of shades of gray decreases.[66] On the other hand, if the bit stream is dithered into larger grains to simulate additional shades of gray, the halftone screen will be much coarser. Unless the scan resolution is very high, which greatly increases the cost of the scanner, it is difficult to get a fine image with a high gray-scale level when dithering. For example, a 300-dpi scanned image dithered with an eight-by-eight pixel pattern to produce 65 levels of gray will have a screen density of 37 lpi (about half the screen density of a newspaper). If the same 300-dpi image were dithered into a four-by-four array, the resulting 75-lpi screen density would yield a sharper picture, but the problems with false contours at 17 levels of gray would appear.

As a compromise, experts suggest using a six-by-six dither pattern for scanning at 300-dpi resolution when reproducing halftones on a 300-dpi laser printer.[67] This dither pattern allows for 37 shades of gray and a 50-lpi screen density, which will normally provide an adequate picture. Alternatively, some vendors use a rectangular four-by-eight dither pattern because it helps avoid aliasing problems.[68]

62 Nagy [83], p. 17
63 Gonzalez [87], pp. 92–94
64 Gonzalez [87], pp. 92–94
65 Jantz [88], p. 4
66 McNaul [88], p. 29
67 McNaul [88], p. 129
68 Wood [89], p. 67

Dithered halftones can cause other problems.[69] After dithering, for example, the original digitized bits are lost; not even a high-resolution printer or screen will be able to reproduce the image as well as the original. Another problem with dithering is that the image can no longer be scaled up or down in size without creating image defects, such as *moirè* patterns (dot formations producing the effect of artificial checkerboard-like patterns of light and dark imposed on an otherwise consistently shaded area) or raggedness in curves and diagonal lines.[70] Also, because dithered bitmaps simulate gray scale by altering the actual bits of the pixels, text images are not as sharp as in bilevel scanning, which can present problems to character recognition devices.

To avoid some of the problems with digital halftones, Microtek's scanner engines store images in analog voltage form with full gray-scale information before applying the dithering process.[71] A scanner operator can specify one of twelve different halftone screens (such as linear tone curve, logarithmic curve, spiral, press, random, circle, mesh, and line) or can have the option of downloading an operator-definable screen from the host computer to change the image dynamically into the desired pattern. This control feature allows enhancement of the image before the final conversion to digital form. Choosing the type of dither pattern to use can help prevent unwanted patterns, especially when scanning halftone images.[72] Some software packages also allow control of the angle of the printing of the dither patterns. IBM ImageEdit software suggests angling the dither patter 45 degrees when using a PostScript printer because printing at such an angle tricks the eye into not noticing the dither patterns.[73]

Another solution to dithered halftone problems is to store the original digitized image in the Encapsulated PostScript (EPS) format.[74] EPS, which is based on Adobe's PostScript page description language (PDL), uses the geometric parameters of the image to store it in a vector format. Using EPS allows for manipulation of the image by PostScript software, thus making it possible to enhance the image before dithering, as well as making it easy to transport the file for device independent printing.

3.2.2.5.3. Gray Scale

True gray-scale scanning has become popular in the last 18 months because it avoids many of the problems with halftone dithering (see section *3.2.2.5.2. Halftone*).[75] Gray-scale scanners

69 McNaul [88], p. 29
70 ANSI/AIIM MS44-1988, pp. 1–2
71 Microtek [n.d.]
72 Williams+ [89], pp. 271–272
73 IBM [n.d.]
74 Stanton [87], pp. 187–189
75 O'Malley [89], pp. 103–105

store each multiple-bit pixel as the bitmap of the image. This approach delivers sharper halftones and increases control over their appearance. Table 6 is a list of edgefeed gray-scale scanners; table 7 is a list of flatbed gray-scale scanners. Note that all gray-scale scanners can also scan in bitonal or dithered modes. All information in these tables is derived from phone conversations with the vendors or from vendor-supplied specification sheets.

COMPANY	MODEL	MAX. SCAN SIZE (in.)	LEVELS OF GRAY	RESOLUTION (dpi)	FILE FORMAT	INTERFACE	PRICE
Datacopy	Jet Reader	10.1 × 14.3	16	300	TIFF, IMG, PCX	Proprietary Parallel	$1,300
Desta[a]	PC Scan 2000	8.5 × 14	256	300	TIFF, EPS	SCSI	$2,000

[a] Scanner engine made by Canon

TABLE 6. *Gray-scale Edgefeed Scannners*

Since the human eye can distinguish between 50 and 100 shades of gray in a single image, a 4-bit scanner (which captures 16 gray-scale levels) is seldom used to capture continuous-tone images.[76] Using 16 gray-scale levels also introduces problems of false contours when subtle changes in shading occur. To avoid these issues, a minimum of a 6-bit scanner should be used when creating halftones to capture 64 levels of gray. An 8-bit scanner can capture as many as 256 shades of gray. The additional levels of gray-scale information, allow the use of sophisticated editing programs, such as Image Studio and Digital Darkroom for the Macintosh or Picture Publisher and Picasso for the PC.

76 Microtek [n.d.]

COMPANY	MODEL	MAX. SCAN SIZE (in.)	LEVELS OF GRAY	RESOLUTION (dpi)	FILE FORMAT	INTERFACE	PRICE
Abaton Tech	DTP Scan 4[a]	8.5 × 11	16	300	PCX	Parallel	$ 1,490
	Scan 300/S[a]	8.5 × 14	16	300	TIFF, PCX	Parallel	$ 1,795
AGFA	S600 GS	8.5 × 13	64	600	IMG, TIFF, PCX, EPS	SCSI	$ 6,390
	S800 GS	8.5 × 13	64	800	IMG, TIFF, PCX, EPS	SCSI	$ 6,390
AT&T	Overview[b]	8 × 10	16	80	PCX	Proprietary	$ 2,300[c]
Datacopy	730 GS[a]	8.5 × 11.6	64	300[d]	TIFF, IMG, PCX	SCSI2; Bidirectional	$ 1,300[e]
	830[a]	8.5 × 11	64	300	TIFF, IMG, PCX	Bidirectional	$ 2,800
	840[a]	8.5 × 11	256	400	TIFF, IMG, PCX	SCSI	$ 6,800
Dest	PC Scan 1000[f]	8.5 × 11.7	16	300	TIFF, EPS	SCSI	$ 2,250
HP	Scan Jet Plus[f]	8.5 × 11.7	256	300[g]	TIFF, EPS, PCX	Bidirectional	$ 1,595[h]
IBM	3119 Page Scanner	8.5 × 11.7	128	300[i]	TIFF	cable/card	$ 1,656
Intelligent Optics	200	8.5 × 14	256	400	TIFF, PCX	RS232C, SCSI	$ 3,500
Kurzweil	K-5000[j]	8.5 × 14	64	400[i]	TIFF, PCX, RES	Proprietary	$14,355
Microtek	MSF-300G	8.5 × 14	256	300	TIFF, PCX, MSP, IMG	RS232C, RS422, Bidirectional	$ 3,495
	MSF-400G	8.5 × 14	256	400	TIFF, PCX, MSP, IMG	RS232C, RS422, Bidirectional	$ 3,995
	MSF-300Q	8.5 × 14	64	300	TIFF, PCX, MSP, IMG	RS232C, RS422, Bidirectional	$ 2,495
Olivetti USA	SG-100[f]	8.5 × 11	16	300[i]	TIFF	Proprietary	$ 1,495[k]
Panasonic	FX-RS506	8.5 × 14	16	400	TIFF, PCX	Proprietary	$ 1,899
Pentax	SB-A4301	8.5 × 11.7	16	300	TIFF, IMG	Parallel	$ 1,465[l]
Ricoh	RS-312[m]	8.5 × 11.7	64	300	TIFF, PCX, MSP	Bidirectional parallel	—[n]
Xerox	7650 Pro Imager	11.7 × 17	256	600[o]	RES, IMG	Proprietary	—[n]

[a] Scanner engine made by Microtek Lab or Ricoh
[b] Overhead scanning mechanism
[c] Software is an additional $750
[d] Resolution can be built to 450 dpi
[e] Software is an additional $695
[f] Scanner engine made by Canon
[g] Resolution can be built to 1500 dpi
[h] Software is an additional $595
[i] Resolution can be built to 600 dpi
[j] Scanner engine made by Fujitsu
[k] Software is an additional $730
[l] Software is an additional $496
[m] Available in the fall of 1989
[n] Information not available at press time
[o] Resolution can be built to 1200 dpi

Table 7. *Gray-scale Flatbed Scannners*

Gray-scale images increase in size linearly with the number of bits of gray-scale information.[77] Images with gray-scale information typically contain many megabytes of data, which thus introduces storage concerns. For example, an 8.5-by-11-inch page scanned at 300 dpi requires only

77 McNaul [88], p. 28

1.1MB for storage when scanned in bilevel mode but requires 8.8MB when scanned at the same resolution at eight bits per pixel. (See the table in section *3.2.2.4. Resolution* for relationship between gray scale and file size.)

Displaying the stored gray-scale information requires a high-resolution monitor for viewing; printing the image requires an expensive phototypesetter, such as a Linotronic L-300.[78] Furthermore, gray-scale editing software for the PC is slow in coming. Gray-scale scanners are primarily used for professional publishing, which takes full advantage of the captured gray-scale information to reproduce an image nearly identical to the original.

Gray-scale scanners will likely become more popular in the near future.[79] Recent announcements by vendors—such as Intel Corporation, Picsus Inc., and Microtek Inc. (for products to print gray scale on standard laser printers) and Moniterm and Microtek Inc. (for gray-scale editing software)—suggest that 6- or 8-bit-per-pixel scanners will become the standard soon. In January 1989, Hewlett-Packard, the leader in market share, introduced the ScanJet Plus ($2190), which can capture 256 levels of gray. Older image-editing software that was originally made to handle only bilevel scanning, such as Publisher's Paintbrush (ZSoft) or ImageEdit (IBM), have been revised to handle true gray-scale information. Such advancements should enable true gray-scale scanners to do a better job than other graphics scanners of reproducing photographs and other complex images.[80]

3.2.2.5.4. Color[81]

Not long ago, capturing color data required expensive bulky console-type scanners. Fully functional color scanners today are smaller and less expensive. They are still much more expensive, however, than gray-scale scanners, which can scan color images because they treat colors as shades of gray to produce black-and-white dots (like a color program shown on a black-and-white TV). See table 8 for a comparison of flatbed color scanners. Note that color scanners can also scan in bitonal, dithered, and gray-scale modes. All information in this table is derived from phone conversations with the vendors or from vendor-supplied specification sheets.

An example of such a desktop-size color scanner is the Sharp JX-450 Color Scanner. It uses a single, 3648-element CCD sensor, capable of capturing an 11.75-inch wide document at a resolution of 300 dpi. The JX-450 has three fluorescent lamps to capture the red, green, and blue images. The scanner executes three rapid, successive sequential scans using one CCD, each time using a different colored fluorescent lamp. To ensure that all three colors are precisely aligned, the Sharp scanner keeps the original image stationary until all three colored lamps have fired and captured the same point of the image. This process is repeated until the entire page has been scanned. Once captured, the scanner converts the analog signals to 8-bit pixels

78 O'Malley [89], pp. 105–106
79 Mueller [89], p. 18–19
80 O'Malley [89], p. 103
81 Sharp [n.d.]

with 256 data gradations for each color, although sharp guarantees color accuracy only to 6 bits. Through software in the host computer, the output gradations of the color can be tuned to match the characteristics of a particular display monitor or printer. Another model, the Sharp JX-300 Color Scanner, works in the same manner as the JX-450 except that it uses a movable CCD (the JX-450 uses a moving flatbed to pass the document over a mounted CCD). The Howtek Scanmaster uses the same engine as the Sharp color scanners, but claims better color control and supports a wider range of data formats.[82]

COMPANY	MODEL	MAX. SCAN SIZE (in.)	LEVELS OF GRAY	RESOLUTION (dpi)	FILE FORMAT	INTERFACE	PRICE
Howtek	Scanmaster[a]	11 × 17	256	300	TIFF, TARGA	GPIB	$8,195
Imapro	QCS-120	5.8 × 17	256	600	TIFF, TARGA	GPIB	$11,990[b]
	QCS-450	11 × 17	256	300	TIFF, TARGA	GPIB	$11,990[b]
Sharp Electronics	JX-300	8.5 × 11	256	300	PCX, TARGA	GPIB	$4,995
	JX-450	11.7 × 17	256	300	PCX, TARGA	GPIB	$6,995
Truvel	TZ-3BWC[c]	12 × 17	256	300–900[d]	PCX, TIFF	SCSI	$11,185

[a] Scanner engine made by Sharp [b] Software is an additional $495 [c] Overhead scanning mechanism [d] Resolution is changed by adjusting the scan area

Table 8. *Color Flatbed Scanners*

By producing eight bits for each primary color, these scanners can produce 16 million different colors (256^3). They also increase the scan time and triple the storage size of the bitmap. A palette color scan representation can reduce the storage requirements.[83] Palette color scanning uses the value of a single multiple-bit pixel as an index into a color map to retrieve the specific RGB triplet, which defines the pixel's actual color. This method reduces the necessary storage of a full-color scan by one third.

3.2.2.5.5. A Scanning Example

For this example, assume that an image of the capital letter "T" was scanned at 300 dpi and digitized into 4-bit pixels (see figure 4.)

82 Howtek [n.d.]

83 Aldus/Microsoft [88], p. 13

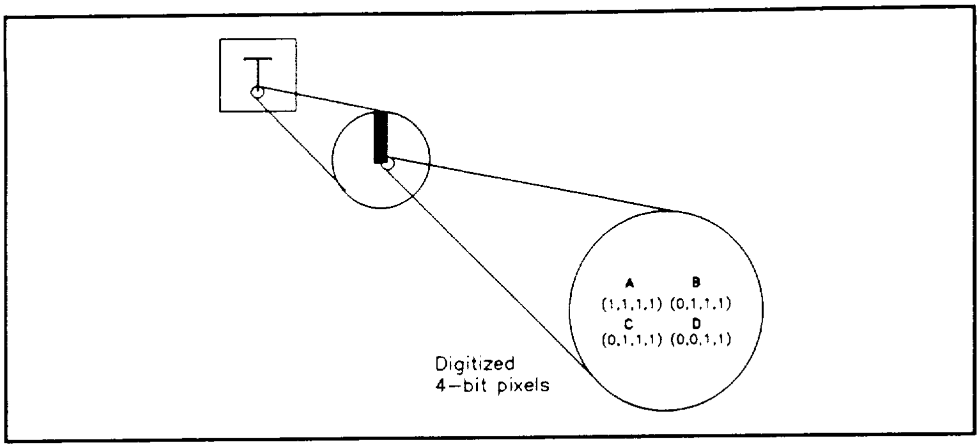

FIGURE 4: *Digitizing an Image*

If the threshold to turn a bit on (black) in bilevel mode is a value of eight, the four pixels (reduced to one bit each) would be as shown in figure 5.

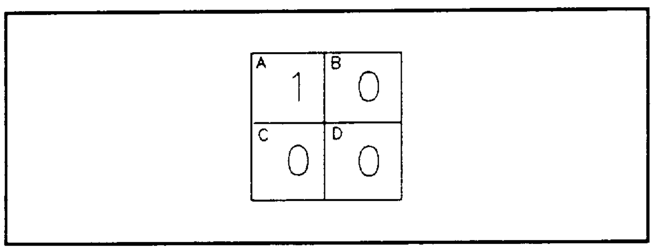

FIGURE 5: *Bilevel Pattern*

Pixel *A* would be the only pixel turned on because it has a value larger than the threshold value. Gray-scale information is lost using this method. If the scanner used the dithered halftone method and a two-by-two matrix, it could simulate only 5 levels of gray even though it captured 16 levels. Since the four pixels had a total value of 32 out of a total possible gray-scale value of 64 (4 times 16), proportionally, two of the four halftone dots will be turned on. The dithered halftone pattern would be as shown in figure 6.

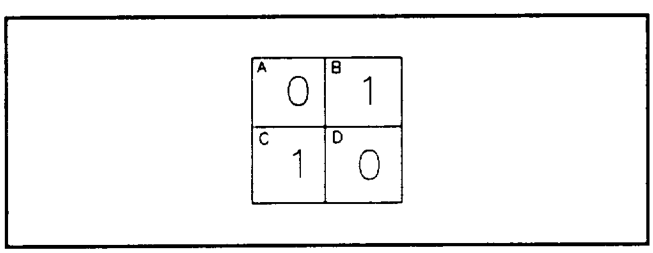

FIGURE 6: *Dithered Halftone Pattern*

If the scanner uses gray scale, it would format all the original gray-scale information into the bitmap with all four bits per pixel. This method probably produces the best image, but it also increases the storage size of the bitmap by three times over the other two methods.

3.2.2.6. Formats and Compression

Many vendors allow their scanners to store images in a file format that will allow subsequent editing of the bitmap.[84] Some of the more common formats are TIFF (Aldus's Tagged Image File Format), PCX (ZSoft's PC Paintbrush file format) and MSP (Microsoft's Paint file format). Because of the large size of image files, especially true color and gray-scale images, scanner vendors use various compression techniques to reduce the size of the images.[85] (See sections *3.2.2. Compression* and *3.2.3. Formats* for more details.)

3.2.2.7. Scanner Speed

The scanner system speed, or the time it takes a document to enter the system for scanning and then exit, varies from scanner to scanner.[86] Typically, it requires between 10 and 20 seconds per page. The time specification vendors report for their scanners can be misleading because it is often a measure of the time it takes to do only the actual image capture.[87] The complete scanning speed is dependent on the size, type, and quality of the paper, the scanner-to-PC interface, any character recognition software, and the resolution of the scan.

Because bitmap image files are usually large, PC memory is an important factor in the overall throughput time. Built-in random access memory (RAM) often is not enough to store images; hard disks (which have large storage spaces, but slower access times than RAM) are required. Improvements in the speeds at which rollers in an edgefeed scanner moves documents or the light source in a flatbed scanner moves over documents is unlikely because vibrations caused by the faster speeds will result in a blurred image.

The time it takes just for the actual image capture varies among manufacturers. For example, the Microtek 300G can scan a letter-size document at 300 dpi in 9.9 seconds capturing eight bits per pixel.[88] The Imnet SCN-304, using a Fujitsu scan engine, can scan a letter- or A4-size document in 14 seconds at 300 dpi and in 9 seconds at 200 dpi.[89] High-speed flatbed scanners, such as the Imnet SCN-430, can capture an A4-size document in 2 seconds at 400 dpi. Computer Microfilm Corporation of Atlanta, Georgia, is currently converting 36 million pages of U.S. patents into digital images for the U.S. Patent and Trade Office as part of the Automated Patent System.[90] They are using high-speed scanners that digitize both sides of a page at 300 dpi in less than 2 seconds. An example of one such high-speed scanner is the Improvision PAGS-1002.[91] This scanner, which contains a Ricoh engine, can capture both sides of a page at 200 dpi in about 2 seconds by using a separate CCD for each side. The color mode of a color

84 Wood [89], p. 68
85 Stanton [87], pp. 189, 194
86 Robinson [88], p. 166
87 Brown [88], p. 55
88 Microtek [n.d.]
89 Imnet [n.d.]
90 Huther [8?], p. 2
91 Improvision [n.d.]

scanner drastically increases the scan time. For example, the Sharp JX-300 takes 15 seconds to scan a letter-size document at 300 dpi in monochrome mode, but takes 150 seconds to scan the same page at the same resolution in color mode.[92]

3.2.2.8. Scanner Interface

The interface between the scanner and host also varies greatly and has a large effect on the total throughput time;[93] it can mean the difference between seconds versus minutes to complete a scan. Many scanners, such as the Imnet SCN-430 and Improvision PAGS-1002, use the RS-232C as a serial interface for controlling the scanner and a separate RS-422 for the serial image transfer.

Other scanners, such as the Sharp JX-300 or Imnet SCN-304, use the IEEE-488 general-purpose interface bus (GPIB), a bidirectional parallel interface for both control and image information. This interface is sometimes called modified Centronics and supports rates of about 1MB per second.[94]

Still other scanners, such as the Microtek MSF-300GS, use a built-in Small Computer System Interface (SCSI). Even though SCSI, which is the standard interface for the Apple Macintosh, costs more than the other two, it is becoming more popular for the PC.[95] SCSI interfaces have a broad bandwidth, which allows for faster data transmission—as fast as 10MB per second.

Whether the interface has synchronous or asynchronous transmission also plays an important role in scanner speed. Synchronous transmission (that is, transmission of data with constant time between successive bits) is usually faster than asynchronous transmission (that is, transmission of data sent at irregular intervals by using start and stop bits).

3.2.2.9. Optional Scanner Features

To produce the best possible image, scanners usually have software settings—rarely do they have hardware settings anymore—that operators can set either before or after the scan.[96] These settings allow for the automatic or manual enhancement of the scanned image. Many scanners now do the image processing themselves before sending the images to the PC, thus freeing the PC from this time-consuming function.[97]

3.2.2.9.1. Contrast, Brightness, and Density

Contrast, brightness, and density are interchangeable terms referring to the control that determines how much light will be measured.[98] These options have no effect upon the light source of the scanner. If adjusted before the scan, these options set the upper and lower limits of the

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92 Sharp [n.d.]
93 Brown [88], p. 56
94 Wood [89], p. 67
95 Brown [88], p. 56
96 Stanton [87], p. 196
97 McNaul [88], p. 30
98 Stanton [87], pp. 188–189

CCD; if adjusted after the scan, they affect the translation of input gray shades into output gray shades. For example, the Microtek MS-300A has 196 different brightness and contrast variations.[99]

Other scanners simply have three adjustable settings of high, low, and medium.[100] High is used to sharpen the edges of an image when scanning a true continuous tone. Low is used to dull the edges of and prevent moirè patterns in an image when scanning a halftone at high resolution. Medium is used to capture bilevel images when scanning line art or text since edge enhancements are usually not necessary.

Some software, such as IBM's ImageEdit, distinguishes between brightness and contrast.[101] While the brightness control lightens or darkens the image, the contrast control makes the differences between light or dark shades larger or smaller, depending upon the surrounding environment. Although density is sometimes synonymous with contrast or brightness, it can refer to halftone screen density as well.

3.2.2.9.2. Scaling

Scaling is the process of changing a scanned image's size or resolution.[102] Before the common use of low-cost scanners, expensive and time-consuming cut-and-paste photographic operations were used to scale an image to size. Today, provided the gray-scale information captured during the scan is kept, it is possible to scale an image electronically from 25 to 100 percent on either the X-axis, Y-axis, or both and still produce a good quality picture without moirè patterns.[103] For example, the Microtek G-series scanner in single bit per pixel mode has 16 different scaling settings, ranging from 25 to 100 percent, while in the multiple bit per pixel mode, 1 to 100 percent scaling is possible in 1-percent increments. To prevent jagged edges and rough lines caused by resizing, some software packages have smooth functions to minimize the stair-stepping effect at the expense of a longer processing time.[104]

Scaling can change the resolution of an image by using the gray-scale information contained in each pixel.[105] It is even possible to use software algorithms to quadruple the scanned resolution and still have a good picture. NASA has used such algorithms with great success on some Voyager photographs.[106] When enlarging a gray-scale image, however, experts suggest using a higher resolution than normal so that detail will not be lost.[107]

99 Microtek [n.d.]
100 Howtek [n.d.]
101 IBM [n.d.]
102 McNaul [88], p. 29
103 Microtek [n.d.]
104 IBM [n.d.]
105 McNaul [88], p. 29
106 Helgerson [87], p. 10
107 Aldus [8?], p. ?

3.2.2.9.3. Thresholding

Some scanners have a thresholding option that allows the scanner operator to set the level at which bits are determined to be on or off.[108] Using this feature, which eliminates some of the gray-scale information, allows the sharpening of the image and the reduction in the amount of processed data. Some software packages allow the operator to set the threshold level by actually drawing a curve that the scanner will apply either before or after the scan.[109] The scanner will use this curve to affect the translation of input gray shades into output gray shades.

Other scanners have an adaptive threshold feature that automatically adjusts the detection threshold to accommodate local contrast variations.[110] This feature is useful when the original copy has unexpected contrast variations, such as a coffee stain over some of the text. In this situation, the scanner would use one threshold for the unstained portion and a higher threshold for the stained portion.

Adaptive thresholding scanners are not appropriate in all circumstances. They sometimes have difficulty in detecting thin lines. Adaptive thresholding can also yield poor images when the scanner chooses the wrong threshold to use.

3.2.2.9.4. Image Enhancements

After scanning an image, scanners can employ various methods to enhance the image. These image-enhancement methods include *convolution processing* and correction methods to *gamma, color, modulation transfer function (MTF),* and *halftone.*

Convolution Processing.[111] This process can make an image appear softer or sharper. By passing a gray-scale image file through a filter, convolution processing changes the gray-scale level of the image depending on the nature of the filter.

Gamma Correction.[112] Sometimes called contrast control, gamma correction changes the linear distribution of gray-scale levels of an image into a nonlinear distribution to bring out the details in a desired portion of the image. This option, which is usually used on images that contain too many dark or light areas, serves as an equalizer function to spread the gray shades over the whole gray spectrum between black and white.

Color Correction.[113] This method is available on color scanners from Howtek and Sharp. These scanners contain red, green, and blue look-up tables (LUTs) through which data is passed before being presented to the host. The scanner operator can change the color balance and image contrast by modifying the LUTs, thus controlling the final appearance of the image.

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108 McNaul [88], p. 29
109 IBM [n.d.]
110 ANSI/AIIM MS44-1988, p. 17
111 McNaul [88], p. 29
112 McNaul [88], pp. 29–30
113 Howtek [n.d.]

Modulation Transfer Function (MTF) Correction.[114] Some scanners, such as the Ricoh RS-320 or Sharp JX-450, have MTF correction. This allows for the enhancement of image quality by bringing out better detail on poor contrast originals, especially line drawings. If not used carefully, this edge-enhancement function can make images appear spotted or dirty by detecting unwanted image details.

Halftone Correction. Scanning original halftones, as opposed to true continuous-tone images (such as photographs), poses unique problems for many scanners.[115] Because few scan lines will capture each halftone dot, very light or dark areas may appear as solid white or black and moirè patterns will appear. Factors affecting the moirè patterns are the scan resolution, line screen of the halftone image, printed angle of the halftone, and the angle of placement of the image on the scanner. Scanning original halftones using the halftone-scanning mode often increases the severity of the moirè patterns because of the beating of the two screens on top of each other.

In the past, the solution to scanning halftones was to scan in the gray-scale mode or scan with a very high resolution (above 1000 dpi).[116] These methods, however, take more time and storage space. Scanners with adjustable thresholds, which can vary the tone range of capture, offer some improvement, but are mainly beneficial for low-frequency halftones (below 85 lpi).

Recently, vendors such as Xerox and Afga are attempting to solve these problems by using a hardware-implemented, 2-D FIR (finite-extent impulse response) digital filter in their newer scanners (the 7650 and S800-G, respectively). The programmable low-pass filter, called the *descreening function*, removes the fundamental frequency and higher harmonics of the original halftone pattern after scanning. After descreening the halftone, the scanner software applies its own appropriate halftone screen. This two-step method produces a much improved image. Because the low-pass filter causes the loss of some image detail, experts recommend using this technique only for high-frequency halftones (usually above 120 lpi).

3.2.2.9.5. Image Rotation[117]

Once scanned, many scanners offer software packages that allow the operator to rotate images either 180 or 360 degrees, usually in 45- or 90-degree increments. These packages usually accomplish the rotation by using algorithms that shift the bit arrays.

3.2.2.9.6. Selectable Scanning Area

In addition to scanning a standard input area, many scanners permit the operator to specify the scanning input area manually. By doing so, the operator is actually changing the aspect ratio of

114 Ricoh [n.d.]
115 ANSI/AIIM MS44-1988, p. 10
116 Williams+ [89], pp. 275–276
117 IBM [n.d.]

the scan area.[118] Using a smaller scan area reduces the size of the bitmap since only the necessary information is stored. Some scanners, such as the Howtek Scanmaster, can save a template of frequently used scanning areas so the scanner operator does not have to reenter the coordinates.[119] Many scanners, such as the Ricoh RS-312 and the Howtek Scanmaster, also have a preview function that allows for a quick low-resolution scan in half the time of a normal scan. By using a pointing device, such as a mouse or the arrow keys on a keyboard, the operator can select a subsection of the original image produced by the preview scan. The scanner will rescan the selected portion at a higher resolution.

3.2.2.9.7. Other Features

Noise (extraneous marks) can be removed either manually after a scan or automatically through software before a scan using a smoothing function.[120] This function usually operates by moving the threshold to such a level that allows the scanner to detect a light line but ignore dirt, dust, and other image defects. If not used carefully, however, this function can degrade images containing faint broken lines or small isolated characters. The scanner operator must manually fill in any void spaces (blanks) in a line.

Some scanners have software packages that sharpen an image to compensate for an original blurred image.[121] Other packages, such as IBM's ImageEdit, allows a specific area of a picture to be retouched using a customized painting tool. This tool allows the operator to pick the exact shade of gray from a palette of shades and to apply it to any portion of an image. Other optional features include changing positive images to negative and back, creating mirror images, applying paint and airbrush special effects, and typical editing tasks of cutting, pasting, moving, and duplicating.

3.2.3. Display Devices

3.2.3.1. Introduction and Summary

Most of the production work done at the STI Facility with digital images will be based on images manifested on displays (or monitors). Therefore, the resolution, color, gray-scale, size, speed, and human engineering factors are important.

Minimally adequate monitors for use in digital document applications are only now about to be become common. The widespread EGA monitors, for example, offer 350 pixel rows in what is often a 7-inch viewing height. A full-height, 11-inch document is thus reduced to 7 inches and viewed at an effective 32 dots per inch of original image (50 dpi at the screen surface). Extended VGA conventions which are beginning to appear in the marketplace are doubling that capability. High resolution monitors are available up to about 200 dots per inch

118 Brown [88], p. 56

119 Howtek [n.d.]

120 ANSI/AIIM MS44-1988, p. 17

121 IBM [n.d.]

at the screen surface. These monitors have proved themselves quite adequate for digital imaging, particularly when true gray scale images are available — even though they are not a true reflection of the original scanning resolution of 300 or 400 dots per inch.

3.2.3.2. Operating Principles

There are different methods for displaying images on a display. Some of these methods are liquid-crystal displays (LCDs), light-emitting diodes (LEDs), and cathode ray tube (CRTs).[122] LCDs and LEDs are mainly used in portable computers where the bulk and weight of CRT displays. CRT is the only practical method for displaying color or gray-scale images at sufficient resolution for use in an imaging system.

3.2.3.3. Display Types

CRT displays come in three different types: *monochrome, color,* and *gray scale*. Until the introduction of the Hercules Graphic Card (HGC), monochrome displays could not show graphics. Color displays were developed to display images produced by the Color Graphics Adapter (CGA) and other higher-resolution color adapters. Gray-scale displays came into vogue for desktop publishing applications, where the gray-scale display of graphics information can come close to producing a what-you-see-is-what-you get (WYSIWYG) representation of a printed page.

3.2.3.3.1. Monochrome[123]

Monochrome displays are basic two-color displays. One color is for the foreground image, the other color (usually black) is for the background. Common foreground colors for monochrome displays are white, amber, or green. CRTs, which resemble pyramids leaning on their sides, are filled with inert gases through a vacuum to prevent discoloration within the tubes. A beam of electrons is transmitted touching the bottom of the screen, which is covered with phosphorous from the inside causing it to glow at contact. This glowing is the actual image perceived by the operator facing the display and the pixels represented in different brightness are caused by the different intensity the beam is displaying. Table 9 is a list of multiscanning monochrome displays.

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122 Cinnamon [88], p. 45

123 Cinnamon [88], p. 46

COMPANY	MODEL	SCREEN SIZE	RESOLUTION	MODES	PRICE
Princeton Graphic	Ultrasync	12.5 × 12.33	800 × 600	MDA, HGC, CGA, EGA, PGC, VGA	$ 849
Samsung Electronics	Sync Master CN4551	14.75 × 14.25	800 × 560	CGA, EGA, PGC, VGA	$ 699
Sigma Design	L-view	14 × 10.5	1,664 × 1,200	MDA, HGC	$2,495
3Lynx Technologies	IntelliSync SCC-1435	13.75 × 13.5	940 × 600	MDA, HGC, CGA, EGA, PGC, VGA	$ 695

Table 9. *Monochrome Displays*[124]

The beam is manipulated by a device called heated cathode (or electron gun) that is mounted at the peak of the pyramid. Color displays include a metal or ceramic screen also referred to as a mask between the electron gun and the glass screen, which improves the pixel clarity as the electron beam is focussed while passing through the screen. The size of the holes in the mask, being square or round for graphic use, determine the size of the pixel.

A magnetic field is created between the electron gun and the screen by a device called a yoke, which rescans the image before reaching the screen. The speed and direction of the electron beam relies on the magnetic field that is generated by the Yoke which ranges 40 to 60 screen scans per second. Any scan speed slower than 40 screen scans per second will cause a noticeable flickering on the screen.

3.2.3.3.2. Color[125]

Color CRTs operations are the same as what was mentioned above with the exception that it uses three electron guns representing the three primary colors red, green, and blue (RGB). Each color penetrates through the shadow mask in the direction of the colored phosphorous on the screen. This process is how the different colors are generated on the screen.

124 Rosch [89], pp. 112–113
125 Cinnamon [88], p. 43

COMPANY	MODEL	SCREEN SIZE	RESOLUTION	MODES	PRICE
Moniterm	Viking 10	15.25 × 11.25	1,024 × 768	MDA	$4,695
Mitsubishi Electronics	Diamond Scan 14	12.75 × 14.25	800 × 600	MDA, HGC, CGA, EGA, PGC, VGA	$ 889
	XC3710	39.3 × 36.9	640 × 480	EGA, VGA	$7,599
NEC Home Electronics	MultiSync Plus	11.125 × 8.25	960 × 720	MDA, HGC, CGA, EGA, PGC, VGA	$2,898
Taxan USA	Multivision 770 Plus	12 × 14	800 × 600	MDA, HGC, CGA, EGA, PGC, VGA	$ 915

Table 10. *Color Displays*[126]

This type of display is the most suitable for the imaging project. It is capable of displaying colored satellite images of which all the important information is revealed through the colors represented in the photo.

3.2.3.3.3. Gray Scale[127]

To obtain gray-scale images on the screen one must first have an image scanned through a scanner with a halftone process so that the different levels of gray can be obtained. Such displays are crucial for pictorial images. Some image processing is necessary for matching the image gray scale to the capability of the display. For example if a display can provide up to 16 levels of gray an image that contains 256 gray levels will be displayed with only 16 levels instead. The electron beam mentioned in the previous section, brightens and darkens each pixel. A black and white image, that is with no gray-scale information is created by two possible pixels black or white. On the other hand with gray scale, the electron beam must be varied at different levels of brightness not just black or white. Table 10 is a list of gray-scale monitors.

126 Crider [88], p. 80; Rosch [88] pp. 112–113

127 Cinnamon [88], p. 47

COMPANY	MODEL	SCREEN SIZE	RESOLUTION	MODES	GRAY LEVEL	PRICE
Cornerstone Technology	DualPage Display	14.625 × 11.5	1,600 × 1,280	HGC and CGA	16	$2,790
E-Machine Inc.	The Big Picture IQ	13.125 × 10.25	1,024 × 808	—[a]	256	$3,195
Radius Inc.	Radius	14.625 × 11.5	1,152 × 882	—[a]	256	$3,590
a Information not available at press time						

Table 11. *Gray-scale Displays*[128]

The gray-scale display would be ideal for the imaging project since it displays better graphic images and handles halftones better than a monochrome. The only advantage over the color display is its cheaper price.

3.2.3.4. Display Configurations

Ordinary displays exceed in width rather than length causing a problem for viewing an 8.5-by-11-inch image on one screen. In case of quality control if two images needed to be brought out simultaneously to be compared the ordinary display would not be able to display both images. Two types of displays emerged recently—portrait and landscape.

3.2.3.4.1. Portrait

Portrait displays exceed in height rather than width. This type of display is very well suited for 8.5-by-11-inch documents such as letters, business forms, and pictorial images.

3.2.3.4.2. Landscape

Landscape displays are the opposite of portrait displays, they exceed in width rather than height. They are the common displays that existed for some time with the exception that they have become wider than before. They could be used for engineering drawings and for displaying two images side by side for quality control.

3.2.3.5. Display Considerations

Many considerations must be given in choosing the proper display and adapter for imaging applications. The three most notable considerations are *image manipulation, software compatibility,* and *screen size.*

128 Crider [88], p. 78

3.2.3.5.1. Image Manipulation[129]

There are two methods to present an entire image on the screen. The first is *image reduction* (or zooming out), which reduces the image by the same degree both horizontally and vertically. The other method is *image enlargement*. This method allows the user to choose a section and magnify it by a factor of four (two in each dimension) to be able to view it at a full resolution.

3.2.3.5.2. Software Compatibility[130]

An important factor to take into consideration before purchasing the display is if the display manufacturer provides a software driver for each program that will run on that system. This driver combined with the graphic adapter translate video output code so images can be drawn on the screen. Screen fonts are also an important consideration. Bitstream Fontware, a soft font creation and downloading program, is capable of generating screen fonts for almost any display.

3.2.3.5.3. Screen Size[131]

The size of the screen is usually not the actual size of the image displayed. A screen that measures 15 inches may have an image of 13 inches diagonally or less. Hence, a display screen measurement similar to TV screen measurements is always diagonal rather than vertical and horizontal. An important issue to consider when purchasing a large screen is how closely does the size of a page on the screen match the original. The screen does not always represent 100 percent of the page viewed. Usually 90 percent of the original image is satisfactory; 80 percent or less is not, since it could distort the image.

3.2.3.5.4. Interface

There is only one particular way to connect a display with other hardware devices. This interface involves connecting the display to the PC's CPU by a standard CPU display signal cable. If the display device, however, is connected to a dumb terminal then all that is required to operate the device is plugging the power cable into the electric outlet.

3.2.3.6. Graphic Boards[132]

The graphic board is what allows the PC to generate high-quality graphics on the display device. These graphics could be represented in color, gray scale, or black-and-white. The graphic board also controls the resolution. High-resolution boards range in price between $1,000 and $4,000. Unfortunately since there is no set standard for high-resolution boards not all boards work with all software or all displays. For instance, only a few high-resolution boards can be used with IBM's PS/2 but up-to-date there are none that work with the OS/2 operating

129 Cinnamon [88], p. 48
130 Crider [88], p. 73
131 Crider [88], p. 72
132 Gralla [88], pp. 105–111

system. A disadvantage with high-resolution boards is their slow speed. Gala Graph, a graphics display board manufacturer in Tel Aviv, Israel, offers a solution to this problem with it Galaxy Mercury/2. This high-resolution board is faster and works in an IBM PS/2. At $995, the Galaxy Mercury/2 is much less expensive than other high-resolution boards.

3.2.3.7. Resolution

One of the most important characteristics of the display device is its resolution. It relies on the number of horizontal scanned lines (vertical resolution) and the number of pixels displayed on the line (horizontal resolution).[133] The standard resolution on VGA displays is 640 by 480 pixels. Displays with resolution as high as 1,600 by 1,280 pixels are available. For example, the DualPage display from Cornerstone has a resolution as high as 109 by 121 pixels per inch (or dots per inch). The formula to derive the number of pixels per inch is the number of pixels divided by the number of inches.[134]

Three factors that affect the clarity of the color display's image are its *convergence*, *bandwidth*, and *dot pitch*. The accuracy of convergence is the most important factor because it brings out the color display's actual performance abilities. The other two factors can only predict the color display's capabilities but are not always accurate.

3.2.3.8. Display Modes[135]

Display modes have greatly improved through the years raising the resolution that is enhancing the quality of the image by adding more pixels on the screen. The conventions being discussed are *Hercules, CGA, EGA, multiscanning, VGA, Super VGA,* and *noninterlaced.*

3.2.3.8.1. Hercules, CGA, and EGA

The Hercules Graphic Card (HGC) was originally invented to display the Thai alphabet on a computer screen. The HGC could generate graphics on a PC's monochrome display at a resolution of 720-by-348 pixels. Released after the HGC, the Color Graphics Adapter (CGA) was the first graphics-mode card released by IBM for its original PC. It can display four colors at a resolution of 320-by-200 pixels and two colors at 640-by-200. The Enhanced Graphic Adapter (EGA), which was introduced with the IBM PC/AT, can produce 16 colors at a resolution of 640 by 350.

3.2.3.8.2. Multiscanning, VGA, and Super VGA

Multiscanning displays, first introduced by NEC with its MultiSync monitor, are capable of displaying a variety of modes because it can handle multiple frequencies. Bill Machrone, editor-in-chief of *PC Magazine*, called the original MultiSync, "the ideal hedge against emerging technologies." Available for almost a year before the next generation of video mode

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133 Cinnamon [88], p. 47

134 Crider [88], p. 73

135 Rosch + [89], p. 96–97

resolution—the Video Graphics Array—multiscanning displays could handle the new mode by replacing the original 9-pin cable that attached to an EGA with a new 15-pin cable to attach to the VGA. The MultiSync Plus, NEC latest multiscanning display, offers a high resolution of 1,024 by 768. The clarity of its images is pleasing to the eye. At $1,395, the MultiSync is more expensive than most other displays.

VGA, easily the most widely accepted high-resolution standard in color graphic display modes, can produce 16 colors at 640-by-480 resolution and 256 colors at 320-by-200 resolution. Originally built into the system board of IBM Personal System/2 Micro Channel computers, VGA was quickly adopted by the industry as the current standard in color displays for PC compatibles with industry-standard buses. Super VGA, also known as enhanced VGA, displays 56-percent more pixels than VGA. Without waiting for IBM to take the next step at improving the VGA standard, eight leading video board manufacturers (at the strong urging of NEC) formed the Video Electronics Standards Association (VESA) to promote and standardize the Super VGA mode. Its resolution is 800 by 600 for 16 colors—more than twice the resolution of regular VGA. Super VGA adapters are naturally more expensive than regular VGA adapters.

3.2.3.8.3. Noninterlaced Displays and Adapters

Noninterlaced mode is the latest desirable feature in high-resolution displays. It refers to displaying a resolution of 1,024-by-768 pixels on a display screen at one time without having to redraw the screen. This resolution standard corresponds to the one IBM introduced with 8514/A display adapter. The 8514/A, coupled with IBM's high-resolution 8514 display, is for applications that require excellent image quality (such as engineering workstations). The 8514 can display 256 colors (512KB video RAM required) at 1,024-by-768 pixels in noninterlaced mode. Other video board and display manufacturers touted their products' (mainly Super VGA boards) ability to display this higher resolution. To do this, however, they had to use interlacing—a technique wherein only half of the screens pixels are lit up in one pass and a second pass lights up the other half. Interlacing results in noticeable screen flicker, which is tiring on the eyes. Since noninterlaced displays are relatively new, they are extremely expensive and require special drivers. Few software applications exist that can take advantage of this convention.

3.2.3.9. Display Factors

A number of factors affect how well a display can show an image. Three important factors are *convergence, bandwidth,* and *dot pitch.*

3.2.3.9.1. Convergence[136]

Convergence determines how close each one of the three RGB dots is in relation to the other two dots. When perfect convergence is established a white pixel is produced. Some of the fac-

136 Rosch + [89], p. 121

tors that might eliminate perfection are irregularity of the electronic that controls each colored gun, different gun alignments and the irregularity of the magnetic field that guides the electron beams. The outcome of one or more of these factors introduces the blurry colors and unclear text as a result of uneven dot alignment and enlarged pixels.

3.2.3.9.2. Bandwidth

The bandwidth defines the range of the lowest and highest signal frequencies that its circuits can handle, which determines the closeness of the dots on the screen. This varied frequency determines the resolution of the display device.[137]

3.2.3.9.3. Dot Pitch

Dot pitch is a measurement in millimeters (mm) of the space between pixels. A color screen consists of pixels that represent the primary colors (red, green, and blue)—each color being a dot on the pixel. The distance between the holes on the shadow mask of the display's CRT determines the pitch. An average 12- or 14-inch display has a dot pitch of .31 mm. As the dot pitch of the display decreases, the sharper the display image becomes.

3.2.4. Optical Storage

3.2.4.1. Introduction and Summary

Optical storage media have been evolving for almost 30 years. Most research in the early 1970s involved analog laser recording of information on a master disk and later reading of the same information from a replicated disk. Thus came the video disk to the market. Work continued on digital approaches until researchers solved a series of problems involving recording technology, media construction, media life, and error detection and correction. In the 1980s, write-once, read-many (WORM) optical disk technology has matured and development of erasable optical devices has accelerated.

Optical disks offer very large capacities, which are at least an order of magnitude beyond magnetic disks, and random access characteristics, which are deceptively analogous to magnetic disks. The average response time specifications, which are typically cited approximately 10 times slower than magnetic disks, only begin to suggest the response delays which can be incurred through queueing phenomena. Many of the software device handlers which have been written do not manage the optical characteristics well enough to minimize these delays and appear to degrade optical performance even more than necessary.

3.2.4.2. Advantages of Optical Storage Media

The following features make optical storage distinctive and attractive:

137 Rosch + [89], p. 120

- *high-capacity storage at low cost.* A 12-inch optical disk can hold from 2 to 3.2 gigabytes (GB) of data at a storage cost of $0.12 per megabyte; the Kodak 14-inch disk can hold as much as 6.8GB of data at a cost of $0.11 per megabyte. Vendors are projecting 6.4GB capacities in the near future for 12-inch media.
- *random access.* Multiple platters can be mounted successively on the same drive using a jukebox—a mechanical device (similar to a record-playing jukebox) that can change the platter in a drive upon command (see section *3.2.4.10. Jukeboxes.*)
- *removable media.* Like magnetic tape, optical platters are removable for off-site storage.
- *freedom from contamination and scratches.* Optical disk manufacturers encase the recording layer in glass or plastic. The optical head in the drive is suspended over the media—the head and the media do not make physical contact. These factors make optical disks immune to dust and scratches.
- *exceptional reliability, accuracy, and durability.* A read-after-write option can verify data in real time. Powerful error detection and correction codes can reduce the bit error rate to 10^{-12} for most drives. The useful lifetime of the media is 10 to 30 years. One major manufacturer, Sony Corporation has trademarked the name "Sony Century Media" for its line of optical disks, which the company claims will last 100 years.
- *mass replication.* Mass production of optical disks is comparatively easy and inexpensive.

3.2.4.3. Magnetic, Optical, and Film Storage

Magnetic disk drives employ an entirely different method for writing information on a surface than do optical disk drives. When writing to a disk, the magnetic read/write head creates a high-density magnetic field to change the orientation of a surface magnetic field. When reading from a disk, the magnetic head will respond with a change in voltage when it encounters the change in the surface magnetic field. To achieve high recording densities, the magnetic head must be positioned very close to the disk's surface. The engineering that achieves this positioning, makes it impossible to remove the disk from the read/write head.

Optical disks have several advantages over magnetic disks. The information storage density of optical disks is about 10 to 25 times higher than magnetic disks. Unlike a high-density magnetic disk drive, the optical disk can be removed from the drive. It is easier and less expensive to mass reproduce optical disks than magnetic disks. On the other hand, optical drives have longer access time than magnetic drives. The average access time for optical drives is in the range of 50 to 200 milliseconds (ms); magnetic drives have average access times from 18 to 30 ms. Whereas magnetic disks are highly standardized, few industry-recognized standards are in place for many forms of optical disks—only the 5.25-inch format is standardized.

Photographic film, including microfilm and microfiche, is the oldest high-density optical storage media. Compared with current optical disks, some photographic film processes can achieve higher optical sensitivity and three or four times better resolution. Processing the film, however, is a lengthy and costly process. Photographic film is not suitable for computer processing.

3.2.4.4. Optical Disk Drives

Optical disk technology uses light rather than magnetism to read and write data. Optical disk drives read the data, usually written as pits on the recording medium, by focusing a laser beam on the disk's surface. The read/write optical head uses the reflected beam, which is modulated by the deflection of the light, to generate a proportionate electrical signal.

Three types of optical disks are currently available—*CD-ROM* (compact disk, read-only memory), *WORM* (write-once read-many), and *erasable disk*. Data on CD-ROMs are permanently stored by a mastering process. Users can only read data from CD-ROMs—they cannot write to or modify them (see section *3.2.4.8. CD-ROMs*). With WORMs, users can both read and write data; however, the data are written to WORMs permanently and cannot be changed. With erasable disks, users can read, write, and update data as many times as they want (just like they do with magnetic disks). The technology of erasable disks, however, is relatively new and still under development (see section *3.2.4.9. Erasable Optical Disks*).

3.2.4.4.1. Optical Drive Mechanics and Operation

The components of an optical disk system are the lasers, the polarizing beam splitters, the focusing lenses, the output detector arrays, and the recording media. To generate the write beam, a semiconductor laser diode is momentarily pulsed to generate 20 or more milliwatts of output power. The write beam emerging from the disk drive's read/write head is directed at the underside of the disk to prevent dust collection. To read, the laser beam shines continuously, but at a lower power level (1 to 2 milliwatts). The differences in reflection levels between burn holes and the original surface allows the optical disk to detect zero and one signals.[138]

Optical drives have a single actuator arm with one large optical head. Compared with magnetic disk heads, optical heads are complicated and massive. Consequently, optical heads move slower than magnetic heads. The optical seek process first requires a coarse movement to the neighborhood of the requested track, then a fine movement to focus it.

3.2.4.4.2. Optical Disk Controllers

Optical disk controllers convert commands from the host computer into physical actions for the optical disk drive; it also performs error detection and correction to provide data integrity.

138 Fujitani [84]

Today most controllers use high-level interfaces such as SCSI (small computer system interface) and IPI (intelligent peripherals interface), both of which have been standardized by the American National Standards Institute (ANSI). These interfaces allow all rotating memory devices, including optical memories, to be addressed as logical devices. Differences in drive technology are invisible to operating systems.[139]

A truly standard software interface to SCSI, however, has not been defined. Vendors implement SCSI in slightly different ways. SCSI devices cannot always be daisy-chained together; they often require separate, dedicated controllers. For example, PC users with IBM PC SCSI ports cannot access Apple Macintosh SCSI drives, and vice versa. Vendors are continuing to improve the compatibility of SCSI implementations.[140]

3.2.4.5. Optical Media

3.2.4.5.1. Media Construction

WORM disks typically consist of three layers sandwiched together. The *substrate layer* is a rigid stratum made of glass, plastic, or aluminum. This layer reduces oxidation of recording layer and resists the warping forces generated from the platter's high-speed rotation. Depending on the recording technology used, the *recording layer* consists of one or more layers of thin metal, dye/polymer, or alloy. Data are encoded by changing the physical structure of the surface of the recording layer with heat from the write laser to cause a change of reflectivity during read back. The *protective layer* is a transparent outer layer made of plastic or glass. This layer shields the recording layer from external damage.

During the manufacturing process, either a controlled atmosphere or a vacuum is inserted between the recording and protective layers. This airspace reduces the oxidation of the reflective surfaces. It also serves as an expansion area for the recording layer to form bubbles or holes when written to by the laser beam.

3.2.4.5.2. Media Format

No industry-wide standard currently exists for formatting 12-inch WORM disks. Most WORM disk drives can only read from or write to its own WORM disks. One notable exception is the Optimem disk drives, which can read from and write to 3M, DuPont-Philips, and ATG WORM disks. Table 11 lists 5.25-inch WORM disk drives; table 12 lists 12- and 14-inch drives.

139 Fujitani [84]
140 Brownstein [88]

VENDOR	MODEL	FORMAT	CAPACITY (MB)	DTR[a] (byte/s)	ACCESS (ms)	MTBF[b] (hrs.)	PRICE
AGA[141]	DISCUS	—[c]	800	1250 (burst)	75	—[c]	$5,000
Maxtor[142]	RXT-800	CLV	800	156	168	—[c]	—[d]
Mitsubishi 143	MW-5D1	CAV	600	688	80	20,000	—[d]
Panasonic 144	LF-5010[e]	CLV	940	655	115	20,000	—[d]
Ricoh[145]	RS-F series	CLV	800	312	168	5,000	—[d]
Toshiba[146]	WM-S070	CAV	600	693	123	10,000	—[d]
		MCAV[f]	900	325–650	156	10,000	—[d]

[a] Data Transfer Rate
[b] Mean Time Between Failure
[c] Information unavailable at press time
[d] Price varies with configuration
[e] Uses Plasmon disks
[f] Modified CAV

Table 12: *5.25-inch WORM Disk Drives*

141 AGA [88]
142 Maxtor [88]
143 Mitsubishi [88]
144 Panasonic [88]
145 Ricoh [89]
146 Toshiba [88]

VENDOR	MODEL	FORMAT	CAPACITY (GB)	DTR[a] (Kbps)	ACCESS (ms)	MTBF[b] (hrs.)	PRICE[c]
AGA[147]	DISCUS 1200W	CAV	2.0	475	150	— [d]	$15,000
ATG[148]	GD1002	CAV	2.0	480	145	12,000	$15,500
	GD6000	CAV	6.4	1,000	120	15,000	$28,900
Hitachi[149]	OD301A-1	CAV	2.6	440	250	— [d]	$12,500
Kodak[150]	System 6800[e]	QLV[f]	6.8	1,000	100	— [d]	$47,709
LMS[151]	1200/1250E	CAV	2.0	262	212	12,000	$ 9,500[g]
Optimem 152	2400M	CAV	2.4	625	177	12,000	$14,990
	4000	CAV	3.9	723	177	25,000	$17,950
Sony[153]	WDD-3000	CAV	2.1	300	232	8,000	$18,975
		CLV	3.2	300	542–583	8,000	— [d]
Toshiba[154]	WM-S500A	MCAV[h]	5.0	500–1000	257	10,000	— [d]

a Data Transfer Rate; b Mean Time Between Failure; c Includes drive and controller; d Information unavailable at press time; e 14-inch format; f Quantized Linear Velocity; g Price for OEMs only; h Modified CAV

Table 13: *12- and 14-inch WORM Disk Drives*

Currently, two formatting methods have been applied to WORM disks: *continuous/composite* and *sample/servo.* Continuous/composite, also named pregrooving, relies on the creation of a stamping master. Grooves, embedded with header patterns and timing markers, are impressed upon the disk similarly to the grooves on a phonograph record. The read/write head is continuously tracked across the surface of the disk. In the sample/servo method, The blank disks are also preformatted during manufacture. A series of optical bursts or tracking pads guide the read/write head, and the head alternates between the servo and data fields.

Each method has its proponents. Kodak and LMSI, for example, use the sample/servo method. Other vendors, such as Optotech, use the pregrooving technique. Both continuous-/composite and sample/servo can be organized in either concentric or spiral grooves. The sample/servo method is more accurate, but more complicated; the pregrooving method is

147 Idnani [88]
148 ATG [88]
149 Hitachi [88]
150 Idnani [88]
151 LMS [88]
152 Optimem [88]
153 Sony [88]
154 Toshiba [88]

simpler and less expensive at high production volumes, but may lose certain accuracy from the stamping process. Such differences delay the adoption of a formatting standard for WORM disks.

3.2.4.6. Recording Techniques and Formats

3.2.4.6.1. Recording Techniques

WORM disk drive use the following recording techniques:

- o *Ablative (pit forming).* This technique uses the laser beam to burn a small hole on the recording layer, causing exposure of the underlayer. The intensity of light reflected from areas with no holes will differ from that reflected from areas with holes.
- o *Vesicular (bubble forming).* This techniques uses the laser beam to heat a sensitive layer causing thermal decomposition and forming a bubble. The spherical bubble disperses the light and causes a lower-intensity reflection at the site of the bubble.
- o *Phase-change.* This technique uses the laser beam to heat a metal-alloy thin film recording layer. The heat causes the layer to change from crystal to amorphous (or vice versa). The two structures cause different reflective intensities.
- o *Photochromic (dye/polymer).* This technique uses the laser beam to heat a high concentration of organic dye that is held in a polymer binder. The dye/polymer mix changes color when heated and will remain as the new color after resolidifying. When the read laser (using a specific wavelength) is directed to the surface, the different colors of the disk absorb and reflect the laser light differently.

3.2.4.6.2. Recording Formats

Optical disk drives operate at either *constant angular velocity* (CAV) or *constant linear velocity* (CLV). With CAV, each track has an equal amount of data, and the disk rotates at constant speed. The data are unevenly recorded on disk—that is, data are spaced closer together at the inside tracks and spaced further apart at the outside tracks. With CLV disks, the data-recording density is constant across the tracks. CLV disks rotate at higher speeds when the read/write head is at the inner edge and progressively slow down as the head moves toward the outer edge. (See figure 7).

By not having to adjust the motor speed, CAV disks offer faster response times, but give up storage capacity. CLV disks have higher capacity, but their access to data is slower.

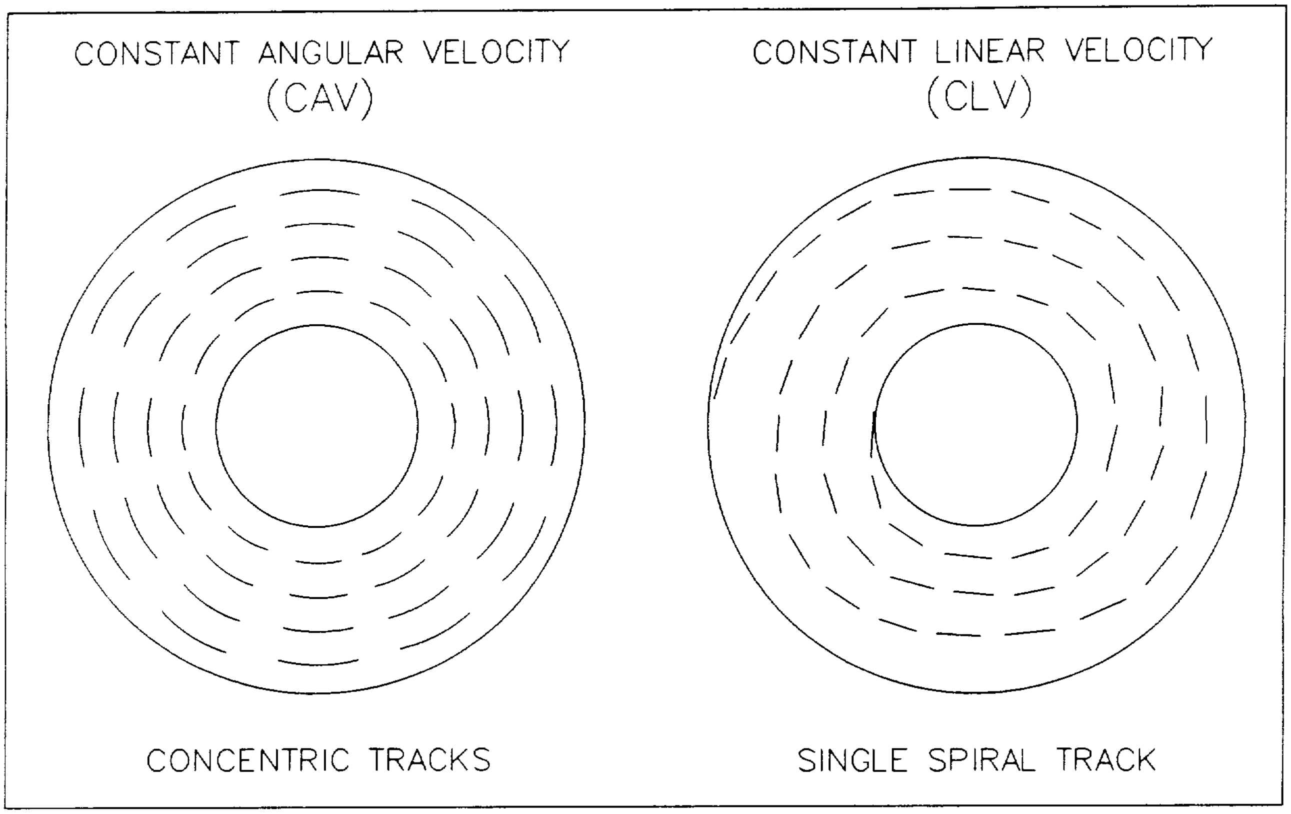

Figure 7. *CAV versus CLV*[155]

Some vendors have created modified CAV and CLV schemes to suit their own hardware needs. For example, Optimem drives use *modified constant angular velocity* (MCAV). This scheme divides the entire disk into several bands; instead of changing motor speed, MCAV changes the laser firing speed for each band. Another approach, implemented by Kodak, is *quantized linear velocity* (QLV). This scheme divides the disk into five separate recording bands. The recording speed varies on each band to achieve higher recording densities without losing access speed.

3.2.4.7. Key Enabling Technologies for Optical Drives

3.2.4.7.1. Error Correction and Data Integrity

Due to extraordinary bit and track density, optical disks have higher bit-error rates than conventional magnetic disks; their error correction systems are not just important, they are essential. Most WORM disks apply either a single or a double Reed-Solomon code to each sector. The more bits used in the error correction code (ECC), the higher the recovery capability when multiple bit errors occur.

155 Helgerson [88a], p. 63

The Reed-Solomon code decreases correction ability when the disk-error rate is 10^{-4} or higher. When such high error rates occur, the situation is uncorrectable and the entire sector is written elsewhere on the disk.

During the write operation, most systems offer a read-after-write function to verify data in real time. This is done by the controller when it immediately reads the data from a written sector and compares them with the data in the writing buffer to ensure the data were correctly written. If not, the optical head performs a rewrite to an alternate sector.[156]

Depending on the specific implementation of each manufacturer, space devoted to error correction varies from 0 to 33 percent of the available data area. Usually, this sacrificed space is excluded from disk capacity specifications.

3.2.4.7.2. Recording Density

Although optical disks have much higher storage capacity than traditional magnetic disks, manufacturers are striving to increase recording densities. These efforts have resulted in several promising approaches—some are newly implemented, some are still being developed.

One approach is to use shorter wave-length lasers. Increasing the laser diode's power allows a sharper laser beam to focus more closely without interference. Currently, optical disk drives use solid-state lasers that operate at 820 nanometers. Drives using Argon ion lasers (operating at 488 nanometers) will be available soon.[157]

Another approach is to change the recording scheme. Instead of using an encoding scheme based on the center hole of recorded patterns, the data are encoded on leading and trailing edges in an RLL 2/7 scheme that almost doubles recording density. Optimem 4000 disk drives use this scheme.

IBM is experimenting with a third approach, called *photon gating*, at its Almaden Research Center in San Jose, California. This approach overlaps data on the disk's surface to increase storage capacity. Photon-gated material allows variations in the laser beam's wavelength. Each narrow-bandwidth laser selectively excites only those molecules that resonate at that particular frequency. This permits multiple bits of data to be encoded within the same focal diameter, but at different wavelengths. The data are stored in the spectral rather than the spatial domain. Photon gating may be able to increase encoding densities as much as 1000 times more than the densities that are possible using current technologies.[158]

3.2.4.7.3. Data Transfer Rate

Maximum data transfer rates of optical disks are determined by rotational speeds, the disk recording density, and the recording method.

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156 Sony [88]

157 Idnani [88]

158 Desmarais [88]

Rotational speed is constrained by disk material. High rotational speed requires a rigid platter to ensure stability. Usually, disks with glass or aluminum substrate can be rotated faster than disks with polycarbonate or other plastic substrates.[159] Sony's 12-inch disks, which are made with polycarbonate substrates, can be rotated at speeds as high as 720 revolutions per minute (rpm). Kodak's 14-inch disks, which are made with aluminum substrates, can be rotated at speeds as high as 1600 rpm.

The recording methods CAV or CLV (discussed in section *3.2.4.5.2. Media Format*) provide either constant- or variable-speed rotation. The delay caused by changing motor speeds on CLV drives lowers data transfer rates. On the other hand, the higher recording density of CLV drives yields higher data transfer rates because data are more condensed.

Recently, researches have proposed using multiple laser beams on optical read/write heads to increase data transfer rates. By using an array of nine laser beams, eight bits of data can be transferred at one time. GE/RCA has demonstrated a three-beam system in its laboratory.[160]

3.2.4.8. CD-ROMs

CD-ROMs are mass-produced, read-only memory media. CD-ROMs store data permanently—users cannot write or modify data. CD-ROM applications are mainly in database publishing and other fields requiring large storage capacities and low-cost distribution.

Typical characteristics of CD-ROMs are their fixed 4.72-inch diameter, 540 to 600MB formatted capacities, CLV recording format, 1.2 megabit per second (Mbps) data transfer rate, 0.5 second average access time, and 10^{-12} corrected bit-error rate. CD-ROMs are one of the few types of optical media that have manufacturer's standards.[161]

CD-ROM disks are produced by a stamping and replication process, like CD audio disks. This process includes three distinct operations: *data preparation* (setting up data in CD-ROM format), *mastering* (transferring original digital information to a stamping master) and *replication* (reproduction from the stamping master).

In CD-ROM manufacturing, an extremely flat glass master disk receives a thin layer of light-sensitive photoresistors on one side. Exposing the photoresistors to the recording laser beam and then dipping the master in an alkaline bath to remove unwanted resistors, leaves a data pattern on the glass surface. One nickle impression is made from the glass master. This nickle negative is used to create four or five positives, each of which is used to make metal stampers for the polycarbonate substrate. Each stamper can create as many as 10,000 CD-ROM disks. One glass master can thus be the source for as many as 250,000 CD-ROM disks. A vaporized aluminum layer is then applied in a vacuum chamber to be the reflective surface during player reading.

159 Rothchild [88]
160 Idnani [88]
161 Rothchild [88]

3.2.4.9. Erasable Optical Disks

Erasable optical disk technology has begun to move out of laboratory and into the marketplace. Combining the erasability of magnetic storage with the high capacity and stability of optical storage, erasable optical disk may soon be regarded as an attractive alternative to magnetic disks.

Construction of erasable optical disks is similar to that of WORM disks. Erasable optical disks are manufactured in 3.5-, 5.25-, and 14-inch sizes. A list of 5.25-inch erasable optical disk drives (the most common size) is given in table 13. The mechanical and electromechanical components of erasable optical disk drive are almost the same as those of WORM disk drives.

VENDOR	MODEL	FORMAT	CAPACITY[a] (MB)	DTR[b] (KB/s)	ACCESS (ms)	BUFFER (KB)	MTBF[c] (hrs.)	PRICE
AGA162	DISCUS	CAV	594; 650	1200[d]	61.0	256	2000	$6,495
Alphatronix 163	INSPIRE	CAV	594; 650	875[e]	83.0[f]	—[g]	—[g]	—[h]
Maxtor164	Tahiti	CAV	N/A; 650	1250	51.7	—[g]	30,000	—[h]
		ZCAV	N/A; 1,000	1250	48.6	—[g]	30,000	—[h]
Ricoh165	RO-5030E[i]	CAV	594; 650	1400[d]	66.7	256	20,000	—[h]
Sony166	SMO-S501	CAV	594; N/A	925	107.5	64	—[g]	$5,250
	SMO-D501	CAV	N/A; 650	1200[d]	107.5	64	—[g]	$5,250

a The first number is the capacity of single-density disks (512 bytes/sector); the second is that of double-density disks (1024 bytes/sector)
b Data Transfer Rate
c Mean Time Between Failure
d Maximum rate at interface
e Maximum burst rate
f Seek only
g Information unavailable at press time
h Price varies with configuration
i Uses PDO disks

Table 14: *5.25-inch Erasable Optical Disk Drives*

Erasable optical disks use one of the following recording techniques: *phase change*, *magneto-optics* (M-O), and *dye/polymer bubble*. M-O recording, currently the most commonly used technique, is based on the fact that light waves are affected by the presence of a magnetic field. Two effects used in M-O data recording and reading are the Kerr effect (on reflection) and the Faraday effect (on transmission). The recording material used on M-O disks has a high Curie Point, the temperature at which the material can lose its resistance to magnetic reorientation. The Curie Point for M-O disks is approximately 150°C. This characteristic ensures the stability of recorded data.

162 AGA [88]

163 Alphatronix [89]

164 Maxtro [88]; these models will be available in November 1989

165 Richoh [89]

166 Sony [89]

The major disadvantage of erasable optical media is slow access time, about 60 to 120 ms. Erasability and high storage capacity, however, make erasable optical media suitable for supporting applications in high-resolution graphics, imaging, desktop publishing, and medical diagnostics.

3.2.4.10. Jukeboxes

Optical jukeboxes are robotic subsystems containing one or more disk drives and many disk cartridges. Through the jukebox interface or controller, host systems can manipulate every disk cartridge without having to handle the complexities of robotics or cartridge management.

Jukeboxes are available for all types and sizes of disks, but 5.25- and 12-inch WORM disk jukeboxes are the most common. Kodak is the only manufacturer of 14-inch disk jukeboxes. Table 14 lists jukeboxes for 5.25-and 12-inch platters. Supporting from 5 to 300 platters, jukeboxes provide a broad range of storage capacities. Multiple jukeboxes can also be linked together to expand storage capacity.

VENDOR	MODEL	DRIVE MAKER	# OF DRIVES	MAX. # OF PLATTERS	CAPACITY, MAX. (GB)	MET[a] (sec.)	PRICE
Cygnet[167]	5000 series	— [b]	1–2	25	20	< 4.0	$16,480
NKK[168]	DISC INN N-556W	— [b]	1–2	56	50	2.5	— [c]
Mitsubishi 169	MW-5G1-A	Mitsubishi	1–2	56	34	11.0	— [c]
	MW-5G1-B	Mitsubishi	1–4	152	90	13.0	— [c]
Panasonic 170	LF-J5000	Panasonic	2	50	47	10.0	— [c]
Ricoh[171]	RJ-5160	Ricoh	2	20	16	7.0	— [c]

[a] Media Exchange Time [b] Information unavailable at press time [c] Price varies with configuration

Table 15: *Jukeboxes for 5.25-inch WORM Disks*

167 Cygnet series 5000 specification sheet
168 NKK Corporation DISC INN N-556W specification sheet
169 Mitsubishi ME9114/5-89/5M specification sheet
170 Panasonic Optical Disk Autoexchanger specification sheet
171 Ricoh [89]

VENDOR	MODEL	DRIVE MAKER	# OF DRIVES	MAX. # OF PLATTERS	CAPACITY, MAX. (GB)	MET[a] (sec.)	PRICE
Cygnet[172]	1800 series	Hitachi LMS Optimem	1–5	141 (Hi) 95 (LMS) 141 (Op)	109 (Hi) 84 (LMS) 164 (Op)	< 8.7	$64,100[b] $79,000[c]
FileNet[173]	OSAR 200 Library	Hitachi	1–4	204	408	13.0	—[d]
Memorex 174	Telex 3500	LMS	1–5	89	178	7.5	—[d]
Sony[175]	WDA-3000-10	Sony	1–2	50	160	6.0	—[d]

[a] Media Exchange Time [b] 61-disk version [c] 141-disk version [d] Price varies with configuration

Table 16: *Jukeboxes for 12-inch WORM Disks*

Data access times for jukeboxes depend on whether the platter is on-line or off-line. For off-line platters, access times includes time for spinning-down, disk dismounting, disk mounting, spinning-up, seeking, and transferring. Off-line disk access times vary from three to eight seconds, and transfer rates vary from 0.35 to 50MB per second.

For better performance, most jukeboxes use multiple disk drives and the controller to provide buffers and to perform queuing and dispatching. Most jukeboxes have self-diagnostic abilities that make them reliable and make their complexity almost transparent to host system.

3.2.5. Printers

3.2.5.1. Introduction and Summary

Recent technological improvements in printers have produced dramatic improvements in speed and print quality. Developments in color and gray-scale printers make it possible to produce images approximating the high quality associated with magazines. Software products such as Intel's Visual Edge and Microtek's GLZ improve laser-printed images beyond the quality that could be expected from manufacturer's specifications. Page description languages (PDLs) improve text by offering more fonts and text enhancements. The resolutions at which printers operate can greatly improve the quality of both images and text.

172 Cygnet series 1800 specification sheet
173 FileNet-authorized Federal Supply Schedule Catalog [89]
174 Memorex 3500 DS specification sheet [88]
175 Sony [88]

3.2.5.2. *Types of Printers*

Three types of printers are discussed below: *bilevel*, *gray scale*, and *color*. Briefly, bilevel printers produce two-color copy, usually black on white; gray-scale printers produce varying shades between white and black; and color printers produce a variety of colors. Commercial examples of the various types are found in tables under their respective headings.

3.2.5.2.1. Bilevel

Several printer types are commonly used to produce bilevel printed copy. The most familiar are the laser printers, sometimes called photographic or electrophotographic printers. Ink-jet printers are also widely available. Together, these printers and some close variations compose the class of printers known as *nonimpact* printers. This class of printer is most suitable for the STI Facility's printing needs. See table 15 for a list of bilevel laser printers.

Many, if not most, of the printers today are *impact* printers—that is, dot-matrix and daisy-wheel printers. Daisy-wheel printers, among other printers that use typewriter-like printing elements, produce characters only; in other words, they cannot produce bitmapped images. Dot-matrix printers are often regarded as alternatives to their daisy-wheel counterparts, but they are slower, louder, and typically deliver lower resolution than laser printers. While they are appropriate for personal printing stations in an imaging system, they are not an attractive alternative as central system printers.

Laser printers, as the name implies, use either a laser beam or reflected light to create a temporary image of what is being printed. This image is subsequently stored on a photosensitive drum or belt, converted to a video representation within circuitry in the control computer, and transmitted to the video input of the printer. The last step involves transferring the representation to the laser scanning circuitry inside the printer engine. Once the toner produces the printed image, the paper is ejected from the printer.[176]

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176 Cinnamon [88], p. 43

COMPANY	MODEL	RESOLUTION (dpi)	SPEED (ppm)	RAM (MB)	PRICE
AST	Turbo PS	400	8	3	$ 6,495
Hewlett-Packard	LaserJet Series II	300	8	.5	$ 1,805
	Series 2000 2684A	300	20	1.5	$ 13,397
IBM[177]	3827	240	92 in./min.	2	$203,500
	3800 Model 3	240	215	.5	$283,500
QMS[178]	PS-810	300	8	2	$ 4,995
Talaris[179]	1590	300	15	3	$ 7,990

Table 17. *Bilevel Laser Printers*

Ink-jet printers force a stream of tiny ink droplets toward the paper.[180] Some maintain a steady stream of droplets, alternately deflecting the appropriate dots to the desired paper position or to a receiving tray for recycling. Other models modify the time and direction of droplet launching so that only appropriate droplets are directed, through ballistic trajectory, to the exact position on the paper. Ink jet printers are intrinsically reliable because they have few moving parts,[181] but their liquid inks can be more difficult to handle.[182]

3.2.5.2.2. Gray Scale

Only one true gray-scale printer has been encountered during the Imaging Project, the Seikosha Videoprinter VP-3500. It can produce up to 64 levels of gray and deliver up to a 1280 by 1240 pixel array (approximately equivalent to an 8.5-by-11-inch document at 100 dpi).[183] Because the unit is a video printer, however, its function is restricted to reproducing images displayed on a CRT screen.

177 IBM [89]
178 Laser Connection [87], pp. 1–2
179 Talaris [88], p. 4
180 Mileikowsky [89], p. 50
181 Mileikowsky [89], p. 50
182 Kriss [89], p. 25
183 Seikosha [n.d.]

3.2.5.2.3. Color

High-quality color printers are readily available in the marketplace. Although the printers themselves are competitively priced, the cost of supplies translates to a moderate to high cost per printed page. Additionally, printing speeds are significantly lower than those of the bilevel printers.

Color dot-matrix printers use a print head carrying either 8, 9, or 24 pins. The printer ribbon is multicolored. When a pin strikes a particular spot on the ribbon, a small colored dot appears on the paper. The size of the dot is determined by the diameter of the pin. The printer's resolution not only depends upon the number and size of pins on the print head, but also upon the preciseness of its roller-platten mechanism, which transports the paper through the printer[184]. Table 16 is a list of color dot-matrix printers.

COMPANY	MODEL	RESOLUTION (dpi)	DRAFT SPEED (cps)	STANDARD RAM (KB)	PRICE
AMT Inc.	Accel-500	240 × 480	480	64	$1,285
Citizen	Tribute 124	360 × 180	200	24	$ 699
C. Itoh	C-715A	360 × 380	250	32	$1,295
Fujitsu	DL-3400	360 × 180	240	24	$1,095
Toshiba	3-In-One	180 × 360	1 min/page	34	$ 949

Table 18. *Color Dot-matrix Printers* [185]

Color printing involves printing one color at a time; it is impossible to print all colors on a page at once. Intermixing three colors—cyan, magenta, and yellow (CMY)—together, however, produces all colors of the rainbow. This intermixing process is referred to as *process-color printing.*[186] The three colors are called subtractive primaries because each one results from subtracting the colors red, green, and blue (RGB), which are in turn referred to as additive primaries.

The problem of equating color production on a CRT screen and the printed page centers around the additive/subtractive issue. CRT screens are essentially additive, while the printed page is essentially subtractive. Therefore, matching colors precisely is problematic. Some authorities believe that, to obtain high quality color, one must perform digital color separations analogously to the photographic process.[187]

184 Milcikowsky [89], p. 50
185 Milcikowsky [88], pp. 52–54
186 Datapro [86]
187 Baumann + [89]

The following basic steps are discussed in the Datapro Research Report:

1. Using filters, three individual photographic negative exposures (black and white maps) are produced. In these negatives reside RGB components that are used for positive printing plates (one each for CMY).
2. This process lays down the subtractive primary colors in areas where the additive primary does not appear in the original. The cyan color absorbs the red while reflecting the colors blue and green. Yellow, on the other hand, blocks the blue and transmits green and red. When green is blocked by magenta it transmits a blue and red color.
3. Once the colors are positioned in the appropriate areas the outcome reproduces the original colors of the photograph. When two subtractive primaries print (such as cyan and magenta) all but one additive primaries (such as blue) are blocked out. Furthermore, when all three subtractive primaries print, all three additive primaries are blocked out, producing the color black.
4. Colors are not completely absorbed and transmitted due to the fact that certain printers' ink production is not perfect. For example, production of the color black might appear grayish, and red might resemble orange.

As discussed by Ron Mileikowsky, several competing technologies nearing the marketplace are promising alternatives.[188]

Color Ink-jet printers force tiny drops of colored ink through nozzles using a high-speed device called a bubble jet or thermal jet. Printers that continuously spray ink use a magnetic field for deflecting the unnecessary drops to a recycling tray. Ink-jet printers use raster technology to produce beautiful color images.[189] Table 17 is a list of color ink-jet printers.

188 Mileikowsky [89]
189 Mileikowsky [89], p. 50

COMPANY	MODEL	RESOLUTION (dpi)	SPEED (cps)	RAM (KB)	PRICE
Canon	PJ-1080-A	640 × 560	37	2	$ 699
Hewlett-Packard	HP PaintJet	180 × 180	4 min/page	.5	1,595
Sharp	JX-730	180 × 180	80 per color	19	2,195
Tektronix	TEK 4696	120 × 120	3 min/page	—	1,795
Xerox	4020	240 × 120	80	4	1,495

Table 19. *Color Ink-jet Printers* [190]

Color laser printers produce output based on light-emitting diode (LED) technology. As the photoconductor moves, a line of pixels is produced generating four continuous images in cyan, magenta, yellow, and black (CMYK). LED is still considered an experimental product and some problems have not been resolved. For instance, color problems arise form overlapping pixels. Also, because color lasers cope with four times the data that a bilevel laser printer does, they are much slower.[191]

Thermal transfer printers produce images by inserting a transfer sheet, containing waxy ink, in contact with the print device. A heated print head is used to melt the ink in the appropriate positions. As with most other color printers, the available colors include cyan, magenta, yellow, and black (CMYK). These colors are alternately printed per line. Each time all required colors are used on a line, printing progresses to the next line.[192] Table 18 is a list of color thermal transfer printers.

190 Mileikowsky [88], pp. 52–54
191 Mileikowsky [89], p. 50
192 Mileikowsky [89], p. 51

COMPANY	MODEL	RESOLUTION (dpi)	SPEED (min/page)	RAM (MB)	PRICE
CalComp	ColorMaster	200 × 200	1	0.5	$ 4,795
Howtek	Pixelmaster	240 × 240	2–3	2.5	$ 5,995
QMS	ColorScript 100	300 × 300	1	4.0	$21,995
Seiko	TargaPlot 2	240 × 240	3	2.5	$ 5,995
Seikosha	VP-3500[a]	1280 × 1240	26 sec/page	2.5	$ 6,700

[a] *Restricted to reproducing screen images only (see 3.2.5.2.2. Gray Scale).*

Table 20. *Color Thermal Printers* [193]

Cycolor printers may be the dominant color printer technology. In this technology paper is coated with a film containing millions of light-sensitive minicapsules, called *cyliths*, which are sensitive to red, green and blue light. A single cylith, measuring one-tenth the diameter of the human hair, contains a liquid monomer. The liquid-sensitive photoinitiator and a color-forming leuco dye are dissolved. This Cycolor process uses three types of cyliths that are coated on the film in a single layer.[194]

Other color printers, such as plotters, electrostatic printers, and dot-matrix printers, are either unsuitable or too slow for printing raster images.[195]

3.2.5.3. Printer Features

3.2.5.3.1. Printer Control

A printer requires a page description language (PDL) to determine what type of graphic file and fonts to use for the print. The two most common PDLs are Hewlett-Packard's Printer Command Language (PCL) and Adobe's PostScript. The difference between the two lies in the way the page is formed before being printed.[196] When PostScript was first introduced it was sold as an add-on software product to PCL, which is available with every printer. This add-on product cost between $1,500 and $2,750, depending on fonts, memory, and Adobe's licensing fee. Today, PostScript appears to be the de facto industry standard and most graphics printers incorporate it. Hewlett-Packard, however, has announced products it hopes will challenge PostScript's supremacy.[197]

193 Mileikowsky [88], pp. 52–54
194 Mileikowsky [89], p. 54
195 Mileikowsky [89], p. 50
196 Blum [89], p. 16
197 Dean [89]

Through its use of Bezier curves[198], PostScript utilizes a vector-based graphics approach. The conversion of bitmapped images through PostScript can be time-consuming, and PostScript is already regarded as slow.[199] Many efforts to generate sample PostScript-printed images during testing were aborted due to time constraints. Some attempts took over 45 minutes to print a single page. PostScript printers that have not been modified with an accelerated printer controller board appear ill-suited to the STI Facility's requirements.

3.2.5.3.2. Page Feeding

In addition to the different printing methods, the page-feeding mechanisms and capacities also vary. The three different page-feeding methods are: continuous paper (tractor feed), single sheet, and roller. Continuous paper is used mainly for mass production and mainframe printers. Single sheet, on the other hand, is used for a PC-type environment in which the files being printed might require time. The roller method, mainly used by thermal printers, is the most expensive to maintain and the slowest for heavy production (due to the heavy use of the printer head). Because it uses special paper, cost per page can be as high as twenty-five cents. This paper is usually glossy and may consist of two layers. The first layer is for the leuco dye, the second for the catalyst that reacts with the dye to produce shades of gray or, in case of a color printer, different colors. A printer that uses this type of paper is Seikosha VP-3500.

3.2.5.3.3. Throughput

The largest market for printers is that surrounding personal computers. The finest and most current printer technology is targeted at this market. In contrast, larger production printers often exhibit older, less reliable technology. The printing requirements at the STI Facility will probably be better met by several small printers rather than by one large one.

Note that in many instances a printer's specified speed represents the maximum throughput once the desired page is resident in the printer's memory. Typically, production throughputs are significantly less.

3.2.5.3.4. High Resolution

The most common printer resolution today is 300 dots per inch (dpi). Demand for higher resolution printers, however, has greatly increased. Some manufacturers offer printers with resolution ranging between 400 and 2400 dpi. Resolutions above 1000 dpi are considered to be typeset quality. Typesetters have always been expensive and that is mainly due to the fact that higher resolution requires more memory. Total resolution is a geometric function of the dpi. If the resolution doubles from 300 to 600 dpi, the dots per square inch quadruple $(300 \times 300 = 900)$ and $(600 \times 600 = 36,000)$. For instance, an image at 300 dpi requires 1MB of RAM, whereas the same image being printed at 1200 dpi requires 16MB.[200]

198 Adobe [n.d.], p. 3

199 Cummings [88]

200 Blum [89], p. 16

It remains to be determined whether high-resolution printers can use their additional print rasters to deliver better dither patterns without seriously degrading the effective line resolution of scanned images. Table 19 is a list of high-resolution PostScript paper printers. As the resolution increases the appearance of moirè patterns becomes less likely. Such patterns, which are caused by improper screen angling,[201] are detectable by the human eye as fuzziness. Unfortunately, the higher the resolution, the more expensive the hardware becomes.

COMPANY	MODEL	RESOLUTION (dpi)	SPEED (ppm)	PRICE
Agfa Compugraphic	3400-PS	400 × 400	12	$12,500
Lasersmith	PS-415	415 × 415	8	$ 3,995
Printware	720IP	1200 × 600	8	$19,990
Varityper	VT600P	600 × 600	10	$16,995
	VT600W	600 × 600	10[a]	$22,995

[a] *Can output 11-by-17-inch paper at 7 pages per minute.*

Table 21. *High-resolution PostScript Paper Printers* [202]

3.2.5.3.5. Interfaces

Three types of interfaces connect a printer to other peripheral devices. The first is the serial interface, which transfers one bit at a time at 9600 bits per second (bps). The second, the parallel interface, transfers eight bits at a time, thus improving the transfer rate. Finally, the SCSI interface is represented in two ways: SCSI-1, which has a transfer rate of 2.5MB per second, and SCSI-2, which offers two improvements on data transfer rates. The first, known as wide SCSI, has a transfer rate of 20MB per second; the second, known as fast SCSI, has a transfer rate as fast as 40MB per second.[203]

3.2.5.4. Printer Enhancements

3.2.5.4.1. Visual Edge

Visual Edge is a new software product developed by Intel to enhance halftones for gray-scale images. Essentially, the product prints more dots—of various sizes—per inch and arranges them into halftone cells that can be overlapped, sized and shaped to produce different shades

201 Eckstein [89], p. 47
202 Blum [89], p. 18
203 Simpson [89], p. 36

of gray. The Visual Edge board controls the size of the dots while the Visual Edge translates the gray-scale information in the image file into halftone cells of different sizes and shades. A halftone screen at 70 lines per inch can produce up to 64 shades of gray.[204]

Unfortunately, this product only works for gray-scale images with more than one bit per pixel. It will not be of any use to the STI Facility since most the images here are bilevel.

3.2.5.4.2. GLZ

GLZ is software developed by the combined effort of two companies: Microtek and PIXIE. Similar to Visual Edge, this product enhances an image before it is actually printed. Enhancement is done by reducing and enlarging the dot size of the image to generate true halftones. It costs $2,995 and produces 150 lines per inch at 64 levels of gray. The number of lines per inch is reduced to 75 when 128 shades of gray are used. Since Visual Edge is a less expensive product with better output—hence more popular—Microtek is promoting it rather than its own product.[205]

3.2.5.4.3. Advanced Function Printing (AFP)

AFP is a combination of licensed programs to be used with IBM printers for the sole purpose of improving printed output. It gives the printer full capability to put data on any addressable point, known as pixels (picture elements), on the page.[206]

3.2.5.5. Configurations

3.2.5.5.1. Workstation Printers

A workstation printer configuration involves connecting a printer so that only one machine can use it, that is, the printer is connected to a board in a stand-alone PC.

3.2.5.5.2. Addressable Printers

In this configuration, typical of image system integrators, the printer is connected to a LAN through which multiple users can print. It is also possible to connect different types of printers to the LAN, thus affording the user the choice to print on a laser, dot-matrix, thermal printer or any other available type. In this case each printer has a specific address.

3.2.6. Processors

3.2.6.1. Introduction and Summary

Processors are the hidden workhorses that drive imaging systems. Always present, usually in greater numbers than expected, they are often overlooked. Even in as elegant a survey of image processing systems as Felician, CPUs are relegated to a parenthetical comment, "Setting aside the problem of disk space resulting from increasing demand (and the CPU workload

204 Jantz [89], p. 75
205 Mueller [89], p. 17
206 IBM [88], p. 1

induced),..."[207] Even when arguing the case for open architecture approaches, the CPU/operating system configuration—with which all compatibilities must be defined—can be found to have been bypassed. Steele[208] indicates a Wang PC core only in a diagram caption, and the integration of a device driver around the Motorola 68000 in an ancillary box.

This lapse is especially surprising, since the dominant characteristic of image processing is the sheer size of digital images—a size easily sufficient to tax the capabilities of many common processors. "The basic difficulty is that the megabytes representing the picture must be processed in conveniently short times for the user, i.e., approximately one second. This results in a throughput rate of some 10M picture element operations per second, and this rate of processing cannot be achieved by conventional minicomputers."[209]

In spite of these obstacles, current processors are indeed supporting successful imaging systems, and better solutions are rapidly becoming available. RISC (reduced instruction set computer) processors are currently available in the marketplace, although applications software availability is lacking. The 80386 processors are assuming an ever more dominant role, but again, there is a lag in the availability of software to use 80386 native-mode capabilities. The 80486 processors appear to be moving steadily towards delivery.

3.2.6.2. Role of Processors

Even the simplest image system requires significant CPU operations to process image matrices. It will almost never occur that a scanning resolution will equal a screen resolution will equal a printing resolution within a configuration. These differences require that image scaling be performed every time an image moves from one device to another. Scaling, in these cases, is executed to maintain a more or less fixed appearance of the final image by varying the resolution inherent in an output device. Zooming in and out of images requires scaling in which an intended change in image appearance is achieved. To produce aesthetically acceptable results, scaling algorithms must avoid introducing stair-stepping into the transformed image. What appears to the user as a simple rotation of an image on a display screen is, in fact, a rather time-consuming matrix manipulation on the memory contents of the screen buffer.

Because of the large size of these data structures, if a system is to offer optimal response times—particularly when multiple users are to be supported—the machine instruction specifics of the target processor must be considered in detail. IBM implemented the *Image View Facility* with such attention to detail—and published an account of the trade-offs.[210] In the context of a discussion on workstation design, Meyer-Ebrecht and Wendler[211] provide a table of issues, user functions, and internal image processes coupled with a graphical representation

207 Felician [88], p. 29
208 Steele [86], pp. 20, 22
209 Meyer-Ebrecht [83a], p. 26
210 Anderson +, [87]
211 Meyer-Ebrecht + [83a]

of each issue. Image displaying, zooming, panning, modifying, orienting, overlaying, and comparing are covered. One of the conclusions that emerges is the number and variety of occasions that require CPU processing to support image management. Some of the often required image processes are pixel averaging, image transforms, pixel reordering, interpolation, address shifting, pixel mapping, inversion, and overlaying. Rotation and scaling can be accomplished with excellent aesthetic results through algorithms that use table look-up to replace many otherwise time-consuming computations.[212]

Some authors do point out that production throughputs must be estimated by examining more than the most visible portions of dedicated manipulation in a peripheral device; scanning times, for example, are heavily influenced by the buffer capacities, bus speeds, and processing power of the CPUs receiving images from scanners.[213] These processes represent the differences in manufacturers' specifications between burst and sustained data throughput rates. In burst mode, a raw device and its communications channel fill a target buffer as quickly as possible. Once that buffer is full, however, transmission stops while the CPU's internal bus moves data to its next destination. Only when the buffer is emptied can another burst occur. Sustained data throughput rates are an attempt to indicate communications capacities that consider buffer flushes. Unfortunately, without the users' knowing exactly how the sustained rate was measured or estimated and exactly which queueing phenomena were present or considered, it is very difficult to ascribe precise meaning to the final throughput specification.

An early PACS prototype at the University of Kansas Medical Center used an Intel 8086 processor.[214] One DEC-based hospital system described in 1983[215] had a distributed architecture developed around a DEC VAX 11/750 host equipped with a floating-point accelerator and an array processor. Each terminal was provided with a "2903 bit-slice implementation of a 16-bit processor with a machine cycle time of 190 nanoseconds."[216] An additional DEC T-11 microprocessor in each terminal supported the standard DEC operating system and could provide some central host services in the event of a host crash. A system implemented for the Arab Organization for Industrialization in 1987 was developed using PDP 11-45s.[217]

A more recent example, the *Freestyle* imaging system from Wang Laboratories, operates on Wang's PC/200 and PC/300 CPUs as well as other IBM PC/AT-compatible engines.[218] In arguing that all needed hardware technology exists to deliver truly functional imaging systems and that the missing pieces are software components, David Silver, president of Kofax Image Products, bases his discussion on a processing platform of 80286- and 80386-based PCs.[219]

212 Ward+ [89]
213 Brown [88]
214 Bulatek+ [83], p. 105
215 Zielonka+ [83]
216 ibid., p. 136
217 Khairy+ [79]
218 Briggs [88a], p. 30
219 Silver [89], p. 14

Unusual in that it has been developing around a core of mainframe computers, the imaging effort at the U.S. Patent Office has been providing massive CPU resources. The Automated Patent System was configured to use up to three large-scale mainframe processors, and each workstation contains seven 32-bit microprocessors.[220] Even with such CPU resources, communications hardware is the high-price item in the application; each of their (currently two) central PBX switches cost $10,000,000.[221] Other examples of large scale imaging applications centered around mainframe processors include the USAA and the Citibank systems currently being promoted by IBM as the flagships of their ImagePlus architecture. The USAA system currently has about 130 workstations around a System 370 mainframe and is simulating workloads with 650. Plans call ultimately for the accommodation of 1200. The Citibank installation centers on a System 36 with 85 workstations on two separate LANs.[222]

Embedded processors occur throughout imaging systems. For example, specialized hardware has been embedded within the Xerox 7650 scanner to execute image transforms and filters.[223] The logical design of such an embedded processor, one intended for use as a graphical arts halftone screener, is discussed by Wash and Hamilton.[224] Another example is the incorporation of Motorola 68020 chips in the Falcon multiple-drive optical storage units.[225] IBM has pursued an unusual twist in its project to support Q-coder as an image compression scheme. They published simultaneously both a software and a chip implementation of the scheme.[226] In most cases, embedded processors are not accessible to end users for software modification, and they are not supported with patches or new releases by their originators. Thus, they may be regarded as a merely another unalterable component in the hardware unit in which they are embedded.

Every digital imaging system encountered during this project was supported by a standard operating system, usually MS-DOS. When accessing random access storage, these operating systems are written with the assumption that data can be both read and written. True with magnetic disks, this assumption fails completely with WORM optical drives. An analogous problem exists with mainframe operating systems.

To access an optical disk through a typical operating system thus requires special effort. Few efforts in this direction have been made with mainframe computers.[227] Storage Technology sold such a product for a period, but withdrew it from the marketplace. Other vendors have

220 Huther [n.d.], p. 1

221 Site visit to U.S. Patent and Trademark Office, June 1, 1989

222 Kempster [89]

223 Williams+ [89]

224 Wash+ [89]

225 Hosinski [89], p. 10

226 Arps+ [88], Mitchell+ [88a], and Mitchell+ [88b]

227 Boeing [88], pp. 26-27

provided a partial solution by buffering the mainframe-to-optical-disk connection through a LAN and by redefining the problem to be one of a PC-to-optical-disk integration. Burnside[228] defines the following four principal strategies that have been used to address this issue:

- Develop a specialized device driver that uses an additional layer of optical-disk-resident indexing between the native file structure of the device and the operating system of the CPU. This strategy features easily-written device drivers, but can make poor utilization of device capacity.
- Proceed as in the first alternative, but place the intermediary indexing on the operating system's usual random access storage (e.g., the hard disk). The device driver becomes larger and more complex, particularly because of the synchronization issues with the intermediate index (which has become a cache). Much better utilization of optical storage capacity is achieved, and the use of the higher speed magnetic storage greatly boosts performance of the configuration.
- Develop a *universal file system* that assumes all file responsibilities of the operating system. The required software is quite complex and can introduce performance problems if not developed with extreme care and sophistication. Storage utilization can suffer, depending upon the indexing schemes used.
- Develop the device driving software on a independent, intermediary *CPU.* This strategy can produce very space- and time-efficient execution, but the hardware and software costs are high.

The performance of alternative image processors is difficult to assess. For one thing, *image processing* has many meanings. It can encompass processes as diverse as one's adjusting a television set, robotic vision, satellite imagery, or document digitization in an office environment. For another, there is a significant variety of hardware architectures currently in use to perform image processing. General-purpose digital computers are used, as are specialized versions of them that have been optimized for image transforms and data rates. Add-in boards for use in microprocessors and parallel systems have more recently been added to the inventory of alternatives. Kendall Preston Jr., has recently reported a benchmark survey[229] that uses a loosely standardized processing problem to rate different image processors. Each participant received a standard image and a specified objective. Some latitude was available in how participants approached the specific steps leading to accomplishment of the task. A scatter diagram plotted the price performance versus quality factors for 39 commercial systems. Both quality and price performance were seen to have increased successively through four different types of machines: "videorate processors," specialized image processing systems, board-level processors, and massively parallel processors.

228 Burnside [89], pp. 17-20
229 Preston [89]

3.2.6.3. RISC Processors

Whether one is considering the upper ends of IBM's 3090 mainframes or small 8086-based personal computers, the hearts of these machines are their CPUs, and their CPUs are part of an evolutionary group of processors known as complex instruction set computers (CISCs). One of the dominant forces behind their continued development has been the implementation of ever more useful and powerful machine-level instructions. In the 1960s and early 1970s, investigators began to monitor exactly which instructions were being executed in typical processing loads. They found that the end products of CISC development, the complex and powerful machine commands, represented a miniscule proportion of the commands executed in practice. Yet, these complex commands had been the driving force behind CPU development, and to accommodate them, chips had become larger and more complex.

Would it be possible, investigators wondered, to eliminate the complex commands, produce a smaller processor streamlined to execute simple commands as fast as possible, and end up with a net gain in processing power? This design strategy received its name from Patterson's RISC project at Berkeley, reduced instruction set computers. Of the first two reduced instruction set computer projects, one (Berkeley's RISC I[230]) emphasized traditional compiler tools, and the other (IBM's 801[231]) used traditional registers.[232] They both outperformed traditional processors by significant margins. IBM now offers a RISC processor, the IBM RT, which is the commercial derivation of the Model 801 experimental processor.[233] To gain their computational advantages, RISCs needed more registers and higher data access rates than their CISC equivalents; these requirements have led to higher prices for RISC processors than CISCs—perhaps increased market activity will lead to a narrower gap. Increased market roles are becoming more likely as systems software begins to appear for RISCs[234]. It is significant to note that at least one imaging board vendor has incorporated a RISC processor (a 5 MIP one) on a commercially available raster image processor (RIP).[235]

3.2.6.4. Bus Architectures

The close relationship between CPU power and data throughput requirements is being played out in the competition between IBM's Micro Channel Architecture (MCA) and the industrial group behind Extended Industry Standard Architecture (EISA). The point of contention is what bus architecture is to replace the predominantly 4-megabit AT bus structure. IBM offers MCA,[236] something new and more complex; other industry participants favor a strategy that is

230 Patterson [82]
231 Hopkins [87]
232 Patterson [82], p. 14
233 Simpson + [87]
234 Simpson [89c]
235 Micro [n.d.]
236 IBM [89]

more AT-compatible, EISA. The recent demonstration of EISA[237] at least removes the argument that EISA is little more than a plan while MCA is available. Soon, perhaps, substantive discussions and measurements will appear.

A trade-off is possible between CPU and network power. The larger the capacity and the faster the speed of the network, the more feasible it becomes to perform image processing centrally and to transmit completely transformed images to wherever they are needed. The slower the network, the more important the local processing capabilities are to transform images as required.[238]

Special attention needs to be given to processors that execute store-and-forward operations, such as those embedded in device controllers. Assuming, for example, that image files of fixed size pass randomly through a store-and-forward buffer, Dor tabulated required buffer sizes as a function of throughput utilization and buffer overflow probability. An overflow probability of 10^{-3} with a 20-percent throughput utilization requires a buffer capacity four times that of the fixed image size.[239] The presence, as is typical in practice, of variable length image sizes will significantly increase buffer space requirements. One project,[240] for example, developed an experimental system around a synchronous 32M-pixel-per-second bus.

One of the factors delaying widespread acceptance of the emerging SCSI-2 interface is that there are so few processors that can handle the high data-transfer rates offered by SCSI-2 (up to 40MB per second). VMEbus, for example can typically accommodate 10MB per second, and some can handle 20MB, but 40MB is simply out of range.[241]

3.2.7. Communications

3.2.7.1. Introduction and Summary

Whenever data (digitally encoded information) is exchanged between two electronic devices, whether over a long or short distance, the issue of data communications arises. The amount of attention the issue commands depends heavily upon the configuration and application of the system. For example, in a stand-alone turn-key system—in which all peripheral devices do not have substantial data processing capability of their own but are instead attached to a central control computer (often called a master–slave relationship)—the issue of communications is limited to the interface between the devices and the central processor.

However, as a system grows to the extent that autonomous computer processors are interconnected with each other and peripheral devices, the communications concerns become much more imperative.[242] In these computer networks, the concern lies not only in the interface, but

237 Depompa [89]

238 Hughes [83], p. 124

239 Cox+ [83], p. 43, citing earlier work: N. M. Dor, "Guide to the Length of Buffer Storage Required for Random (Poisson) Input and Constant Output Rates," IEEE Trans. Elec. Comp., 1967, pp. 683-684.

240 Meyer-Ebrecht [83a], p. 26

241 Simpson [89b]

242 FileNet [n.d.]

in multitasking and simultaneous use of peripheral devices as well. Likewise, the configuration of a network—ranging from small single-server systems (that is, the processor that provides a system service to users on the network), to systems in which services are portioned to run on separate servers, to systems in which multiple servers process tasks in parallel—also plays a large role in determining the complexity of the communication issues.

As needs grow, similar networks can be *bridged* (connected) to each other or attached to a gateway to provide connectivity to other types of networks—thus further adding to the communication complexity. To solve these communication needs, software is playing an important role in the form of device drivers, interfaces, device applications, and network management.[243]

3.2.7.2. *Network Benefits*

Over recent years there has been a shift from centralized computer systems to network computing, variously called *distributed systems* or *cooperative processing*.[244] There are two main reasons for this: to make available to a user on the network any program, data or resource without regard to the geographical location of either the resource or the user. Secondly, to ensure reliability by providing alternate sources of supply in the event of a device failure.

Additional reasons include: using the network as a communication medium among people so that, for example, two people can write one report though they live far apart; there is also a superior price/performance ratio of small computers over large ones—though mainframes may be ten times faster than the largest single chip microprocessor, they cost a thousand times more. (Microcomputer networks are currently being designed that outperform a large mainframe and at a lower cost.)

Distributed systems also allow for migration and growth into large systems by simply adding more processors. They also require simpler software design due to the fact that a processor can be dedicated for a single function in a network instead of resorting to multiprogramming and timesharing.

3.2.7.3. *Network Architectures*

For information to be exchanged, certain standards and prerequisites must exist. In fact, it is a lack of standardization among different hardware and software components that leads to the complexity of communications.[245] Some electrical interfacing standards have been developed and are widely used, but in general, standardization in the U.S. lags behind European countries or Japan where there is more regulation over the communication industry.[246]

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243 Cinnamon [89], p. 12

244 Tanenbaum [81], pp. 3–4

245 Cinnamon [89], p. 12

246 Datapro [88a], p. 3

Over the past few years there has been a strong effort to adopt the International Standards Organization's (ISO) structure of a network.[247] Called the Open System Interconnection (OSI) Reference Model, the structure consists of a hierarchical seven layer model for data communication exchange. Though the model does not describe a particular system, it serves as a reference point for establishing a communication system by defining the electrical characteristics, communication standards, and software applications.

Briefly, each layer or level, built upon its predecessor, offers a distinct service concerning both the transfer of data, and the integrity of that transfer, to the next level without burdening the successive layer with the details of how the service was implemented. Communication takes place by the corresponding layers of different machines, called *peer processes*, using that layer's particular rules and conventions—that is, its *protocol*. The information being transferred between machines is passed only in the lower layer of each machine. Higher levels communicate by passing data and control information to lower levels until the lowest level is reached and the data physically transferred. An interface exists between each pair of adjacent levels defining which services the lower layer is responsible to provide to the upper layer.

This layer structure of the OSI model is thus modularly built, thereby allowing individual layers to be improved or expanded without affecting the operation of the rest of the structure. The total set of layers and protocols are known as the *network architecture*.

The seven layers of the OSI model—from lowest to highest—are presented below along with a brief description of the services each level provides:

1. Physical layer	Transmits raw bits over a communication channel. [248] It provides the mechanical and electrical specifications, as well as the procedures to establish, maintain and end communication.
2. Data-link layer	Transforms the raw bits into units of information called *frames*. Also detects low-level errors so that only correct data will be passed to higher layers.
3. Network layer	Addresses and routes packets of information between two communication systems.
4. Transport layer	Detects end-to-end errors and controls data flow.
5. Session layer	Establishes, manages, and concludes communication between users. This layer can be viewed as the user's interface to a network.
6. Presentation layer	Formats data and converts character to code.
7. Application layer	Provides specialized functions directly to the user.

247 Tanenbaum [81], pp. 10–12

248 Stephens [88], p. 12

Both IBM and DEC have developed their own layered network architectures called System Network Architecture (SNA) and Digital Network Architecture (DNA), respectively.[249] Their goal is to provide a general framework for networking and distributed processing. Though neither SNA nor DNA completely follow the OSI model, they both have correspondences to many layers of the model and are committed to offering gateways to their respective products for those following the OSI model.

3.2.7.4. Local Area Networks

Studies have shown that the distribution of shared information is much higher within local areas than it is outside an establishment.[250] In fact, 50 percent of shared information is distributed within the department from which it originates; only 10 percent is ever distributed outside the establishment. This localized use of information, as well as the trend toward preferring network computing over centralized computing, has led to the emergence of local area networks (LANs). Another factor contributing to the proliferation of LANs is the inherent ability to connect low-cost computing devices to expensive peripherals.[251]

A LAN is a system for connecting two or more communicating devices that are located within a small geographic area.[252] The connections are established with cables privately owned by the network operators.

LANs provide a compromise between computer buses (which achieve high data transfer at the expense of a very limited distance) and voice-band data transmission (which provides unlimited transmission distance in exchange for restricted data rates).[253] The communication speed on a LAN is usually high, ranging from 1 megabit per second (Mbps) to more than 10 Mbps.[254] LANs can support hundreds of various devices for different applications, and provide gateways for communications with locations outside the network area. LANs also allow large numbers of autonomous devices to share resources, such as storage devices and databases, and also support full connectivity so that every user can communicate with every other user device.

As LAN prices are slowly but steadily falling, users no longer question the viability of the technology, but rather the quality and reliability of it.[255]

249 Tanenbaum [81], pp. 23–28
250 IBM [84], p. 2-3
251 Friend + [88], p. 197
252 Tanenbaum [81], pp. 286–287
253 Friend + [88], pp. 197–198
254 Datapro [88b], pp. 6–7
255 Datapro [88b], p. 1

3.2.7.5. LAN Technology

A LAN is a technological implementation of the physical- and data-link layers of the OSI model.[256] It concerns itself with the *cable* (which connects the devices), the *protocol* (which gains access to the cable), and the formation of *packets* (which are the basic units of transmission that contain both control and data information). The operation of the LAN is also dependent upon the network operating system software, which allows the various devices to handle concurrent requests from many users.[257]

Examples of network operating systems are IBM's PC LAN and 3Com's 3+ Share—both MS-DOS-based—and Novell's NetWare, which is a proprietary approach to networking not based on MS-DOS.

It is a mistake to think that true communication can take place with the establishment of a LAN alone. Also necessary are protocols to deal with high-level network management functions among the top levels of the OSI model.[258]

LAN technology can be broken into four fundamental areas: transmission technique, transmission media, topology and access protocol. These areas are discussed below.

3.2.7.5.1. Transmission Technique

Transmission technique refers to the way the electrical signals of a transmission are carried over the network. There are basically only two methods:

(a) Broadband - (Analog)

A broadband system allows for many devices to share a cable by assigning a specific frequency to each device in a technique called Frequency Division Multiplexing (FDM).[259] This method allows a device to have a dedicated frequency channel for itself or to share a frequency channel with other devices. Because there can be as many as 60 frequency channels on one physical cable—each roughly 6 MHz wide and capable of carrying on its communications simultaneously with other frequency channels—the technique is said to have a wide bandwidth.[260] (Bandwidth refers to the range of frequencies a medium can accommodate without signal loss.) Because it can handle many different frequency levels, analog technology is used on broadband systems.

Analog signals are continuous waves of either voltage or current amplitude.[261] Information is transmitted by varying the amplitude of the signal in a process called ampli-

256 IBM [84], p. 3-1

257 Account Data Group [86], pp. 8, 16–20

258 Datapro [88a], p. 4

259 Account Data Group [86], p. 11

260 Friend + [88], p. 213

261 IBM [84], p. 3-6

tude modulation (AM) or varying the frequency of the signal in a process called frequency modulation (FM). Both the telephone and cable television (CATV) systems are examples of this technology.

Though a broadband system with a wide bandwidth allows for a large number of devices and communication paths to be accommodated, it requires the relatively expensive and higher quality coaxial cable, or CATV cable, to be used as the communication medium.[262] Broadband systems also require the use of analog amplifiers that force the signal down the length of the cable over the total range of frequencies. In addition, each device on the network requires its own Radio Frequency Modulator/Demodulator (RF Modem) to allow it to send or receive messages on its assigned frequency.[263] Switchable or multifrequency RF Modems allow devices on different frequencies to communicate.

(b) Baseband - (Digital)

A baseband system allows many devices to share a cable by assigning each device a specific and exclusive time slot in which to transmit.[264] This time sharing technique is called Time Division Multiplexing (TDM). Because only one device has access to the cable at a given time, baseband systems use digital technology. Digital signals do not vary continuously; rather they have only on or off states corresponding to whether there is current.[265] Digital signaling uses a uniform time interval to transmit each bit. Distinct bit patterns are used to represent characters and system commands.

Baseband systems are currently used mainly by computer and satellite networks.[266] Their use is becoming more widespread due both to advances in integrated circuit technology and the fact that they are less expensive than broadband systems.

Depending on the throughput required, many types of transmission media can be used. Because they operate on only one channel, baseband systems do not require RF Modems. Also, the addition of devices to a baseband network is only dependent upon the number of slots available. Though at one time broadband systems had higher throughput than baseband systems—because they allow for simultaneous transmissions—fiber-optic technology has allowed baseband systems to rival, and even exceed, broadband throughputs.

3.2.7.5.2. Transmission Media

The transmission media refers to the type of cable used to carry the communication signal. The medium chosen is dependent upon the specific bandwidth required and whether baseband or

262 Datapro [88b], pp. 18–19
263 Friend + [88], p. 214
264 Account Data Group [86], p. 11
265 Datapro [88a], p. 4
266 IBM [84], p. 3-10

broadband technology is being used. The communication cable is attached to the PC through a network interface board whose purpose is to allow the PC to communicate with the file server and allow access to software applications.[267] The types of medium used can be divided into three groups: *unshielded wire, shield wire,* and *fiber optics.*

Unshielded wire. Unshielded twisted-pair wire is the most widely used form of copper wire and presently composes the majority of the telephone system wiring.[268] It provides quick and easy installation and is the least expensive of all the medium. However, because it is unshielded, it is subject to both electromagnetic interferences and crosstalk between adjacent cables, both of which can produce errors.[269] It is also susceptible to lightning and corrosion. Because of emanating electrical and magnetic waves, data is not secure. Unshielded twisted pair has a low data rate of around 64 kilobits per second (Kbps) with a maximum of 512 Kbps.[270] Because of these disadvantages, unshielded wire is usually only used for voice or low frequency data communications and not for LANs.

Shielded wire. Shielded twisted pair wire and coaxial cable are the two basic types of shielded copper wire.[271] While maintaining the advantages of unshielded twisted wire, shielding removes all the disadvantages. Also, shielding can attain speeds of up to 10 Mbps. Because of its low price and speed, shielded twisted pair wire has become more popular in recent years.[272]

Standard coaxial cable, the second major type of shielded copper wire, is presently the most frequently used cable for LANs.[273] It is very flexible, comprising a single central conductor separated from a copper mesh tube by a dielectric, which provides insulation between the two.[274] It has all the advantages of twisted pair wire except that of cost. Standard coaxial cable costs around ten to twenty times more than twisted pair wire.

For broad bandwidths, higher grade coaxial cable is needed—therefore, the cost rises.[275] For example, CATV cable has a broad bandwidth and can transmit about 350 Mbps. However, because of its thickness, CATV cable is rigid and requires special tools for installation, especially around curves. Another example of non-standard coaxial cable is twinaxial cable. It has two central conductors in the single cable and is usually able to install easier than two separate cables.

267 Account Data Group [86], p. 8
268 IBM [84], p. 3-15
269 Datapro [88a], p. 8
270 IBM [84], p. 3-15
271 Stephens [88], p. 2
272 Anderson + [89], p. 11
273 Anderson + [89], p. 11
274 Datapro [88a], p. 8
275 Datapro [88b], pp. 18–19

Fiber optics. Fiber-optic cable is becoming more popular for applications requiring high speed and capacity.[276] It has a rated transmission speed as high as one trillion bits per second.[277] It is usually constructed of glass fibers, each of which is no thicker than a human hair.[278] One fiber comprises two layers of glass, each of which has a different index of refraction, thus preventing light entering the cable to pass through the outer surface. The glass fibers are usually encased in a protective sheath.

Another advantage fiber-optic cable has over copper wire is that it can propagate a signal without amplification over a longer distance.[279] Though the fiber itself is less expensive than coaxial cable, the installation and connections cost more because it is a new technology.

The communication path of fiber cable is usually unidirectional, so two lines are needed for bidirectional communication.[280] Because of the security it offers, it is usually only useful in point-to-point applications where each pair of nodes have their own communication lines.

Some fiber cable is now made from plastic.[281] Though plastic fiber is lower in performance compared to glass fiber, it is more flexible and it still outperforms the other media. Due to its non-metallic construction, it does not conduct electricity and is therefore immune from noise and electrical interferences. Also, due to its flexibility, no loss of clarity will result through the cable going around corners or passing through loops.[282]

3.2.7.5.3. Topology

The topology of a LAN refers to the physical layout of the medium that connects the devices in the network.[283] These points of contact between the device and the medium are called *nodes*. There are essentially three distinct topology strategies used (although variations exist). They are star, bus, and ring.

3.2.7.5.3.1. Star

The star topology can be described as a group of individual nodes, each of which is directly connected to a central controller.[284] Though this layout allows for easy modification to accommodate changes, it uses more cable than the other topologies because of each node's direct connection.[285]

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276 Glass [89], p. 269
277 IBM [84], p. 3-22
278 Stephens [88], p. 2
279 Datapro [88b], pp. 19–20
280 Stephens [88], p. 2
281 Glass [89], p. 271
282 Anderson [89], p. 31
283 Datapro [88b], p. 20
284 Stephens [88], p. 3
285 Account Data Group [86], p. 9

The topology operates by using the links between the nodes and central controller as bidirectional communication paths. The central controller manages the LAN and all transmissions pass through it from the sending to receiving nodes. This centralized approach simplifies detecting defective nodes and offers the greatest reliability. On the other hand, it implies that the failure of the central controller disables the entire LAN. This topology, the oldest, is usually used by telephone systems.

3.2.7.5.3.2. Bus

The bus topology can be characterized as a group of individual nodes, each of which is connected to a bidirectional communication path.[286] This path has two defined end-points and is known as the *bus*. Generally, bus-configured networks are easily expanded, offer high reliability, and have a high transmission rate. By providing the most direct cabling routes, it uses less cable than the other topologies. However, a bus topology does have the disadvantage of not being able to easily identify and isolate a break in the cable.

The method of operation for this topology is for a transmitting node to propagate its signal in both directions along the bus.[287] The receiving node recognizes the address attached to the signal and accepts the data transmission. To prevent simultaneous transmissions from occurring, this topology requires some form of traffic control which can either be centralized or distributed in the individual nodes.

The so-called tree topology is basically an extended version of the bus topology.[288] It differs from the standard bus only in that its branches from the bus can connect more than one node. Functionally, however, it is identical in operation. A CATV network is an example of a tree topology.

3.2.7.5.3.3. Ring

As the newest of the three topologies, the ring topology can be described as a circular transmission path containing the nodes.[289] The communication path is unidirectional thus simplifying control. Like the bus topology, this control can be distributed or centralized. Also, because of its unidirectional nature, it lends itself to the use of fiber optics as the transmission medium. The topology operates by a node transmitting a message which is then passed around the ring from node to node until the receiving node recognizes its address and accepts the data.[290]

Because each node retransmits the data, thus regenerating the signal to its full strength, this topology can span a longer distance than the others.[291] Like the star topology, the location of

286 Stephens [88], p. 3
287 Account Data Group [86], p. 9
288 IBM [84], p. 3-24
289 Account Data Group [86], p. 10
290 Stephens [88], p. 3
291 Datapro [88b], p. 11

a defective node can be easily detected through the interrogation of each point along the communication path. A major disadvantage of this topology is that a defect in one node breaks the circuit and disables the entire network. However, this problem can be avoided by running parallel rings to bypass inoperable nodes or cables.

A common extension of the ring topology is the star wired ring.[292] It uses the physical wiring of a star in that all connections are made to central devices but the flow of data in those devices is that of a ring.

3.2.7.5.4. LAN Access Protocol

The specific protocol used to gain access to a network comprises two factors[293]: one is the control strategy to resolve conflicts when two nodes want to transmit simultaneously. This control can be centralized or distributed within each node. The second factor is the type of access method used: demand or controlled. Demand access means that a node receives access to the network upon demand; controlled access involves an algorithm to determine which node should gain access. Permutations of these two factors produce the following four access protocols:

3.2.7.5.4.1. Circuit Switching

Circuit switching, used by most telephone systems, is typically employed for a star topology.[294] Whenever a node wants to transmit to another node, the central controller connects the two through a switch. If the connection is completed, the circuit becomes dedicated until that communication is completed. If the receiving node is already communicating, access is denied to the calling node. This technique thus uses demand access with a centralized control. The switching process takes considerable time, resulting in high system overhead. Recent computerized control of switching and new solid state switches have lowered the overhead of circuit switching.

3.2.7.5.4.2. CSMA/CD

Many bus topologies use the Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol.[295] This protocol also uses demand access but differs from circuit switching in using the distributed approach as the control strategy. Before transmitting, a node senses the bus to see whether it is clear of signals indicating that it is being used by another node. If the bus is clear, it begins its transmission. If the bus is busy, the node must wait until the channel becomes free.

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292 Account Data Group [86], p. 10
293 Datapro [88b], pp. 20–21
294 IBM [84], p. 3-29
295 Stephens [88], p. 4

A problem can occur if two nodes begin transmitting simultaneously. To resolve such collisions of transmissions, both colliding nodes can detect such an act and then wait for a predetermined amount of time before attempting to retransmit. The rate of collisions of a network using this access protocol is dependent on the number of nodes and how active the network is.[296]

Reductions of throughputs due to the increased rate of collisions are common during periods of high activity for large networks using the CSMA/CD access protocol. To calculate the mean throughput rate for the CSMA/CD protocol, one must consider the total time to transmit the message (both control and data information), the interframe time to detect whether the line is clear, and the time to resolve any collisions if they occur.[297]

3.2.7.5.4.3. Polling

Polling is another protocol commonly used by star topologies.[298] Like circuit switching, it also has a centralized controller to determine whether a connection can be made. However, it differs with circuit switching in that instead of using demand access, the centralized controller asks (polls) each node at predetermined intervals whether it wishes to communicate. Though no collisions are possible with this protocol, the polling process entails considerable overhead, especially when certain devices rarely request access.

3.2.7.5.4.4. Token Passing

The token passing protocol can be used by both the bus and ring topologies.[299] A token is a sequence of bits passed from one device to another to which data can be appended. Using a controlled access method based upon predetermined time intervals, a token is passed to each node, enabling the node to transmit for a specified length of time. Thus, the token ring uses a distributed rather than a centralized control strategy.

To calculate the mean throughput rate for this access method, one must consider the total time to transmit a message and the time spent by the token.[300] Total message time includes both the time necessary for the transmission of data and control information. Token time consists of the time to detect and decide what to do with the token as it approaches the device interface, as well as the propagation time for each token, which is dependent upon the demands on the LAN by the connected peripherals.

Token passing differs from both the bus and ring topologies in where the token is passed when a node completes its transmission.[301] In a ring topology, implicit token passing is used and therefore the token is passed to the next physical node on the ring. To protect against a node failing to pass a token, ring topologies usually have time-out circuits which will automatically

296 Account Data Group [86], pp. 10–11

297 Stuck + [83], p. 74

298 Datapro [88a], p. 10

299 Anderson + [89], p. 31

300 Stuck + [83], p. 73

301 IBM [84], p. 3-32

release a new free token after a specified period of time. Also, because the ring topology is used, the single channel can be time division multiplexed so that low rate data applications can appear to be processed simultaneously.[302]

If token-ring access is to be implemented in a bus topology, a logical ring is created for each node being programmed, specifying where the token is to be passed.[303] This is often called explicit token passing. If a node fails with this access protocol, the previous node must be reprogrammed to maintain the logical ring.

However, explicit token passing does have its advantages.[304] For example, because of the explicit programming, a terminating-only node, such as a printer, never needs to be passed a token because it will never begin a transmission. Furthermore, the ability to program where the token is passed allows a high priority node to receive the token more often than other nodes.

3.2.7.6. LAN Extensions

Often LAN-attached devices can be configured to communicate with other devices not directly connected to the LAN through the use of bridges and gateways.

Bridges are equipment which connect separate LANs, thus allowing communication between devices using similar protocols, while at the same time allowing each topology to operate independently.[305] Bridges can also be used to link other bridges, thus greatly expanding the size of the network while still maintaining the speed inherent in each individual LAN.

A *gateway* is a device that allows a LAN to communicate with other devices or networks that have a different protocols. The gateway captures the data sent by the sending device and retransmits it according to the protocol of the LAN.[306] Therefore, gateways are, in effect, a LAN's means to communicate with the world.

3.2.7.7. LAN Cost Factors

The selection of the specific technology to construct a LAN plays a significant role in determining its total cost.[307] When originally constructing the LAN, there are the costs of wiring and establishing interfaces between the devices and the communication medium. Naturally, there are also labor costs—usually more than the material cost.

In addition to the construction cost, there are preventive and corrective maintenance costs. Furthermore, adding and deleting LAN devices should be considered part of the reconfiguration cost of the LAN.

302 Friend [88], p. 209
303 IBM [84], p. 3-33
304 Friend + [88], p. 208
305 Datapro [88b], p. 22
306 Account Data Group [86], p. 29
307 IBM [84], p. 3-2

3.2.7.8. LAN Performance Factors and Concerns

To balance the cost of a LAN, one must look at various performance factors of the LAN. Besides looking for a high throughput (the total information transfer rate under various use conditions), one must also consider the maximum number and types of devices that can be attached to the LAN.[308] The more devices that can be accommodated by the LAN without degrading its performance level, the more economical the network is. As with many other communication devices, both asynchronous and synchronous data flow should be accommodated.[309] To help acquire a high throughput, one should seek a low transmission error rate.[310] If errors do occur, the network should be constructed so that detecting, isolating, and recovering from transmission errors is quick and reliable.

Similarly, the ability to detect, isolate, and bypass failing devices or transmission paths is also very desirable as it impacts the reliability and availability of the total LAN. Some other factors to consider are: whether existing systems can be incorporated in the LAN, whether the LAN will meet the future needs of its environment, and whether emerging devices can be easily added to the network.[311]

3.2.7.9. LAN Standardization

Standardization of LAN technology would provide significant benefits in three areas.[312] First, the cost of connecting devices would be greatly reduced. Also, standardization would improve the maintainability of the LAN. Finally, and probably most importantly, various devices from different sources would be compatible with one another.

As the LAN market matures, the dominant suppliers are being forced to release their proprietary interface specifications, thus allowing for more connectivity between devices.

To establish LAN standards, the Institute of Electrical and Electronic Engineers (IEEE) created Project 802 in 1980.[313] This standardization committee was welcomed by both industry organizations trying to legislate standards ahead of the market and by large manufacturers who wanted to establish de facto standards by making their interfaces widely available at low cost.

The IEEE committee has released standards 802.1 and 802.2—high level standards applying to all lower level implementations—and standards 802.3, 802.4, and 802.5, which are low level standards defining LAN media access methods.[314] The specific topics of each standard are discussed below:

308 IBM [84], p. 3-3
309 Datapro [88a], p. 6
310 IBM [84], p. 3-3
311 Account Data Group [86], pp. 24–25
312 IBM [84], p. 3-38
313 Datapro [88b], p. 23
314 Friend + [88], p. 217

C-2

802.1 Coordinates the interface between the two lowest levels of the OSI model with the top five levels

802.2 Divides the OSI level two Data Link layer into two parts, called the Media Access Control (MAC) sublayer and the Logical Link Control (LLC) sublayer

802.3 Establishes a baseband CSMA/CD bus network (similar to Ethernet)

802.4 Establishes a baseband or broadband token passing bus network (similar to ARCnet)

802.5 Establishes a baseband star wired ring network using token passing (similar to Token Ring)

The MAC sublayer of Standard 802.2 deals with the access protocol, such as token passing or CSMA/CD, for each LAN implementation.

The LLC sublayer handles the error control, acknowledgement, and flow control functions. Thus both the MAC and LLC sublayers correspond to the function of the Data Link layer of the OSI model.

Standard 802.3 has become very popular because it closely resembles the original Ethernet and requires little change for compliance to the standard.[315] The standard has evolved to cover four separate specifications of different variations of Ethernet.

Standard 802.4 has recently become accepted in manufacturing environments in conjunction with Manufacturing Automation Protocol (MAP). (MAP is a protocol created by General Motors to define communications among different plant floor application systems.) Because of IBM's influence, Standard 802.5 is also becoming very popular. Standard 802.7 is currently in draft form and will provide specifications for broadband LANs.

American National Standards Institute (ANSI) Committee X3T9 published the draft Fiber Distributed Data Interface (FDDI) standard in 1986.[316] FDDI provides a standard for the creation of a LAN using fiber-optic technology featuring high speed and reliability. It can support up to 500 nodes with speeds of 100 Mbps. Though similar to a token ring network because of its star wired ring topology with token passing protocol, it differs in the data encoding scheme and the implementation of the token passing protocol.

3.2.7.10. Private Branch Exchange (PBX)

Though originally intended for use by the telephone system, many manufacturers are now suggesting Private Branch Exchanges (PBX) as an alternative to a LAN implementation.[317] This is largely due to the fact that a PBX can use cheap unshielded twisted pair telephone wire of the kind typically installed in most buildings. PBX systems are star wired and use the circuit switching access protocol.

315 Datapro [88b], p. 23

316 Glass [89], pp. 269–270

317 Datapro [88a], pp. 13–14

The PBX was originally created to enable telephone communication within an establishment independent of a central telephone exchange.[318] Instead of connecting all telephone twisted pair wire of an establishment to a cable trunk leading to the central exchange, they are connected to the PBX device. This device allows for connections between telephone wires within an establishment to be made directly in the PBX; only calls outside the establishment require the use of the central exchange.

The development of the modem in the 1960s enabled a digital device to use the analog telephone system as a means of transmission. (A modem converts binary electronic signals to analog signals and analog signals back to binary form.) Although the unshielded twisted pair wire originally limited the transmission speed because of electrical interference and error checking, the lines are now improved so that throughputs of 4800 bits per second (bps) and 64,000 bps are possible for switched and dedicated lines, respectively.

But in the late 1970s and early 1980s, PBXs began to adopt new digital technology.[319] A digital PBX allows for faster circuit switching and has cheaper components than its analog counterpart. Besides reducing the overhead time needed for the circuit switching, the digital PBX also allows for digital transmission over the twisted pair wire. The new technology allows for transmission speeds (across existing telephone wire) ranging from 64 to 128 Kbps, depending on the network structure. It also places no limit on the amount of devices that can be attached to the PBX. Because of these advancements, the PBX is capable of serving as the LAN for digital devices.

The main concern over using the PBX is that control of the entire network depends on the switching device—if that device fails, the entire network is inoperable.[320]

An alternative use of the PBX, which partially alleviates this problem, is as simply a node on a LAN. This allows any digital device attached to the PBX to communicate with any other node on the LAN while ensuring the continued operation of the LAN even if the PBX fails.

3.2.7.11. Popular Networks

The three most popular types of LANs today are: Ethernet, Token Ring, and ARCnet. Though each implementation is now available from a variety of companies, each is discussed from the viewpoint of their respective developers: Xerox, IBM, and Datapoint.

3.2.7.11.1. Ethernet (Xerox)

Though not the oldest LAN, Ethernet is the most popular one today.[321] Created in 1976 as a joint effort between Xerox, Intel, and Digital Equipment, it was the first LAN to be made commercially-available.[322]

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318 IBM [84], p. 4-5

319 IBM [84], p. 4-6

320 Datapro [88a], p. 13

321 Stephens [88], p. 6

322 Friend + [88], p. 203

Based on the Aloha satellite communications network—developed at the University of Hawaii—Ethernet uses a broadcast architecture. All independent devices are connected to a single communication channel, which traditionally has been a baseband coaxial cable. Depending on the implementation, this cable allows for transmission rates of either 3 or 10 Mbps.[323]

Ethernet uses the CSMA/CD access methodology.[324] When a device wants to communicate, it determines whether the channel is being used by another device. (Although using only a digital signal—and not a continuous carrier such as a sine wave in an analog systems—the coding is in Manchester Line Code form. This form features continuous transitions, thus ensuring that the signal can always be sensed.) If the channel is clear, the transmitting device sends a data frame.

A data frame consists of the data itself, the source and destination addresses, and check bits to ensure there are no transmission errors. Ethernet data frames can range in size from 64 to 1518 bytes.

As with other broadcast systems, all devices monitor all transmissions to determine whether they are to receive any data. Upon receiving a data frame, the receiving node returns an acknowledgement signal to the transmitting node. The transmitting device retransmits the message if no acknowledgement signal is received in a specified time interval, operating under the assumption that either line noise interfered with the message or that a collision occurred due to simultaneous signals.

Transmission collisions can occur only if two stations begin transmitting within a time interval equal to the propagation delay between the stations.[325] If no collision is detected within a round trip propagation time, the transmitting device is assured that no collision will occur. Systems are usually constructed so that collisions are detected in the early transmission of the frame to minimize wasted transmission time. If a collision does occur, the involved devices will detect it and wait, in random amounts of time, before trying to retransmit. By randomizing the waiting periods of the different colliding devices, the probability of repeated collisions are reduced. In heavy usage periods, it is common for retransmission delay time to increase after a few unsuccessful repeated transmissions. Some Ethernet systems will return an error message to the sending device after a certain amount of failed transmissions.

Because the number of collisions, waiting periods, and retransmissions increases in proportion to the increase in transmissions, Ethernet is not typically used in a heavy traffic environment.[326] It performs best in low traffic or burst-oriented conditions because the channel is usually clear for transmission and no time is required to wait for the token to arrive—as in a token passing access method.

323 Glass [89], p. 269
324 Friend + [88], pp. 203–206
325 Friend + [88], pp. 203–206
326 Account Data Group [86], pp. 10–11

3.2.7.11.2. Token Ring (IBM)

After years of research, IBM believes the optimum LAN revolves around a digital baseband transmission using a star wired ring topology with implicit token passing as the access protocol.[327] In fact, this approach is emerging as the most popular LAN for PC oriented implementations.[328]

Though shielded twisted pair copper wire is usually suggested as the communications medium, fiber optics can also be used where high speed transfer justifies the cost. The token ring was originally created to run at 4 Mbps but IBM announced a 16-Mbps version in November 1988. By using a star wired ring approach, the LAN operates as a ring but has the additional advantage of easy configuration because of its star-like wiring.[329]

Usually, the token ring LAN is actually composed of two rings so that the second ring can serve as a backup in the event there is a break in the primary ring. The rings themselves are composed of connected wire concentrators to which the nodes have been attached with twisted pair wire. These wire concentrators give this topology much flexibility since it is easy to add or remove a node. They also provide the means for automatic bypassing of any breaks in the primary or alternative rings as well as isolating a faulty node from the network.

Operating as a token passing ring, a free token is passed from successive node to node on the ring.[330] If a node wants to transmit, it must wait until a free token is passed to it. Upon receiving the free token, the node can then append the data to be transferred, address information, and other control information to it. By doing so, the node transforms the token into a frame, sets the token to busy, and then sends it to the next node. The frame is passed along the ring and retransmitted from node to node until reaching the receiving node.

The transfer time of the frame from node to node is dependent upon several factors, including the ring speed, the number of nodes on the ring, the length of the ring, and the ring utilization-.[331] The receiving node copies the data from the frame and sets the copy bit in the frame to indicate that the data was received. When the frame returns to the sending node, it checks the copy bit, removes the data, and resets the token to free. As long as the token is busy, no token besides the addressed node can use it.

To ensure that data is transmitted correctly, the token ring has built-in error and fault detection.[332] The frame contains a sequence check to guard against noise on the line, and also contains an address-recognized indicator to check that the correct receiving node got the data.

327 Stephens [88], p. 7
328 Kong [89], p. 81
329 IBM [84], p. 5-1
330 Stephens [88], p. 7
331 IBM [84], p. 5-16
332 IBM [84], p. 5-7

The network also designates a node to be a monitor to see that a free token passes through the ring within a specific time limit and that the token is not always busy. The ring can even detect when the monitor itself is faulty.

Because of the sophistication and the cost of the hardware and cabling of the token passing ring, it is better-suited for a larger network.[333] Its chief benefit lies in a large-data and high-use environment since it does not suffer from the collision and retransmission problems that the Ethernet LAN has. Another benefit is that it prevents a single node from monopolizing the network by guaranteeing access time above a minimum level.

3.2.7.11.3. ARCnet (Datapoint)

The last major LAN type is the Attached Resource Computer Network (ARCnet).[334] Developed in 1977 by Datapoint Corporation, ARCnet is an example of a token passing bus with a hybrid bus/star topology. Rather than have individual nodes directly connected to the central bus, the network is structured so that only the hubs are. Individual devices are attached to the hubs through Resource Interface Modules (RIMS), thus giving each hub a star-like appearance. Signal quality is controlled by built in amplifiers. ARCnet uses inexpensive RG62 coaxial cable to achieve baseband transmission of 2.5 Mbps. Although the transmission rate is slower than Ethernet or Token Ring, it is more dependable and efficient.[335]

Like the IBM Token Ring LAN, ARCnet uses the token passing access protocol.[336] If a node wishes to transmit, upon receiving a free token it inquires whether the destination node is free to receive a message. If an acknowledgement message is returned, the transmitting node can send a message of 1 to 253 bytes. The token is then passed to the next logical node. Like the token ring LAN, ARCnet has a built-in error detection feature that enables the token to skip a node if that node does not respond within a predetermined amount of time.

3.2.7.12. LAN–Mainframe Gateway

Ever since Digital Communication Associates (DCA) invented the IRMA card, it has been possible for the PC to double as a mainframe terminal.[337] This plug-in card, combined with hardware and software, enables a PC to simulate a 3270 Terminal, which is the generic name for an IBM system component that communicates with a mainframe using IBM's Systems Network Architecture (SNA), itself the fastest growing mainframe connection scheme.

Another early method for PC-to-mainframe communication was to use a protocol converter between the two. The purpose of both the plug-in card and the protocol converter is to provide the PC with the extra keys and special graphic characters that a 3270 terminal has, as well as convert the ASCII used by the PC into the EBCDIC alphabet used by the mainframe. With the

333 Account Data Group [86], pp. 9–10
334 Stephens [88], p. 5
335 Glass [89], p. 269
336 Friend + [88], p. 212
337 Derfler [88], pp. 92–95

introduction of LANs, it is now possible to use the gateway of a LAN as a means of sharing a mainframe connection for all the connected PCs.[338] This precludes the need for expensive mainframe links for each individual PC.

Currently IBM offers two approaches for a LAN to host gateways. The older of the two approaches is to designate a PC on the LAN as the gateway to the mainframe. Sometimes this PC becomes a dedicated host gateway, but often it can act simultaneously as both a gateway and a LAN workstation. Any PC on the LAN can communicate directly to the mainframe through the PC gateway using the Network Basic Input/Output System (NETBIOS) interface.

The NETBIOS interface was introduced by IBM in 1984 as a software interface between a network adapter and an operating system.[339] It offers an alternative to the high level structure established by the IEEE 802 committees and has emerged as the de facto standard to supply network transport services for PC-only LANs. Though each PC is recognized as a Logical Unit (LU) by the mainframe, only the gateway PC is recognized as a Physical Unit (PU).[340] An LU is an addressable unit in the SNA architecture which allows a user access to the network and the functions it provides. A PU is also an addressable unit in the SNA architecture and allows the system to manage and perform administrative functions on the node. The PC gateway approach is the most prevalent on the market today, used primarily for small LANs that only interconnect PCs.[341]

For larger networks as well as those involving minicomputers and controllers in addition to PCs, IBM recently announced the use of communication processors to act as the physical gateway.[342] Examples of these processors are the 3174 terminal controller, which provides efficient transmission to the mainframe by gathering and clustering messages for a group of terminals; the 3725 front-end processor (FEP), which links groups of cluster controllers to the mainframe; and the 3745 communications controller, which can combine the functions of a cluster controller and FEP.

IBM's recently announced midframe computer, Application System (AS)/400, can also be used as the physical gateway. Under this methodology, each node on the LAN is not only a LU, but also a PU which can be accessed by the mainframe.[343] For the mainframe to have control over every node on the LAN, the low level IEEE 802.2 protocol is used instead of NETBIOS. Because this approach is more complicated and requires a finer level of detail than the PC gateway approach, most third party gateway suppliers do not offer similar products.

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338 Kong [89], p. 84
339 Account Data Group [86], p. 14
340 Derfler [88], pp. 96–97
341 Kong [89], pp. 81, 84
342 Derfler [88], pp. 95–96
343 Kong [89], p. 84

Neither of the two LAN gateways is easily installed.[344] Much collaboration is required between the LAN administrator and the mainframe system programmer to properly set the many electrical and software parameters. Specifically, variables in the mainframe's communications, operating, and security systems must be properly set for the gateway to communicate.

It has been discovered that software, not hardware, is usually the key to gateway performance. This is because large software programs usually include menus that make the programs easier to use and are generally more tolerant of errors.

3.2.7.13. Wide Area Networks (WANs)

As an establishment grows, it sometimes becomes necessary to communicate with locations outside of the local area. Through the use of gateway devices, LANs can communicate with devices on networks located in different geographic areas. Communications between these two separate areas can take place through the wide area telephone network or the other following long distance communications links:

3.2.7.13.1. Telephone Networks

A relatively inexpensive manner to communicate over long distances is to use the public telephone networks.[345] Modems allow the use of standard switched (dial-up) services. This means of communication is typically only used for low-speed sporadic transmissions because it is error prone and cannot guarantee a connection.

Leased lines, sometimes called *nonswitched service*, offers some improvement by guaranteeing a connection through the private line. It is also less error prone and can handle both voice and data communication.

3.2.7.13.2. Digital Lines

Digital lines are becoming more popular as a means of long distance communication since they offer more error free transmission than the older analog lines, yet at a cheaper cost than microwave or satellite facilities.[346] They also have the advantage of requiring neither modems nor amplification (since the signal is digital).

The two most popular digital services today are Dataphone Digital Service (DDS), which has a transmission of 56 Kbps, and T-1 lines, which can handle a transmission of 1.544 Mbps. T-1 multiplexers also exist that use time division methods to allow voice, data, and video signals to be transmitted over a single T-1 line. Users who do not need—or cannot justify the cost of—a full T-1 line, can take advantage of the recent introduction of fractional T-1 lines that may be purchased 64 Kbps increments.

344 Derfler [88], pp. 182–183
345 Datapro [88a], p. 6
346 Datapro [88a], pp. 7, 12

A new area of digital communications is the integration of voice and data.[347] Previous methods of integration were limited to either having only one line to be alternately used by data or a digitized voice, or two lines to allow concurrent voice/data communication. A more recent method involves storing the digitized voice in the same way as computer data and to transmit both concurrently.[348] As part of the Integrated Services Digital Network (ISDN), this last method is being expanded so that text, voice, data, and video can all be communicated over the same digital lines.

Using fiber-optic cable because of its capacity to transmit huge quantities of information, ISDN is capable of transmitting at 144 Kbps. According to the December 1988 adopted CCITT standard, this is accomplished by using two channels of 64 Kbps each to transmit data and a separate 16 Kbps channel reserved for control and signaling information.

Work is currently taking place to create a broadband ISDN line with transmission speeds of more than 100 Mbps. IEEE Committee 802.9 is currently working on a standard to integrate ISDN with LANs so that each network implementation does not require a specialized interface.[349]

3.2.7.13.3. Packet Switching

Another method for communicating over long distances is to subscribe to a public data network (PDN).[350] Also called value-added networks, PDNs are private or government-owned networks that provide communication services to customers over long distances using *packet switching.* Packets are groups of bits which include both control and data information transferred as a unit. Packets are dynamically routed through the network to find the most efficient path to the final destination. Because a message can be composed of multiple packets, each of which may travel through a different route, packets are normally numbered so the message can later be reassembled correctly.

To gain access to these networks, protocols have been developed and accepted by the international community.[351] For the physical layer protocol of the OSI model, Standard X.21 has been developed for digital transmission; and an interface similar to the RS-232C has been developed for analog transmission. Both layers two and three of the OSI model also have established protocols for access to the PDN. The protocols for the first three OSI layers are known collectively as Standard X.25.

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347 IBM [84], p. 4-8

348 Martin [89], p. 60

349 Datapro [88b], p. 23

350 Datapro [88a], p. 6

351 Tanenbaum [81], p. 28

3.2.7.13.4. Facsimile Transmission

Using the traditional fax machine—or the relatively new fax boards installed in a PC—provides an inexpensive wide area communication method.[352]

Current fax transmission revolves around the international standard established by CCITT in the early 1980's, known as Group 3. This standard provides for a 9600-bps transfer rate to transmit compressed data over regular voice-grade phone lines. Depending on what factor compression was done, the time to transfer a page can take from 30 to 60 seconds. Group 3 improved resolution from 100 by 100 dots per inch (dpi) to a choice between 100 by 200 dpi (standard resolution) or 200 by 200 (fine resolution).

Group 4 fax devices were recently introduced. They can improve the transmission rate to 5 to 10 seconds, and the picture resolution to 400 dpi. However, Group 4 devices require digital transmission networks; consequently, analog telephone lines prevent Group 4 fax from being widely used. Because of the relatively slow rate of transmission when compared to other methods, fax is only used in low volume situations where convenience and cost are the main factors.

3.2.7.13.5. Satellite Communication

Satellites offer long distance communication for high volume environments, albeit at a high cost.[353] The satellite, which is largely composed of antennas and transponders, remains in geosynchronous orbit serving as an active relay. It receives a transmission from a sending earth station and retransmits the message to the designated receiving station after amplifying the transmission. The retransmitted message is often changed to a different frequency to prevent interference caused by two signals having the same frequency.

3.2.7.13.6. Microwave Communication

Microwave communication has recently become a strong competitor to standard telephone wire as a means of long distance communications.[354] Microwave communication is actually radio communication operating in the frequencies of 1 GHz to 30 GHz of the electromagnetic spectrum. The drawback to this method is that the radio waves require a clear path between transmitter and receiver. To avoid interference from high buildings or tall trees, microwave towers must be built very high.

3.2.7.14. Communication and Image Document Systems

For any document processing image system larger than a simple stand-alone turn-key system, communication networking plays a role. In fact, many corporations are installing their first LAN in conjunction with their image processing system.[355]

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352 Stone [89], pp. 95–98

353 Datapro [88a], p. 6

354 Datapro [88a], p. 6

355 Greenstein [89], p. 44

The possible topologies of image system networks are similar to the traditional LANs.[356] A star topology can be used with the file server acting as the central controller to which the workstations and image devices—such as scanners, disk drives, and printers—are attached. With a bus or ring topology, the file server, to which all image-related devices are attached, is connected to the central cable and acts as a node on the network—like all other connected workstations.

The advantages and disadvantages of each topology, as well as the type of medium or access protocol used, are also similar to traditional LANs. Hybrid systems combining the three basic topologies can also be used. As an alternative to the usual topology, the Automated Patent System of the U.S. Patent and Trademark Office uses an image system network based on a digital PBX wired with fiber-optic cable.[357]

The central area of concern for communications in an image system is that of document access speed.[358] Though the LAN may have a stated transmission rate of 10 Mbps, often it cannot transmit at that speed for various reasons. First, image files are not the only data transmitted along the network; these files are competing with data files, commands between the control computer and peripheral devices, and network overhead. Furthermore, this nonimage data increases as the size of the network grows. Some vendors have attempted to solve this problem by having two concurrent LANs, one reserved exclusively for image data. Other causes for slow response time may stem from the fact that the devices on the LAN cannot transmit or receive data at the same speed of the network; and delays occur for the compression and decompression of image files.

The major reason for the slow response time in an image system network is that current networks were designed for data processing applications, not images.[359] Pages of text from a word processor require only 2KB of storage while an image bit map file of the same textual page requires 40 to 50KB after compression. A digitized page which contains a picture can easily require over 1MB of storage. Therefore, though a network may not place any inherent maximum on the size of the information transferred, large image files clearly strain the actual transmission speed. Furthermore, putting many images on-line at once can totally stop a network.[360] According to Stephen Elliot, consultant with Arthur Andersen and Company, "It doesn't take many images to blow away an Ethernet. A 10 or 20 page file can make other people on the Ethernet grind to a halt."

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356 Cinnamon [89], p. 61
357 PTO [n.d.]
358 Cinnamon [89], p. 63
359 Anderson + [89], p. 31
360 Greenstein [89], p. 44

The critical issues for the success of transmitting images over a LAN are the design of the topology and the speed components that best fits each application.[361] The Automated Patent System of the US Patent and Trademark Office has optimized their PBX LAN for each channel to support transmission of over 700 Kbps with an overall actual network capacity exceeding 1000 Mbps.[362]

When dealing with wide area networking, image transmissions become more complex because of the distance involved. However, as David Liddel, manager of IBM's marketing plans for image application systems, said, "As customers decide to implement more image processing applications, there will be a demand for more wide area, high bandwidth facilities. Image processing will drive the demand for communication services; I think it's the applications that will be driving the communications. Wide area communications is the first order design variable for image processing."[363]

On the low end of image communication over widely dispersed areas, fax transmission offers an inexpensive solution for low volume document image input and output capabilities. Many scanner vendors, such as Xerox, Microtek Lab, and Panasonic, offer fax cards for the PC which can take a scanned image file, usually in a TIFF file format, and convert it into Group 3 fax for transmission.[364] Ricoh Corporation has recently displayed a prototype of Group 4 fax which will be capable of transmitting images over a digital medium.[365]

For high-speed communications over a wide area, T-1 digital lines, fiber-optic networks, and satellite communications can be used. As part of United Services Automobile Association's (USAA) image processing system, T-1 lines will be used to transfer data.[366] They estimate that their 40 to 50KB compressed images will require only 17 percent of their present T-1 lines. Many image system vendors have teamed with communication companies to provide business and government organizations worldwide with image processing capabilities. For example, FileNet has teamed with International Datacasting Corporation of Canada to provide high bandwidth image/data satellite communications.[367] Wang has signed an agreement with AT&T to sell its Wang Integrated Image System (WIIS) along with AT&T's ISDN.[368]

3.3. Process Components

3.3.1. Introduction and Summary

The process components discussed in the following sections can be thought of as the software side of imaging technology. However, they are often implemented on embedded processors

361 Anderson + [89], p. 31
362 PTO [n.d.]
363 Greenstein [89], p. 44
364 Stone [89], pp. 102–103
365 Ricoh [n.d.]
366 Moran [88], p. 60
367 FileNet [n.d.]
368 Greenstein [89], p. 44

where they function analogously to equipment components. This duality is very clear in the case of optical character readers, which, for example, are usually acquired as separate units or add-in boards, but which can also be acquired as "pure" software products.

3.3.2. Character Recognition

3.3.2.1. Introduction and Summary

Often the desired result of scanning a page is not the created digital bitmap of the image. Rather it is the quick and accurate conversion of the bitmap into ASCII or some other format by means of automatic electronic recognition of characters. The obvious advantage of this technology is the savings of both time and labor costs associated with rekeying data from paper.[369]

Service bureaus currently offering text conversion services employ off-shore workers in the Caribbean region, Mexico, or the Philippines. Typically, two operators independently enter the text into files that are then compared and checked for spelling by computers. The cost for this method is estimated to be about three dollars per page. In addition to the increased input rate over human effort, conservatively estimated at 5 : 1, machine recognition is not subject to fatigue or other human characteristics. [370]

On a larger scale, a new application of character recognition lies in creating large text-oriented databases to provide fast full-text search capability.[371] This enables searching for the occurrence of certain words against the full text of a collection of documents rather than against a simple key-word index. Such full-text searches are efficient in saving time and eliminating irrelevant material, as well as in terms of the quantity of significant information returned. Character recognition technology has also been applied to facsimile technology (fax); pages can now be scanned and faxed and then reprocessed using character recognition software.[372]

Though scanner technology may not have advanced much over the past three years, character recognition capabilities have drastically changed during the same period.[373] The present trend of using feature extraction to replace matrix matching as the method of choice in character identification has increased the capability of reading typeset text instead of only monospaced typed text.

Another area of improvement is the ability to read dot matrix fonts. In 1986 not one device could recognize dot matrix text.[374] This was due to the fact that a dot matrix printer does not print a solid line but rather only distinct dots; and there were not enough dots printed to allow

369 Friedman [88], p. 14
370 Crossan [89], p. 28
371 Fruchterman [88], p. 17
372 Stanton [87], p. 186
373 Stanton [89], pp. 187–188
374 Stanton [87], p. 194

the software to recognize a character. Today, however, some devices can read better quality dot matrix fonts as well as those from a phototypesetter, laser and impact printers, and even output from some fax machines.

The most recent advancement in recognition technology is limited recognition of handwriting, under development by such firms as Nestor Inc., Bell & Howell, and TRW.[375] These companies are using advanced techniques which center around the use of neural networks along with a software/hardware combination. Neural networks greatly improve the recognition process since they operate more like a human brain in that, in uncertain or unclear circumstances, they make judgements based upon probabilities rather than only on absolute rules. The U.S. Postal Service is testing these handwriting techniques in order to automate the process of reading zip codes on hand-addressed letters.\[376]

Concurrent with the improved functionality of character recognition devices is the lowering of their cost.[377] In 1986, a recognition device for reading typeset cost about $40,000 and required a minicomputer for processing. Today, a device with the same capability costs under $10,000 and requires only the power of a PC. Steve Nickel of The Technology Group predicts that sophisticated recognition packages will drop to as low as $500 by the 1990's.[378]

As the new technology becomes more powerful, it will require more software support. This support will probably come in the form of AI software experts trying to improve the accuracy of the recognition.[379] Besides new software support, the future of character recognition also will depend on how well it integrates with application that view a data file in an object-oriented fashion.

Though advancing, character recognition still has a long way to go. John Kozlowski, Director of Marketing for Microtek Lab Inc., explained, "OCR technology is by nature an inaccurate science. There is no such thing as 100 percent accuracy. The whole concept of OCR is to get a large majority of text in without errors. You're just hoping to keep them down to a minimum."[380] However, as Kozlowski continued, "A lot of products were probably oversold. People made claims they were doing more they actually could."

This has led purchasers to expect fully automatic text recognition on a complex typeset page with acceptable output. Since machines do not presently have this capability, these buyers have been disappointed. Because of this, Datek Information Systems, a market research firm, predicts that revenues of OCR scanners—which were more than $35 million in 1987—will fall to $20 million this year, and are unlikely to grow by much in the future.[381]

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375 Sherer [88], p. 102
376 Grimm [89], pp. 63–64
377 Stanton [89], pp. 187–188
378 Karsh [89], p. 64
379 Doebler [89], pp. 52–53
380 Sherer [88], p. 101
381 Mueller [89], p. 14

For certain applications, however, the present technology is quite sufficient. Even today, character recognition plays a beneficial role in information processing as a bridge between the paper and electronic worlds.

3.3.2.2. History

Though character recognition is an application of a scanner, it in fact provided the stimulus for the scanner's invention.[382] The oldest form of the scanner was an optical character reader created by C. R. Carey in Boston in 1870. Carey's device took the form of a retina scanner used to aid the blind. In the early 1900s, AT&T patented and commercially sold a device developed by E. Goldberg which scanned a typed message for the purpose of encoding it into Morse Code. In 1938, IBM also began using optical character readers in conjunction with its EAM equipment.

Widespread commercial use of character recognition devices did not occur until the mid 1950s.[383] These devices were designed to recognize text and numbers and translate them into binary code. These hardware-based machines often required special typefaces and paper and were usually only used by firms whose large-volume needs justified the cost.[384]

To help machines better distinguish between similar characters, especially characters like *1* or *l* and *4* or *9*, the American Bankers Association adopted the Magnetic Ink Character Recognition (MICR) typeface in 1956.[385] Soon afterwards, the American National Standards Institute (ANSI) developed another typeface called OCR-A and a European version called OCR-B. These typefaces were created for specific environments such as publishing applications, rather than for commercial use.[386]

By the 1970s, special typefaces were no longer needed for character recognition, but a restricted set of fixed-space typewriter fonts, such as Courier 10 and Courier 12, was still required.[387] Proportional spacing and multiple font capability were possible, but only available in very expensive machines. In 1975, Raymond Kurzweil, founder of Kurzweil Computer Products—one of the leading manufacturers of character recognition equipment today—created a reading machine that has been immensely useful to the blind.[388] It could recognize a wide variety of fonts, convert the printed characters into machine code, and then manipulate the resulting words into synthesized speech.

382 Helgerson [87], p. 3
383 Gunn [88], p. 1
384 Karsh [89], p. 56
385 Helgerson [87], p. 3
386 Doebler [89], p. 51
387 Helgerson [87], p. 3
388 Friedman [88], p. 13

Today these once-advanced capabilities and many more are software-based and available for under $10,000.[389] The decreasing costs and technological advancements are responsible for today's commercialization of character recognition devices in a wide range of industries, including financial and legal services and full-text database development. In fact, according to The Technology Group, a custom market research company specializing in the electronics industry, of the 85,000 scanners shipped in 1988, about 25,000 of them contained some form of character recognition capability.[390]

3.3.2.3. OCR Applications

3.3.2.3.1. Remittance Processing

Character recognition is usually performed for one of three purposes: the earliest and still common use is for turn-around documents of the type issued by utility and insurance companies.[391] A turn-around document is preprinted by the sender who leaves only specified areas for the recipient to enter information and return the document. OCR is then used to read the selected area for the recipient-specific data. These documents use a special typeface and often an embedded check digit to catch misreads—consequently, high volumes are handled at very fast speeds.

For example, Recognition Equipment Inc. produces recognition equipment that uses a low scanning resolution to achieve recognition speeds of 5000 characters per second (cps). Because these devices are mostly dedicated to a specific, high-volume function, they are both very expensive and unsuitable for environments handling a broad range of documents.[392]

3.3.2.3.2. Form Processing

A second common application of character recognition is to process standardized forms.[393] One common approach uses special ink that does not reflect the illumination of a scanner on those portions of the form which require no data capture, and to provide for easy to locate registration points. Another approach gives the user control of software which uses X and Y coordinates and user-supplied inch measurements to limit the scanning boundaries to specified fields.[394] Using this methodology, recognition rates achieve as high as 99.5 percent accuracy.[395]

389 Stanton [87], p. 186
390 Karsh [89], p. 57
391 Gunn [88], pp. 1–2
392 Helgerson [87], p. 3
393 Friedman [88], p. 15
394 Calera [88]
395 Gunn [88], p. 3

Plexus Computers Inc. (which filed for Chapter 11 bankruptcy protection in March 1989 and is currently in the process of restructuring[396]) installed such a system at Glaxo Inc., a pharmaceutical manufacturer.[397] Called the Extended Data Processing (EDP) system, it enabled batch jobs to run at night to transform text on form sheets into ASCII.

A more specific application of this type of OCR reads a fixed spot on a page and uses the information as an index for storage and retrieval purposes.[398] To avoid specifying the location of the area to be processed, it is common to use a handheld scanner with built in OCR capability for such situations.[399]

3.3.2.3.3. Document Processing

The third common use of a recognition device is to capture text from an entire page. This method greatly reduces the cost of entering data into a database.[400] It also greatly reduces the amount of storage space required for a file. A digitized bitmap file of an 8.5-by-11-inch average text page requires approximately one megabyte of storage space if scanned at a resolution of 300 dpi; using character recognition the same page requires only 4KB of storage. Even if the image were compressed by a factor of 20, the 50KB image file would still be 12 times the size of the character recognized text. Furthermore, the text file itself could be compressed.

Systems currently exist which allow a single PC and character recognition devices to recognize and encode 450,000 pages a year. However, to do a good job, the recognition software must be capable of handling complex page layouts, including columns, various fonts and point sizes, as well as distinguishing between text and images.

Character recognition for document processing provides for the preservation and improved accessibility of documents, and for the reduction of storage and retrieval costs associated with them. This conversion of older documents to character recognized form is potentially the largest application of character recognition and also one of its biggest challenges.[401] Older documents can be hard to read due to deterioration of print (perhaps only a copy of the original), a complex layout, and elements such as footnotes, scientific notation, and special symbols.

The Department of Defense (DOD) has contracted Anamet Laboratories, a California-based systems integrator, to transfer information from some five million microfiche and twenty-five million aperture cards to a database using character recognition.[402] Savings for this system are estimated to be around five million dollars.

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396 Neubarth + [89], p. 4
397 Moran [88], p. 59
398 Gunn [88], p. 2
399 Brown [88], p. 55
400 Friedman [88], p. 13
401 Doebler [89], p. 52
402 Fruchterman [88], pp. 17–18

Character recognition is also being combined with artificial intelligence software. For example, the Aluminum Company of America (Alcoa) is reducing downtime during manufacturing failures by searching a 40,000 page character recognized database with artificial intelligence software to locate documentation relevant to the problem, thus enabling the problem to be isolated and diagnosed.[403]

Project Mercury, at Carnegie-Mellon University's Hunt Library is another example.[404] This project is studying the feasibility of creating an electronic library by converting a knowledge-base in the artificial intelligence field to electronic form and then operating it as an electronic reference library, which itself would support dial-in search and retrieval services. Character recognition is converting the text to electronic form, as well as the supplying of descriptive data about each document to support the search and retrieval.

Finally, character recognition is also used by desktop publishers and commercial typesetters as a means to input information without having to retype them.[405]

3.3.2.3.4. Types of Devices

Like scanners, character recognition devices come in various forms and sizes. Technically, there are two groups of recognition devices: those that are integrated with a scanner, optical character recognition (OCR) devices, and those that are scanner independent, simply called recognition devices.

OCR devices can be further divided into two groups based upon relative size. On the smaller end are handheld OCR devices, such as the Everex System TransImage 1000 or Saba Technologies' Handscan. These first scan and then perform the recognition process.[406] Handheld OCR devices are generally hard to use since their scan area is very small and the slightest deviation from a straight line produces unintelligible characters. (The TransImage 1000 partially solves this problem by using long rollers to glide across the page.) Handheld devices are generally not used for character recognition on a page but rather only for recognition of strips of text.

When dealing with larger areas or complete pages, high throughput OCR devices, such as the Kurzweil K-5000 or Calera Compound Document Processor (CDP) 9000 are used.[407] Both of these machines perform full page or user-defined template scanning and character recognition in batch mode. This is usually accomplished through the use of automatic document feeders and some user-defined technique for signaling the start and end of a file.

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403 Fruchterman [88], pp. 18–19

404 Doebler [89], pp. 52–53

405 Stanton [87], pp. 185–186

406 Robinson [88], p. 171

407 Karsh [89], pp. 60–61

A major difference exists, however, between these two devices: the K-5000, like most older scanners, requires separate passes when scanning for graphics and text.[408] This is due to the fact that, when scanning for text recognition purposes, images and graphics are masked out, and when scanning for images, the entire page is captured as a bitmap—there is no attempt to interpret the textual portion of the bitmap as characters. On the other hand, the CDP 9000 has a single pass text and graphics recognition option that allows a page to be scanned only once to produce separate image and character recognized text files.[409]

Calera's TrueScan and Caere's OmniPage are two examples of recognition devices that accept bitmap image files from a variety of scanners—provided they are in an uncompressed TIFF format—and perform character recognition on them.[410] Optionally, both products can drive specific scanners, producing both an image and text file from a single scan. Both are installed on a PC in the form of a coprocessor board, a Motorola 68020 accelerator, 2 to 4MB of RAM and diskettes.

Computer Aided Technology's CAT Reader is another character recognition software program that requires no processor boards.[411] It enables recognition to be performed on bitmaps produced by both handheld and desktop scanners.

3.3.2.4. The Character Recognition Process

No matter how the scan is done, the actual recognition is typically accomplished in the same way by all recognition devices. The process can be sub-divided into three functions, each of which accounts for roughly one-third of the total processing time.[412] They are: Layout Analysis, Character Segmentation and Character Identification.

3.3.2.4.1. Layout Analysis

Layout Analysis involves recognizing the layout pattern of text on the page.[413] All columns, paragraphs and embedded graphics are identified, thereby increasing the throughput of the entire process by precluding the system from trying to recognize a graphic as a character. Many software packages perform this function automatically, but user intervention in the form of blocking out certain sections greatly increases the speed and accuracy.[414] On some packages, the graphics must be sectioned out manually to avoid producing a stream of garbage bits intermixed among text.

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408 Kurzweil [n.d.]
409 Calera [88]
410 Robinson [89], pp. 203–204
411 CAT [88]
412 Sherer [88], p. 102
413 Gunn [88], p. 7
414 Sherer [88], p. 101

Layout analysis is becoming increasingly complex in corresponding proportion to the layout complexity of documents from high end word processors.[415] New software must also be able to recognize side captions as separate layout elements.

An example of a package which can analyze the layout automatically is Caere's OmniPage.[416] The software locates and isolates each paragraph and graphical element in a separate box, labeled in numerical order. The software then processes the contents of each area and displays a magnified view of what is currently being analyzed.

3.3.2.4.2. Character Segmentation

The next step in recognition processing is segmenting or separating characters from one another—and from other information on a page (such as borders)—as a precursor to identifying the characters.[417] Italicized characters and ligatures—which is the joining of pairs of letters such as *ae* or *fl* into a single character—pose challenges to this step since the letters are too close to, or actually touching, each other, thus preventing the software from determining the extent of the individual characters.[418]

Typeset documents provide the worst documents for run-together characters because they use *kerning*, a typesetting technique that adjusts letter spacing for esthetic purposes. One type of problems caused by kerning involves interpreting two letters as one; for example, *in* may be mistaken for the single character *m*. Some current software has a limited ability to recognize kerned text, but it is far from perfect.

Laser printers also pose problems for character recognition since they use proportional spacing, making it hard for software to identify each letter.

3.3.2.4.3. Character Identification

The last and probably most important step of the recognition process is identifying the isolated character.[419] In fact, on a simple monospaced document only this step is required for the recognition of the character to take place. It is the implementation of this step which most distinguishes one recognition engine from another and has the greatest effect upon the speed and accuracy of the entire recognition process. Although each character recognition manufacturer claims to have a proprietary scheme, the majority of manufacturers actually use one of the following three different methods: matrix matching, feature extraction, or a hybrid of the two.

415 Gunn [88], p. 8
416 Caere [89]
417 Gunn [88], p. 7
418 Sherer [88], p. 101
419 Gunn [88], p. 7

3.3.2.4.3.1. Matrix Matching

The cheapest, oldest and still dominant technology in use today is matrix matching.[420] As its name implies, this simple technique tries to identify a character by matching the unknown digitized character image against a stored library of reference matrices of characters on a pixel by pixel basis. Thus, for this method to work for every font that the system will encounter, the system correspondingly must have a defined matrix or template for that font universe. When a character is to be identified, the stored templates are successively accessed until an approximate match is found (See chart). To help the matching process, the system usually deforms the reference character by blurring or smearing the stored template to simulate the performance of the scanner, which has also deformed the unknown character.[421] To further reduce processing time, some recognition software, such as that supplied with the Saba Handscan, allows the user to identify the specific font used.[422]

Dest Corporation's is one of the many users of matrix matching.[423] Its software package for its PC Scan 1000 and 2000 series is called Text Pac. To help accelerate the matching process, Dest implements in hardware an eight-way translation between the centroid of the reference character and the centroid of the unknown character. This method prevents possible mismatches of patterns caused by printing flaws such as non-uniform inking.

To further improve the performance of the recognition process, many packages move the reference matrices of already matched characters to the front of the list of matrices to be tried.[424] Thus, if only one or several fonts and sizes are used within a document, the entire reference list does not have to be repeatedly searched. Once the system determines that an unknown character has been recognize—due to its exceeding the matching threshold, which is commonly known as the system's confidence level—the character is stored and the process repeats until all the unknown characters have been identified.

This simplified approach to identifying characters limits matrix matching to work well only for documents containing a limited set of fixed space typefaces and point sizes.[425] Although some matrix matching software claims to recognize proportionally-spaced characters, they usually only have the ability to recognize such output from an IBM Selectronic or an early model daisy wheel printer. For a document containing multiple fonts, pitch, and point sizes, system speed slows considerably while searching for the correct reference matrix, and can often lead to throughput coming to a standstill.[426] The reason for this slow speed is that a typical reference matrix is a 24 by 35 bitmap and thus over 100 bytes must be processed for each character.[427]

420 Friedman [88], p. 13; Stanton [87], p. 194
421 Gunn [88], p. 10
422 Robinson [88], p. 171
423 Dest [n.d.]
424 Gunn [88], p. 10
425 Stanton [89], p. 189
426 Fruchterman [88], pp. 18–19
427 Stanton [87], p. 194

To solve partially the problem of only identifying specific fonts, some systems, such as the Everex TransImage 1000 and Datacopy's OCR Plus, are trainable.[428] This means that the system provides a user interface through which new reference matrices can either be created and added to the reference library or downloaded from a disk. However, this often takes a few minutes per character and a character often has to be taught to the system more than once—even if the system contains the right font, the point size must be the same for the match to occur.[429]

Some packages contain a learn mode feature that allows the storage of additional fonts based upon existing ones.[430] A user simply adds or removes pixels from an existing reference matrix to correspond to a different point size of the same font. This feature is particularly helpful when teaching the recognition software an extended character set such as a foreign language or for recognizing dot-matrix typefaces. However, as with trainable systems, to learn a new character set in a different point size can take several hours. If multiple fonts are used in a document, throughput time may also be affected because much of the free space of the host computer's RAM is needed to hold the many reference templates.[431]

428 Karsh [89], p. 58

429 Gunn [88], p. 10

430 Stanton [87], p. 194

431 Gunn [88], p. 14

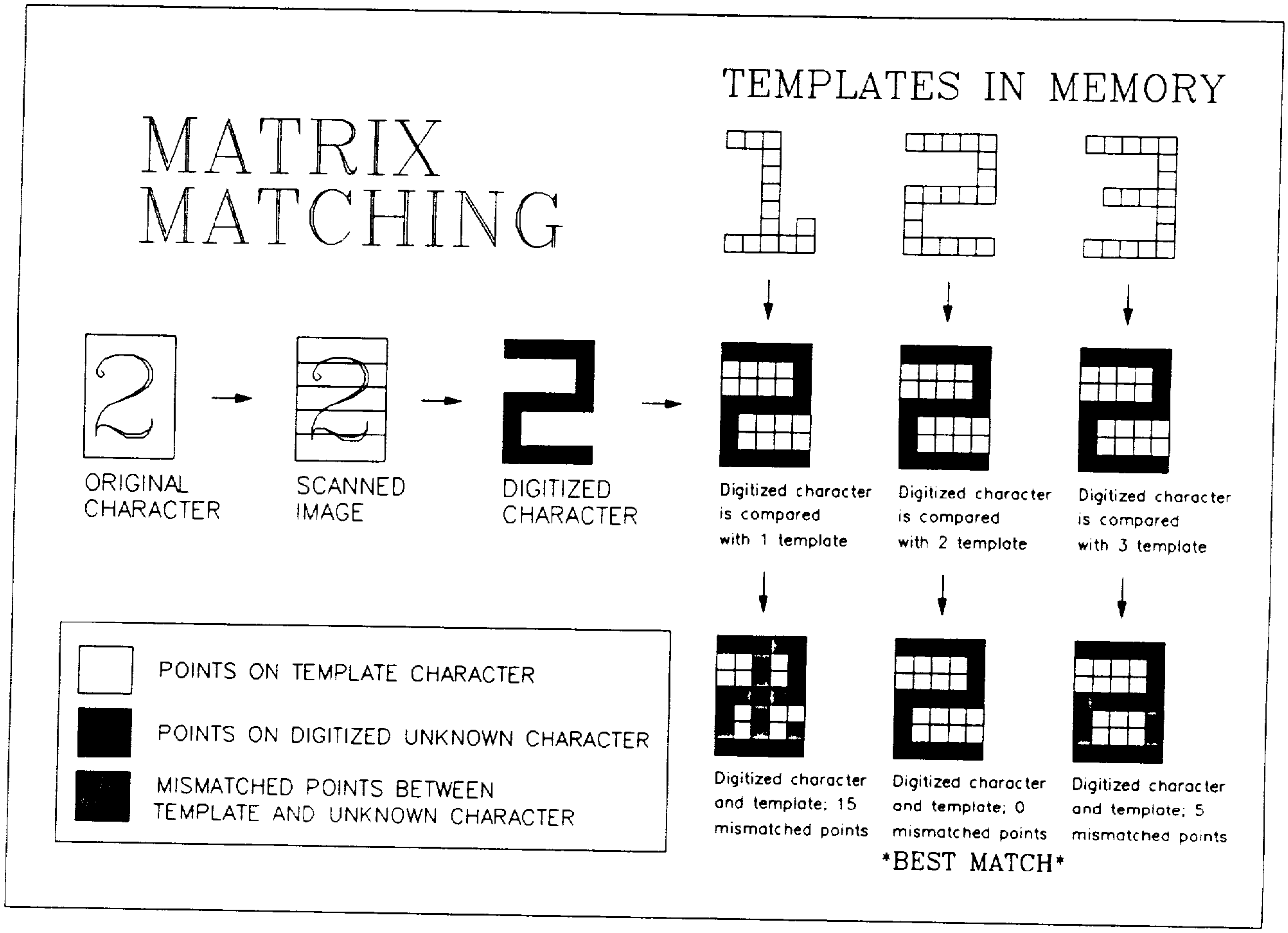

Figure 8. *Matrix Matching*

3.3.2.4.3.2. Feature Extraction

A newer method of character identification which overcomes some of the drawbacks of matrix matching is known as *feature extraction*.[432] Based upon ideas used in pattern recognition, this method identifies text characters irrespective of their typeface or point size by extracting the features of a character that make it unique. Almost all character recognition machines today that recognize proportional typeset characters use some form of feature extraction.[433]

Using the topology of the letter, a character is uniquely identified by the number of horizontal, vertical and diagonal lines it has as well as by the number of loops and line endings (see Figure 8). The character recognition engine searches for these features when trying to identify a character. Because this methodology concentrates on the unique features of a character—which generally are the same no matter which font or point size is used—it is often said to have omnifont recognition capability. This feature also makes it easier to recognize bold or oblique

432 Fruchterman [88], p. 19
433 Stanton [87], p. 194

characters since the unique features of a character are still the same. However, large uppercase or decorated characters—like those often used to begin chapters or paragraphs—still pose problems to recognition devices as the character's unique features are distorted.[434] Kurzweil Computer Products, a leading vendor in character recognition devices using feature extraction, has coined this method as *intelligent character recognition* (ICR).[435]

Though it can recognize a wider range of fonts than can matrix matching, feature extraction does have its weaknesses.[436] Since this method calls for software to examine the entire bit arrangement of each character, it can be slower than the matrix matching method (see figure 9). Documents containing characters which are broken, deformed, or skewed, also pose problems since the characters' unique features are not easily recognizable.[437] Similarly, characters that touch one another or are printed on top of ruled lines are also misinterpreted by recognition devices employing this method.

434 Stanton [89], p. 189

435 Kurzweil [n.d.]

436 Stanton [87], p. 194

437 Fruchterman [88], p. 19

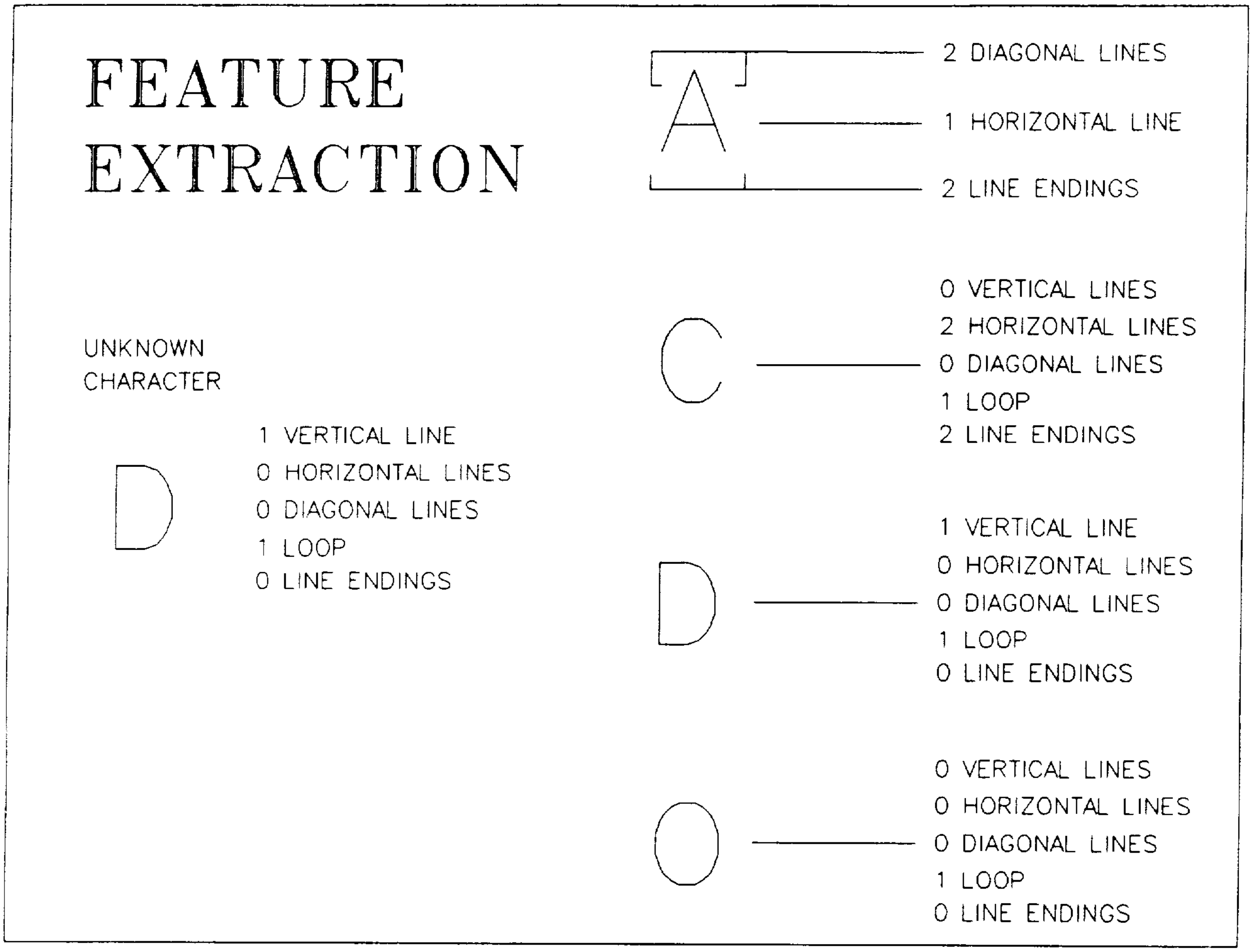

Figure 9. *Feature Extraction*

3.3.2.4.3.3. Hybrid Approach

To get the best of both methods, Calera Recognition Systems (formally Palantir Corporation) employs both feature extraction and matrix matching in a method best described as *gray-scale template matching*.[438] This method creates a reference character for each character in about 200 different fonts as a gray scale representation on an eight by five matrix. These 40 cells per character, as well as an additional sixteen property values containing information about the features of the character, are stored as fifty-six element vectors, each of which is a byte long. In all, the system stores about 20,000 of these vectors.

438 Gunn [88], pp. 10–11

The recognition software first attempts to identify an unknown character by its features.[439] If the attempt is successful no further processing is done. If the character can not be identified, a least mean square function is used to compare all the stored vectors with the unknown character until it is identified. Like matrix matching, this method also places a matching vector at the front of the comparison list for further identification of characters.[440] If the process still fails to recognize the character, it will try to identify the character based upon the character's word placement, spelling relationship, or frequency of appearance. Relying upon dictionary and spelling help is not always useful, however, and the accuracy rate can fall below 90 percent per character when the dictionary is not usable. However, this methodology does seem to be an improvement over earlier recognition systems.

In the fall of 1988, CTA Inc. introduced TextPert for the Macintosh.[441] This software-based package also uses a combination of matrix matching and feature extraction techniques. Compatible with many scanners, it can read complex documents and still retain the layout of the original.

3.3.2.5. Factors Affecting Character Recognition

It can be said that where a scanner's job ends, character recognition begins. Since character recognition software depends on the scanner for the digitization of the image, the quality of the scan plays a large role in the success of the recognition algorithm.[442] Some of the factors that can affect the quality of the scan and, in turn, the quality of recognition process are: source material quality, page illumination, the type of paper, the scan resolution, and thresholding.

3.3.2.5.1. Source Material Quality

Poor source material, such as pages that are torn, smudged or stained, cause visible noise to appear in the digitized bitmaps.[443] Current recognition techniques are not sufficiently advanced to avoid this noise and therefore high quality source material is essential for the cost-effective use of character recognition. Scanning microfilm also produces problems for recognition devices because microfilm sometimes contains bubbles which are digitized as black spots in the bitmap—thus causing the recognition device to try to interpret it.[444]

3.3.2.5.2. Page Illumination

It is not uncommon for a scanner to have a non-uniform illumination of the page. In fact, it is possible for the page center to have a thirty percent decrease in illumination compared to the

439 Fruchterman [88], p. 19
440 Gunn [88], p. 11
441 Karsh [89], p. 64
442 Gunn [88], p. 5
443 Friedman [88], p. 14
444 Gunn [88], p. 3

edges.[445] Non-uniform illumination pages produce poor scans thus lowering the success rate of the character recognition. A better capture of an image takes place in a flatbed scanner, such as the Kurzweil K-5000, where only the light source moves while the paper remains stationary.[446]

3.3.2.5.3. Type of Paper

A scanner requires diffuse reflection to produce a good quality image.[447] Coated paper (as opposed to matte) produces bad images because their glossiness produces a high level of specular reflection and a reduced diffuse reflection.

3.3.2.5.4. Scan Resolution

To recognize characters with high accuracy, at least 8 to 10 lines per character height are necessary to produce an acceptable image, and 10 to 12 lines to produce an excellent image.[448] With a resolution of 100 dpi, not even a 10-point lowercase character reaches the acceptable level of recognition; with a 200 dpi scan, lowercase letters only become acceptable for recognition at 6 points. It is therefore recommended to have at least a 300 dpi scan that produces an acceptable lowercase letter at four point, and an excellent image at six point (see table 20 below).

FONT		LINES PER CHARACTER HEIGHT (dpi)		
Point Size	Case	100	200	300
4	upper	4.30	8.60	12.90
	lower	2.90	5.75	8.60
6	upper	6.25	12.50	18.75
	lower	4.20	8.40	12.60
8	upper	8.25	16.50	24.75
	lower	5.50	11.00	15.15
10	upper	10.25	20.50	30.75
	lower	6.80	13.60	18.24

KEY Lines per character height determine the quality of the image as follows:

Excellent	10 - 12
Acceptable	8 - 10
Low	6 - 8
Unacceptable	0 - 6

Table 22. *Type Sizes for OCR* [449]

445 Gunn [88], p. 5

446 Karsh [89], p. 60

447 Gunn [88], p. 5

448 TDC [89]

449 TDC [89]

3.3.2.5.5. Thresholding

To obtain good results from the character recognition process, the page should be scanned in bitonal mode rather than as a halftone.[450] Scanning in halftone mode creates dither patterns, thus causing letters not to be solid and smooth. Even in bitonal mode, it is important that the threshold value (the level at which a pixel is determined to be on or off) be accurately set to ensure correctly digitized characters. For example, poor thresholding can cause the top of a lowercase *e* to be filled in, and thus become an unrecognizable character.

3.3.2.5.6. Filtering

Many scanners contain filters for convolution processing, which involves passing an image file through a filter to sharpen edges or improve the blackness of a large black region.[451] Of particular importance to character recognition devices is a filter that removes isolated pixels (since it is unlikely that any such pixels have meaning). However, care must be taken that a period is not considered to be an isolated single pixel. This is usually accomplished by using a sufficiently high scanning resolution so that a period will appear on more than one scan line.

3.3.2.5.7. Skewing

Skewing is the slant of an image in relation to the scan optics of the scanner.[452] It is measured primarily to determine the margin of error allowed for character recognition since letters that are askew or tilted in a bitmap cannot be easily read by most software even though all the character information may be present. It is therefore important that the scanned page is closely aligned with the scanning mechanism. Most matrix matching-based character recognition software today can handle skews of up to ±2° but some feature extraction based devices can even handle up to ±10°, depending on the input document.[453]

One method used to handle the skew is to compare only the "hot zones" of the unknown character to the reference matrix instead of every bit.[454] Another method uses algorithms to tilt the reference matrix until a match can be found.

3.3.2.5.8. Output

No matter the methodology employed, the goal of character recognition is to be what is often described as a "printer in reverse."[455] This means that instead of turning electronically encoded data into a hardcopy image, a recognition device should be capable of transforming text into an electronically codable form.

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450 Gunn [88], pp. 5–6
451 Gunn [88], pp. 6–7
452 Stanton [87], pp. 189 and 194
453 CAT [88]
454 Stanton [87], p. 194
455 Helgerson [87], p. 11

On some recognition devices the results are immediately shown, while on others the results must first be saved on disk in a format appropriate for its future application.[456] Input pages can be saved as separate files or as multiple pages within one file.

Some character recognition packages, such as Dest Corporation's Text Pac and Calera's TrueScan, can perform not only character recognition, but also preserve and process page layout information by automatically formatting the text and inputting the proper word processing codes—just as if the document had been manually keyed.[457] In fact, both TrueScan and OmniPage can produce output for more than sixteen different word processing programs.[458]

In addition to use with word processing packages, recognized textual data can be included as part of document architectures such as the International Standards Organization's (ISO) Office Document Architecture (ODA), IBM's Document Content Architecture (DCA), or DEC's Compound Document Architecture (CDA).[459]

Other options include storing captured text in a freestyle database (that allows searching on the text) or a structured database (such as dBASE).[460] Some recognition packages, such as the aforementioned, can also support spreadsheet formats such as Lotus 1-2-3 or Microsoft's Excel.[461] The Kurzweil K-5000 also offers the option of putting the output into a user-defined format (UDF) or a page-layout package such as Interleaf.[462] Other packages allow the output to be generically encoded so that it can be formatted into a particular style through a word processor or page-layout program.[463] This option is particularly useful when producing structural technical publications.

Sometimes character recognition is not the final goal but rather only a means to achieve some other purpose.[464] It is possible to use the electronically coded text produced by a character recognition package as input to other software. For example, Teleprint's <Magic> Markup–CALS converts recognized text into the Department of Defense's version of Standard Generalized Markup Language (SGML) format. This conversion takes place using artificial intelligence techniques that not only analyze geometric shapes and the spatial relationships between character groups to identify list structures, multiple columns, or other document structures, but also analyze the grouping of characters to identify document content elements such as the title or author. Once converted, software programs read the text with the markup coding

456 Robinson [89], p. 203
457 Dest [n.d.]; Calera [88]
458 Robinson [89], pp. 203–204
459 Gunn [88], p. 3
460 Kurzweil [n.d.]
461 Robinson [89], pp. 203–204
462 Kurzweil [n.d.]
463 Karsh [89], pp. 62–63
464 Teleprint [n.d.]

to produce page description languages for printing. Xerox recently released a new product, Datacopy Accutext, which produces SGML coding in the text stream directly from the scanner, thus reducing this two step process into one.[465]

3.3.2.5.9. Accuracy

The success and economic utility of character recognition devices depend on their accuracy.[466] However, the accuracy of these devices is hard to measure. It is possible for a device to recognize the same page *n* times and get *n* different results with regard to errors and flagged characters.[467] This occurs because some characters are printed very thinly and a small difference—only one or two pixels—is enough to cause the software to misinterpret a character. The general rule is that the quality of the original plays a major role in determining the accuracy of the output.

Most vendors agree that getting 95 out of 100 characters correct is not good enough.[468] Using a device with a 95 percent accuracy rate can leave more than a dozen errors on a full page of double spaced text.[469] Many machines now claim accuracy rates of 98 or 99 percent. Rates of 99.9+ percent are also possible for optimal documents and result in only two to four errors in a full page of text.[470]

Furthermore, it is hard to judge a device by its claimed accuracy rate since accuracy is application-dependent.[471] A system may have 100 percent accuracy for some documents, yet produce inadequate results for other documents. Furthermore, one must take into account the user's perspective when dealing with accuracy. For example, when converting thousands of pages of publications into machine-readable files, even one error for every 100 characters is unacceptable since, though more expensive, rekeying the data produces a better accuracy level. (Efficiency is also an important consideration: while an average typist can type 50 words per minute (wpm), a character recognition device can interpret 1500 wpm.[472]) In general, it is presently hard to find one system that will yield an acceptable accuracy when dealing with a wide range of documents.[473]

With regard to the future accuracy of character recognition devices, Xerox's Jim McNaul says: "You don't need a high-scale gray-scale scanner right now to use OCR, but it's entirely possible that in the future, these software algorithms will begin to use gray scale information to improve their accuracy."[474]

465 Xerox [89]
466 Doebler [89], p. 52
467 Stanton [87], p. 194
468 Doebler [89], p. 52
469 O'Malley [89], p. 109
470 Friedman [88], p. 14
471 Doebler [89], p. 52
472 Karsh [89], p. 58
473 Doebler [89], p. 52
474 Mueller [89], p. 18

Another area which is presently contributing to higher recognition accuracy rates is that of artificial intelligence.[475] Using software-based expertise to perform text analysis and resolve ambiguities in identifying a character, these new devices are producing much better results than older recognition devices.

3.3.2.5.10. Speed

Like accuracy, the true speed of a device's character recognition process is an elusive thing to measure. It is heavily dependent upon the input document's quality, the complexity of the layout structure, as well as the typeface and point size.[476]

The speed of recognition varies greatly among different manufacturers. While Computer Aided Technology's CAT Reader claims an average recognition speed of 75 cps, the Calera 9000 Series claims speeds of up to 250 cps.[477] To speed up character recognition without causing conflicts with any existing PC hardware, many manufacturers are adding coprocessors to their interface boards.[478] The emergence of the new 32-bit microprocessors will also greatly improve the performance of character recognition software. For example, Flagstaff Engineering's S.P.O.T. package can recognize a full page in 40 seconds using a 25-MHz 80386 microprocessor; using the 33-MHz chip, the time required drops to only 34 seconds. It is even expected that the recognition time for the same page can go down to as low as 15 seconds when the 80486 chip will be released.

3.3.2.6. Optional Character Recognition Features

Many character recognition devices today enhance the recognition process by using a variety of software tools. These features are discussed below.

3.3.2.6.1. Character Editing

Character editing is handled by recognition devices in one of three methods. One method, employed by Caere's OmniPage, is to perform recognition in a semiautomatic mode.[479] This method allows the user to view each letter in a small window as it is being processed and correct any misinterpretations directly from the keyboard. The Kurzweil K-5000 also uses this method but processes the page in a line-by-line fashion.[480] This allows the operator to control the scroll delay in order to edit a line with more than one mistake.

A second method of character editing has the machine mark an unrecognized character with a default or user-defined flag.[481] This method allows either the user or a word processor with a spelling checker to easily identify and correct unrecognized characters. Some of these devices,

475 Doebler [89], p. 52
476 Brown [88], p. 56
477 Calera [88]
478 Sherer [88], pp. 101–102
479 Caere [89]
480 Kurzweil [n.d.]
481 Friedmann [88], p. 14

such as Calera's TrueScan, optionally make a best guess at an unknown letter.[482] The Caere OmniPage has a statistics feature which counts recognized and unrecognized characters, gives the recognition percentage, and appends the information at the end of the file.[483]

A third method disallows editing errors, rejecting the document if there are unrecognizable characters.[484]

3.3.2.6.2. Text Integration

Most early recognition devices could not differentiate between columns, intermixing multicolumn text into only one column.[485] To correctly perform character recognition on multiple column pages, each column had to be separately scanned and recognized. Today, such devices as the Calera 9000 Series or the Kurzweil K-5000 are capable of recognizing multiple column pages with varying column widths in a single scan. For example, Caere's OmniPage has an Auto Galley feature which can decolumnize text on a page and put it in proper sequence for an output file.[486] It also has a feature which allows one to choose the appropriate sequence for decolumnized text. This is useful for pages on which text does not flow logically from one column to the next.

Similar to the problem of multiple columns is properly integrating text of recognized pages which could not be scanned completely at one time.[487] This is an extremely important feature for character recognition performed via a hand scanner (which only has a maximum scanning width of 2.25 to 4 inches). To solve this problem, such devices as Computer Aided Technology's CAT Reader can automatically pull split columns into one complete page of text. This feature allows for recognition to be done on a oversized document or on documents with a landscape orientation.

3.3.2.6.3. Context Analysis

Some devices, such as the Kurzweil K-5000 or the Calera 9000 Series, offer recognition modes of alpha-only, numeric-only, or alphanumeric.[488] When scanning a spreadsheet, a numeric-only mode significantly increases the accuracy and speed of the recognition since it must only identify 1 of 10 digits or a few punctuation marks.

Another enhancement is the ability to use the estimated proportion of letters to numbers to assist in recognizing an unknown character. For example, in a spreadsheet application, an unknown character is more likely to be a number than a letter.

482 Calera [88]
483 Caere [89]
484 Helgerson [87], p. 11
485 Kurzweil [n.d.]
486 Caere [89]
487 CAT [88]
488 Stanton [87], p. 194

Some character recognition packages use lexicons to aid in the recognition process. Besides its own 50,000 word lexicon, the Kurzweil K-5000 also provides for a 10,000 word user-definable lexicon, thus allowing recognition to take place in a user-defined context.[489] This device also provides an optional mode in which any unrecognized character is ignored and retained in memory. Upon concluding the recognition of the remainder of the page, any previously illegible characters are replaced with the most logical substitute based upon the assessment of the page as a whole.

3.3.2.6.4. Other Features

Character recognition can be done on a wide variety of point sizes—typically from 6 to 28 points—but some software can recognize characters with heights as high as 72 points.[490] Besides the many fonts that recognition packages can process, they can also handle many styles such as: subscripts, superscripts, tables with tabs, centering justification, word wrap, italics, underlines, and boldface.[491] The Calera TrueScan can also perform recognition on a page with landscape orientation.[492]

Some devices, such as the Kurzweil K-5000, can recognize foreign languages including German, French, Italian and Swedish.[493]

Many character recognition devices have their own storage and can handle between 10 to 50 megabytes.[494] Recognition devices based upon the Motorola 68020 processor, such as Caere's OmniPage or the Kurzweil K-5000, can even run another application on the host PC while the actual recognition process is operating in the background.[495] Separate recognition devices can be interfaced with the host computer through SCSI or serial interfaces.[496] The Calera 9000 Series devices also have the option of being directly connected to an Ethernet LAN or to other systems by way of a RS-232 interface.

3.3.3. Compression

3.3.3.1. Introduction and Summary

Unaltered digital images require huge amounts of storage space. Vendors have turned to compression algorithms to reduce the size of image files. The size of a digital image depends on the scanner resolution and the image type itself. The amount of file-size reduction possible depends not only on the type of algorithm used, but also the type of the image file that is being compressed.

489 Kurzweil [n.d.]
490 Caere [89]
491 Robinson [89], p. 203
492 Calera [88]
493 Kurzweil [n.d.]
494 Helgerson [87], p. 11
495 Kurzweil [n.d.]
496 Calera [88]

3.3.3.2. *Image Sizes*

The image type falls into one of three categories: *bilevel* (black-and-white), *gray scale*, and *color*. Bilevel images use 1 bit to represent one picture element (pixel). Gray-scale images use either 4, 6, or 8 bits to represent one pixel. Color images use 24 bits to record three basic colors for each pixel, using the traditional red-green-blue (RGB) recording technique (8 bits for each color). By equation translation, 24-bit RGB can be reduced to 12 bits with the YIQ recording technique.

Table 21 shows the image sizes in bytes of an 8.5-by-11-inch original when scanned at different dots per inch (dpi) resolutions.

RESOLUTION (dpi)	BILEVEL	8-BIT GRAY SCALE	24-BIT COLOR
200	467,500	3,740,000	11,220,000
300	1,051,875	8,415,000	25,245,000
400	1,870,000	14,960,000	44,880,000

Table 23. *Images File Sizes at Different Resolutions*

3.3.3.3. *Compression Categories*

Compression schemes fall into two categories: *lossless* or *lossy*. Compression techniques also fall into two categories: *adaptive* or *nonadaptive*.

3.3.3.3.1. Lossless versus Lossy

The lossless scheme is bit-preserving—the reconstructed pixel values are identical to the original values. CCITT Group 3 and Group 4 compressions belong to it. The lossy scheme always has some discrepancies between the reconstructed pixel values and the original values. The majority of applications, however, can tolerate a certain degree of irreversible image degradation. The AT&T pattern-recognition scheme (see section *3.3.3.4.3. AT&T Pattern Recognition*) belongs to this category.

3.3.3.3.2. Adaptive versus Nonadaptive

The adaptive technique assigns code words based on the real-time probability distribution of each occurrence. The nonadaptive technique assigns code words according to a predefined code-word table.

3.3.3.4. *Major Compression Schemes*

Compression efficiency is highly data-dependent. For bilevel data, the most difficult images to compress effectively are those in which the percentages of black and white pixels are about the same. Compressing halftone images sometimes yields coded compressed files that are even bigger than the original files.

3.3.3.4.1. CCITT Group 3

The CCITT Group 3 compression scheme, Modified Read Code (MRC), is a lossless run-length encoding technique that assembles contiguous runs of black or white pixels for subsequent coding. MRC has both *one-dimensional* (1-D) and *two-dimensional* (2-D) coding schemes.

In the 1-D coding scheme, a line of data is composed of a series of variable-length code words. Each code word represents a run length of either all white or all black. White runs alternate with black runs. Total numbers of pixels for one scan line is fixed by scanning resolution and document size. All data lines begin with a white run length. A zero white run length will be sent if a scanning line begins with a black run.

The 1-D coding scheme has two types of code words: *terminating* and *mark-up*. Each run length is represented by either one terminating code or a mark-up code followed by a terminating code. The end-of-line (EOL) code is used to separated each scan line. Return-to-control (RTC) codes, composed of six consecutive EOLs, are used to indicate the end of a document transmission. FILL, a variable-length string of zeroes, is inserted between a line of data and the EOL code to ensure that each transmitting line exceeds the minimum line transmission time.[497]

The 2-D coding scheme is a line-by-line coding method in which the position of each changing pixel on the current line is coded with respect to the position of a corresponding reference line that lies immediately above the coding line. After the coding line is coded, it becomes the reference line for the next coding line. In order to limit the disturbed area in the event of transmission error, a parameter K is set to limit the number of the following 2-D lines. At the end of every coded line, the EOL code is followed by a single toggle bit that indicates whether 1-D or 2-D coding is used for the next line. Other rules of using and inserting EOL, RTC, and FILL codes are as same as those in the 1-D algorithm.[498]

The CCITT Group 3 standard is still widely used in facsimile (fax) machines. Its compression, however, is not efficient for desktop image processing.

3.3.3.4.2. CCITT Group 4

The CCITT Group 4 compression scheme, Modified MRC (MMRC), is an extension of the Group 3 scheme with many modifications. MMRC is a total 2-D coding algorithm, only the first line of the image is encoded with 1-D code words, the rest of the image lines are encoded with reference to previous lines. FILL bits insertion is not necessary because MMRC requires no minimum transmission time. This scheme also needs no EOL code and supports reduced RTC code. Total overhead is thus greatly reduced. Because of its total 2-D coding and lower overhead, Group 4 compression ratios improve almost 20 to 30 percent over Group 3 ratios,

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497 Urban [80]
498 Urban [80]

depending on image complexity. Group 4 MMRC compression requires an error-free environment—a Group 4 fax machine requirement.[499] Implementing Group 4 MMRC on fax transmission is expensive because it involves high-cost communications connections. The majority of applications that use Group 4 are in desktop image processing, making it the most popular compression scheme for image processing.

3.3.3.4.3. AT&T Pattern Recognition

AT&T proposed pattern-recognition compression for Group 4 fax machines in 1985. It is a lossy compression algorithm. This scheme recognizes recurring patterns and transmits a short ASCII-like code to symbolize this pattern. If the extracted pattern can be found in its library, the position of the pattern in the image and the pattern's library registration will be coded; otherwise, the new pattern is added to the library and its position and bitmap are coded.

The pattern-recognition algorithm works especially well with text; the compression for this scheme exceeds that for Group 4 by a significant degree. Pattern recognition, however, is not good for images that have no recurring patterns.[500] Also, few implementations of this scheme are on the market.

3.3.3.4.4. Huffman and Arithmetic Codings

Huffman coding is the best-known technique for data compression. It proportionally assigns the length of the code word to the probability estimate of that symbol. The total code length is shortened by assigning shorter codes to the highly probable elements and longer codes to the less probable elements.

Arithmetic coding is similar to Huffman, and is good for online lossless data compression/decompression. Ideally, it maps the mutual outcomes of a probabilistic event into nonoverlapping intervals on a real number line and then creates a code word approximately to this ideal length. The benefit of arithmetic coding comes from not just coding one symbol at a time, but coding a string of symbols together. The compression occurs when it takes fewer bits to specify longer intervals than shorter intervals.

3.3.3.4.5. IBM Q-coder

IBM has developed a new arithmetic coding scheme called Q-coder. It combines a simple but efficient arithmetic approximation for the multiple operation, a new formalism (which yields optimally efficient hardware and software implementations), and a new form of probability estimation.

499 Schaphorst [82]
500 Bodson [85]

Q-coder is a lossless compression algorithm that implements Adaptive Binary Arithmetic Coding (ABAC) architecture. It uses three basic components: model, adapter, and coder. The model is used to assemble input data and estimate the probability of each output. The ideal code-word length is generated, based on the following arithmetic coding theory:

$$l_1 = -\log_2(p_i)$$

where l is code-word length, i is compression unit and P is the probability of the unit i. Code words approximating this ideal length should be used to encode each outcome during compression or decode it during decompression. In adapting this methodology, the adapter tracks model outcomes and returns the real-time change of probability distribution into appropriate changes in the lengths of code word in the coder.

The adaptive ABAC algorithm significantly outperforms the nonadaptive Group 4 algorithm. For text, ABAC 20 percent better than Group 4. For halftone images, ABAC perform 2.0 to 4.5 times better. It also works well for continuous-tone gray-scale images. In some cases, however, the Group 4 algorithm does not compress at all but rather expands the data.[501] Q-coder is the best overall compression algorithm. It is good for text, halftones, and continuous tones.

3.3.3.4.6. Lempel-Ziv

The Lempel-Ziv (LZ) scheme is adaptive and extremely applicable to general data streams. It works for bit-per-pixel images as well as byte-per-pixel images. (TIFF file formats accept LZ compression.) The basic methodology is to find common substrings, replace these substrings with variably sized code words, and build a hashed table concurrently. This scheme runs a check on the compressed code at certain points and, if the compression does not continually improve, deletes the table and starts over.[502]

3.3.3.5. Compression Ratio Comparison

Compression ratios are highly dependent upon the complexity of the image files. Simple images have higher compression rates than complicated images. Table 22 gives some compression ratios based on CCITT Group 5 French test document scanned at 200 dpi. The original raw-bits file size is 513,216 bytes.

501 Arps+ [88]
502 Holladay [89]

	CCITT	CCITT	IBM	AT&T
Type	Group 3	Group 4	Q-coder	Pattern
Size (by-tes)	46,725	32,222	26,986	17,639
Ratio (%)	10.98	15.93	19.02	29.05

Table 24. *Compression Sizes and Ratios*[503]

3.3.4. Formats

3.3.4.1. Introduction and Summary

Image files need standard formats to be compatible with the variety of applications. No standard file formats had been established when scanners first appeared—a cause for major concern. There are still many calls for better format standardization, but attention has focused on a small number of formats being widely used and their variants. The CCITT formats for facsimile compression and transmission are probably the most widely applied. Aldus Corporation's Tagged Image File Format (TIFF) is often cited as a de facto standard, and ZSoft's PC Paintbrush format (PCX) is also in widespread use. IBM has published specifications of a Mixed Object Document Content Architecture (MO:DCA) as part of an effort to establish a standard Document Content Architecture (DCA) across its product lines.

The three most common image file conversion utilities are Quick Art's Missing Link and Inset Systems' HiJaak and Inset. These software packages support conversion between TIFF and PCX as well as a number of other image file formats. They are helpful in storing gray-scale images and in combining text and image data stored separately into one file for printing.

3.3.4.2. Image File Formats

IBM's MO:DCA is a deliberate attempt to establish an image standard within the larger context of a unified document structure. TIFF and PCX formats, both of which support halftone images produced by a gray-scale scanner, are simply image file formats supported by a number of applications. TIFF, however, is more widely used and accepted by more OCR machines than PCX.

3.3.4.2.1. Mixed Object Document Content Architecture

IBM developed MO:DCA to identify various function sets that classify a document or object as containing presentation data. Some of MO:DCA's goals are to provide better document sharing, simplify existing IBM document migration, and furnish device independence.[504]

503 Urban [80]; Arps+ [88]; and Bodson [85]
504 Bonsall + [88], p. 10

MO:DCA contains four object content architectures (OCAs), including *image* (IOCA), *presentation text* (PTOCA), *graphic* (GOCA), and *font* (FOCA).

- o IOCA is a format for presenting image information. Its primary purpose is to provide a standard definition for image presentation.[505]
- o PTOCA defines the text information in a file. Presentation text is one of the building blocks needed to allow the mixing of data types.[506]
- o GOCA simplifies the description of complex pictures. It defines how lines are drawn in a picture and the attributes (details) that make up the file.[507]
- o FOCA defines IBM fonts, references to these fonts, and the information accessed from these fonts.[508]

3.3.4.2.2. PC Paintbrush Format

PCX is a image file format created by ZSoft when developing PC Paintbrush, its graphics drawing program, and Frieze, its screen-grabbing utility. PCX begins with a header that is 128 bytes long. This header is important only if the image being processed is represented in color and contains different resolutions, otherwise, it is ignored. It is encoded in a simple byte. For instance, when more than one color is being stored, each line is stored by color plane (red, green, blue, and intensity).[509]

3.3.4.2.3. Tagged Image File Format

Developed by Aldus Corporation, TIFF was originally designed for desktop publishing applications. In the last few years, TIFF has also emerged as a standard for scanned images in part because it is not dependent on processors, compilers, or operating systems. A robust standard that promotes the exchange of image data between different computer systems, TIFF has recently undergone its fifth revision. The data in TIFF are structured in a way that simplifies modification.[510]

TIFF handles the following four data classes: **B**, for bilevel (1-bit) images; **G**, for gray-scale images; **P**, for palette color images; and **R**, for RGB (red-green-blue) color images.[511] TIFF's added support for the last three classes now makes possible the storage and compression of color and gray-scale images.

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505 Bonsall + [88], p. 61
506 Bonsall + [88], p. 47
507 Bonsall + [88], pp. 69
508 Bonsall + [88], p. 37
509 ZSoft [89], p. 4
510 Aldus [n.d.], p. 1
511 Aldus [n.d.], p. G-1

TIFF's file structure allows the largest image file to be 2^{32} bytes (almost 4.3 gigabytes) in length. The file is defined as a sequence of 8-bit bytes numbered *0* to *N*. Because TIFF files use pointers, applications can easily access TIFF files from a hard disk or floppy diskette.[512] The file structure also allows each individual field to be identified with a unique tag. Having a tag structure allows certain fields to be present or absent from the file as required by a particular application.

TIFF files starts with an 8-byte *image file header* that points to one or more image file directories. The first two bytes (0 and 1) of the file header specify the byte order used within the file. The two legal formats used are **II** (4949h), which represents byte order from the least significant to the most significant, and **MM** (4D4Dh), which represents the byte order from the most significant to the least significant. The third and fourth bytes (2 and 3) of the file contain the TIFF version number—42 (2Ah)—a number that will never change because the old and new TIFF versions are implemented to be compatible with each other. The last four bytes (4 through 8) of the image file header contain the offset of the first image file directory, which must begin on a full-word boundary and must be represented in bytes.[513]

3.3.4.3. Conversions

Incompatibility of file formats can be resolved by software that converts from one file format to another. Image file format conversion is possible with utilities from Quick Art (Missing Link) and Inset Systems (HiJaak). Conversions are completed in approximately 10 minutes. Another image-conversion utility is Inset Systems' Inset, which can join two different types of images that were saved differently into one file to be printed together as one image.

3.3.4.3.1. Missing Link

Quick-Art's Missing Link is a two-way file conversion utility for PC and Macintosh paint and graphics software. Some of the image file formats supported are ZSoft's PC Paintbrush Plus (PCX), Microsoft Windows Paint (MSP), Media Cybernetics' Dr. Halo III, PC Paint Plus, Digital Research Inc.'s GEM Paint (IMG), and Rix Softworks' EGA Paint.[514] Although useful, Missing Link is limited in that it cannot handle color images or fax formats.

3.3.4.3.2. HiJaak

Inset Systems' HiJaak ($149) is another two-way file conversion software for PC and Macintosh applications. HiJaak can convert fax files, bidirectional TIFF files, and color images.[515] HiJaak uses as little as 45KB of RAM.

512 Aldus [n.d.], p. 2
513 Aldus [n.d.], p. 5
514 Wetzler [89], p. 27
515 Wetzler [89], p. 27

This product could be useful for future remote transmission of scanned images where the formats are not applicable at a certain sites. It would also be useful for future consideration of both color and fax.

3.3.4.3.3. Inset

Inset, also a $149 product from Inset Systems, has the capability of combining two separate files, such as text or graphics, into a combined image for printing. It does not have the capability, however, of saving the final image for further use.

Inset is appropriate for situations where halftones and text need to be stored separately. For example, dithering (the process of arranging pixels that contain gray-scale information into patterns) enhances halftone images but renders text unreadable because letterforms lose their clarity (see section 3.2.2.5.3. Halftones). Sorting the text separately from the image eliminates this problem. Inset is a valuable utility to have when scanning a large number documents containing halftones.

4. IMAGE PROCESSING AT THE STI FACILITY

4.1. Introduction and Summary

The production processes at the STI Facility currently employ micrographics for image processing technology. The production input flows and the document characteristics are those that would be converted to a digital imaging system. The reproduction throughputs are analogous to those that would proceed under a digital imaging system, but the differing response and quality characteristics could reasonably be expected to lead to greater demand under the digital imaging environment.

4.2. Document Input at the STI Facility

4.2.1. Raw Input

The STI Facility received over 75,000 documents during contract year four, and over 33,000 of these were accepted into the database. NASA documents accounted for one third of all accepted documents, DOE and DTIC documents accounted for another third, foreign documents accounted for one sixth, and other sources accounted for the final sixth. A large proportion of submissions from DTIC, DOE, and NTIS are judged to be irrelevant to the STI Facility's databases and are rejected. Table 23 gives an accounting of the raw input by source to the STI Facility.

SOURCE	RAW INPUT	REJECT COUNT	REJECT PERCENT	ACCEPTED INPUT	PERCENT OF TOTAL DOCs
NASA	10,939	0	0%	10,939	33%
DOE	18,350	14,645	80%	3,705	11%
DTIC	26,762	19,145	72%	7,617	23%
NTIS	10,150	9,476	93%	674	2%
Diss Abstracts	820	0	0%	820	2%
ESA	3,497	1	0%	3,496	10%
Foreign Exchange	1,921	0	0%	1,921	6%
Other	4,449	0	0%	4,449	13%
Totals	76,888	43,267	56%	33,621	100%
Percentages	100%	56%		44%	

Table 25. *Raw Input at the STI Facility*

4.2.2. Accepted Input

Approximately 70 percent of all documents received into the STI Facility are categorized as STAR documents (1N series); comparatively few documents are categorized as LSTAR documents (1X series). Almost 10 percent of the documents received are NASA projects monthly and quarterly progress reports (9N and 9X series). An average of 2,802 documents per month (for a total of 33,621 for contract year four) are accepted by the evaluation station and passed on to the cataloging station. Table 24 gives an accounting of the monthly accepted input to the STI Facility.

MONTH	1N	1X	7N	7X	9N	9X	TOTALS
July 1988	1,739	58	272	201	155	163	2,588
August	2,399	54	92	475	82	199	3,301
September	2,393	13	110	288	60	144	3,008
October	1,760	34	177	375	84	195	2,625
November	1,411	17	100	93	77	108	1,806
December	1,786	104	42	426	103	131	2,592
January 1989	2,248	155	37	416	87	175	3,118
February	2,076	55	172	281	88	157	2,829
March	2,346	33	250	557	141	267	3,594
April	1,517	62	243	104	208	125	2,259
May	1,952	62	172	506	185	81	2,958
June	1,596	32	181	866	183	85	2,943
Totals	23,223	679	1,848	4,588	1,453	1,830	33,621
Percentage	69%	2%	5%	14%	4%	5%	100%
Minimum	1,411	13	37	93	60	81	1,806
Maximum	2,399	155	272	866	208	267	3,594
Avgerage	1,935	57	154	382	121	153	2,802

Table 26. *Accepted Input by Series*

One third of all documents accepted into the database are from NASA. The majority of NASA, Foreign Exchange, and other miscellaneous material arrives in hardcopy format, making up over 50 percent of the input source. ESA documents come in on both hardcopy and microfiche formats deriving another 10 percent of the input source. The remaining 38 percent of the input source is received on microfiche from DOE, DTIC, and NTIS. Table 25 breaks down the accepted raw input to the STI Facility by source and medium.

SOURCE	1N	1X	7N	7X	9N	9X	TOTALS	PERCENT
MICROFICHE ONLY								
DTIC	4,712	0	241	2,664	0	0	7,617	23%
DOE	3,524	0	181	0	0	0	3,705	11%
NTIS	607	0	67	0	0	0	674	2%
Diss Abstracts	820	0	0	0	0	0	820	2%
MF Subtotal	9,663	0	489	2,664	0	0	12,816	38%
MICROFICHE AND HARDCOPY								
ESA	3,496	0	0	0	0	0	3,496	10%
Both Subtotal	3,496	0	0	0	0	0	3,496	10%
HARDCOPY ONLY								
NASA	6,344	679	603	30	1,453	1,830	10,939	33%
Foreign Exchange	1,921	0	0	0	0	0	1,921	6%
Other	1,799	0	756	1,894	0	0	4,449	13%
Hardcopy Subtotal	10,064	679	1,359	1,924	1,453	1,830	17,309	51%
Grand Totals	23,223	679	1,848	4,588	1,453	1,830	33,621	100%
Percentage	69%	2%	5%	14%	4%	5%	100%	

Table 27. *Accepted Input by Source and Medium*

4.2.3. Database Output

An average of approximately 1,700 documents—70 percent of all completely processed documents—are placed into the semimonthly issues of STAR each month, and 47 documents (2 percent of all completed documents) are added to the quarterly issue of LSTAR. The facility emphasizes the processing of STAR documents; 69 percent of incoming documents and 72 percent of outgoing documents are STAR. A monthly average of 2,802 documents have been accepted for processing, and an average of 2,354 documents have been added to the STI Facility databases. The remaining documents have been added to input processing queues. An average of 85 duplicate documents have been detected each month (1,021 total duplicates), 86 percent (883 documents) of which are from the 1N series. Table 26 gives an accounting of the monthly database output from the STI Facility.

SOURCE	1N	1X	7N	7X	9N	9X	TOTAL
July 1988	1,718	36	70	354	0	0	2,178
August	1,716	55	116	346	0	0	2,233
September	1,712	29	194	459	294	480	3,168
October	1,714	34	146	334	0	0	2,228
November	1,698	27	84	189	0	0	1,998
December	1,705	24	79	367	177	42	2,394
January 1989	1,678	104	70	304	0	0	2,156
February	1,674	45	99	305	0	0	2,123
March	1,677	104	87	385	249	129	2,631
April	1,662	46	105	314	0	0	2,127
May	1,694	42	122	321	0	0	2,179
June	1,648	16	153	386	330	305	2,838
Totals	**20,296**	**562**	**1,325**	**4,064**	**1,050**	**956**	**28,253**
Percentage	72%	2%	5%	14%	4%	3%	100%
Minimum	1,648	16	70	189	0	0	1,998
Maximum	1,718	104	194	459	330	480	3,168
Avgerage	1,691	47	110	339	88	80	2,354
Accepted Input	23,223	679	1,848	4,588	1,453	1,830	33,621
(-) Duplicates	883	2	15	45	63	13	1,021
(-) Process Queues	2,044	115	508	479	340	861	4,347
Totals	**20,296**	**562**	**1,325**	**4,064**	**1,050**	**956**	**28,253**

Table 28. *Database Output*

4.3. Document Characteristics at the STI Facility

Documents processed at the STI Facility are scientific and technical reports. They contain running text; some color images; and many line drawings, special symbols, mathematical formulae, and halftone images. The color images require specialized technology to maintain their colors. The halftone images will often be poorly reproduced by digital scanning because of the aliasing phenomena discussed elsewhere in this report. The mathematical formulae, images, and special symbols will be difficult for current OCR technology to accommodate.

A statistical survey is currently underway at the STI Facility to develop quantitative distributions of these and other features within the Facility's document population. Its results will be separately reported.

4.4. Document Reproduction at the STI Facility

The current patterns of document reproduction and distribution at the STI Facility represent the candidate workload to be addressed by an imaging system. There are, at present, two forms of document distribution, automatic and demand. In automatic mode, microfiche copies of documents processed within the most recent month are sent to STI Facility users. In some cases, users receive all documents processed; in others, only selected report series. Demand distribution responds to users who request particular documents.

The data in this discussion reflect information regarding RMS Associates' fourth contract year, which ran from July 1, 1988, to June 30, 1989. The source of the data is the monthly Report on Facility Operations.

4.4.1. Automatic Distribution

Automatic distribution covers the number of microfiche cards (current standard is a 24X fiche containing 98 frames) distributed each month to NASA users. Complete or partial sets of microfiche are automatically distributed to NASA users monthly; the STI Facility retains some copies as a precaution against damage or loss of master versions.

As shown in this report, a large proportion (96 percent) of automatic distribution is STAR. Note that *STAR* refers to the micrographic images of actual documents; *STAR abstracts* refers to images of the STAR abstract journal. Included in the STAR column are the shipment of one set of silver duplicates to GPO and the normal STAR distribution. *LSTAR* refers to the distribution of limited documents, and *news releases* to the NASA press releases. Together, these categories comprise less than 4 percent of the automatic distribution.

An average of almost 90,000 microfiche, each containing up to 98 imaged frames, are distributed each month. For capacity planning purposes, it is significant to note the maximum output of almost 130,000 cards.

MONTH	STAR	LSTAR	STAR ABST	NEWS RLSE	TOTAL
July 1988	84,410	5,815	100	28	90,353
August	88,378	4,039	100	14	92,531
September	103,446	2,521	100	28	106,095
October	79,693	871	100	28	80,692
November	69,508	3,513	100	14	73,135
December	103,968	2,906	100	28	107,002
January 1989	75,789	2,530	100	84	78,503
February	81,327	4,880	100	14	86,321
March	126,527	2,726	100	14	129,367
April	101,475	2,110	100	28	103,713
May	63,449	1,492	100	28	65,069
June	61,026	3,488	100	28	64,642
Total	1,038,996	36891	1200	336	1,077,423
Percentage	96.4%	3.4%	0.1%	0.0%	99.9%
Minimum	61,026	871	100	14	64,642
Maximum	126,527	5,815	100	84	129,367
Avgerage	86,583	3,074	100	28	89,785

Table 29. *Automatic Distribution of Microfiche*

Table 27 above illustrates that, in monthly automatic distribution, a total of 328 set of microfiche are distributed. Most of these, including distribution to other NASA sites and sets retained by the STI Facility, are complete sets. Partial sets number 145. STAR distribution dominates the set requests. Table 28 below breaks down the automatic microfiche distribution by the STI Facility to NASA users, exluding the Government Printing Office (GPO).

TYPE	COMPLETE	PARTIAL	STIF	TOTAL	PERCENT
STAR	120	100	5	225	69%
STAR Abst	17	0	8	25	8%
LSTAR	12	45	7	64	20%
News	5	0	9	14	4%
Total	154	145	29	328	
Percentage	47 %	44%	9%		100%
All destinations are NASA users, GPO has been omitted.					

Table 30. *Sets of Automatic Microfiche Distribution*

4.4.2. Demand Distribution

Demand distribution satisfies specific requests from NASA, NASA contractors, Government agencies and their contractors, and other research organizations. The data are derived from Tables 12 and 16 of the monthly Facility Operations reports.

The data have been divided according to the source of the incoming request: NASA or other. Each group has been further divided into hardcopy (HC) reproduction from film and hardcopy reproduction from hardcopy. Demand distribution of microfiche (reproduced from microfiche) is not tabulated in the monthly reports according to NASA and non-NASA requesters, therefore the column on fiche distribution has been included with the row totals.

In table 29 below, percentage(1) reflects the proportion of NASA-derived requests and of Other-derived requests that are hardcopy reproductions from film and hardcopy reproduction from hardcopy. 75 percent of NASA and 93 percent of other demand distribution is met by hardcopy reproduction from microfiche: 84 percent overall. Percentage(2) indicates the proportions of demand distribution that are NASA, other, or microfiche reproduction—NASA and other requesters provide nearly the same volume of demand requests.

MONTH	NASA			OTHER			TOTALS				
	HC from FILM	HC from HC	NASA TOTAL	HC from FILM	HC from HC	OTHER TOTAL	HC from FILM	HC from HC	HC TOTAL	MF REPRO	GRAND TOTAL
July 1988	341	116	457	533	45	578	874	161	1035	41	1076
August	452	113	565	539	53	592	991	166	1157	96	1253
September	418	94	512	470	38	508	888	132	1020	40	1060
October	314	52	366	308	19	327	622	71	693	69	762
November	293	98	391	381	26	407	674	124	798	148	946
December	307	71	378	446	20	466	753	91	844	75	919
January 1989	243	125	368	406	37	443	649	162	811	80	891
February	369	156	525	394	33	427	763	189	952	154	1106
March	418	188	606	594	28	622	1012	216	1228	127	1355
April	344	110	454	513	35	548	857	145	1002	145	1147
May	352	161	513	401	48	449	753	209	962	129	1091
June	390	122	512	426	42	468	816	164	980	175	1155
Totals	4241	1406	5647	5411	424	5835	9652	1830	11482	1279	12761
Percentage(1)	75%	25%	100%	93%	7%	100%	84%	16%	100%		
Percentage(2)			44%			46%				10%	100%
Minimum	243	52	366	308	19	327	622	71	693	40	762
Maximum	452	188	606	594	53	622	1012	216	1228	175	1355
Average	353	117	471	451	35	486	804	153	957	107	1063

Table 31. *Demand Distribution of Documents*

5. IMAGE PROCESSING AT OTHER SITES

5.1. Introduction and Summary

Digital imaging systems are successfully used in organizations that need rapid access to vast amounts of essential data. Numerous digital imaging systems have been installed in a variety of environments, including banking and insurance, engineering and construction, publishing and printing, health care and medical research, and all levels of local, state, and federal government.

The most likely applications that will derive significant benefits from digital imaging technology share at least five of the following needs:

- rapid lookup
- collection of information from multiple sources
- adjudication of action requests
- transaction processing of documents and data
- key entry and/or OCR from scanned images
- process suspension, pending additional input
- programmed flow of documents and data from workstation to workstation
- local and remote input and display of documents
- communication replacement and/or combined document and data storage.[516]

This section contains information on some of the digital imaging systems in place at other sites. In most cases, pilot projects were implemented at the sites first, followed by intensive testing of the pilot system before attempting to introduce a full-scale digital imaging system. This section is not intended to be a complete list, but rather an indication of the types of imaging projects being conducted at other sites where detailed information about the technology used is readily available. Additional information is continuing to be obtained about imaging systems at other sites with a particular focus on NASA applications. This information is being compiled and will be made available upon request.

5.2. NASA

5.2.1. Langley Research Center[517]

Project Description: NASA will use the optical disk systems to distribute satellite data currently gathered at NASA for the Earth Radiation Budget Experiment (ERBE).

Image System: Aquidneck Systems International has installed 15 OAS 150tm optical disk-based storage and retrieval systems in the United States, Canada, and Europe.

516 Walter [n.d.] p. 1.11

517 IRLA [89], p. 3

Implementation: The data will be archived in a master optical disk; off-line, copies will be made for worldwide distribution on a monthly basis.

Contractor: Aquidneck Systems International has a contract for delivery, installation and support.

Remarks: The Atmospheric Sciences Division at NASA estimates that the cost savings realized from using optical disks instead of tape will pay for the new equipment in approximately 30 months.

5.3. Other Government

5.3.1. Army[518]

Project Name: Military Personnel Records Management System.

Project Description: Army wants to use optical digital image technology to maintain both active and reserve soldiers' personnel records. Those records are duplicated and maintained in many locations (more than 213 million records).

Date and Status: Begun in 1983, the Army contracted for investigation at several locations with several contractors. In 1986, a limited pilot test was established at the Enlisted Record & Evaluation Center, Fort Benjamin Harrison, Indiana. The ODI project is still running.

Implementation: A four-stage implementations is planned.

- o Phase I pilot project cost about $5 million over three years by contractor BDM International Inc. The pilot project uses Hitachi jukeboxes and drives. Components are connected in a fiber-optic LAN.
- o Phase II call for conversion of all official military personnel file at personnel center. Full production is expected in summer 1990.
- o Phase III will convert all other records.
- o Phase IV is projected to expand use of ODI at U.S. Army installations to eliminate paper transactions.

5.3.2. Department of Energy (DOE)[519]

Project Name: Licensing Support System (LSS).

Project Description: This optical disk system will produce up to 10,000 documents that are needed for the licensing review that the department of energy is trying to gain for building a site to store radioactive waste. The optical disk system should be running in 1991; however, the

518 Weisenberger [89]
519 Kaebnick [88], pp. 32–33, 46

actual processing of the licensing application will begin in 1995. LSS will have nodes in Washington DC, Nevada, and Texas. By 2009, LSS will access 10 additional cities. Some of the LSS features include multiple document capture, scanning, text conversion, correction, cataloging, and workstation displaying ASCII text.

Date and Status: Pilot study started in 1988 and is still in progress. The full-scale system will begin in 1991.

Hardware: A PC-based retrieval and display workstation featuring a 300-by-150-dpi resolution on an LV-700 monitor; a Ricoh LP 3080 laser printer; a Ricoh IS-4000 400-dpi scanner with Calera's OCR system; and an Ethernet LAN.

Contractors: Science Application International Corporation.

Remarks: The 10-year life cycle of this system is estimated to cost $200 million.

5.3.3. Food and Drug Administration[520]

Project Description: Center for Devices and Radiological Health (CDRH) leads the evaluation plan and pilot tests of optical document image technology for demonstration of the system's capabilities to staff members of the various FDA components. The system is mainly designed for documents management, archival storage and demand printing. The database size can include up to 10 million pages and a file can include 80,000 pages.

Date and Status: Hardware and software were leased by FDA in October 1986 for a four-year contract; the pilot test project began operation in January 1987.

Image System: FileNet OSAR.

Hardware: A 200-dpi scanner; 400-dpi laser printer; two 20-inch workstations (by spring of 1989, 150 modified PC will service as workstations and will be connected by a T-1 line); a 64-disk jukebox with one 12-inch disk drive; and and Ethernet LAN and external communication via a 1200-bps modem.

Software: FileNet supplied software for document entry, indexing, retrieving, editing; VT100 terminal emulation; and high-level application development language.

Remarks: The pilot test shows the system can solve many of the paper management problems for FDA. From their experiences, the edge-feed scanner has problem of paper jamming.

5.3.4. Library of Congress[521]

Project Name: Optical Disk Program.

520 Krell [88]; and Kaebnick [88]

521 Price [88], pp. 424-432 and Fleischhauer [83]

Project Description: Since the library of congress stores over 80 million items—the largest collection of recorded knowledge in the world—this project was broken up into two parts: print and nonprint. The nonprint project was designed for accessing image material, such as architectural drawings, photographs, motion pictures, television programs, cartoons and even sound recordings. The print program, on the other hand, will access text materials, specifically periodicals.

Date and Status: The pilot study started in 1982 and ended in 1985. The production project started in 1985 and is currently on going.

Hardware: Each hardware component is treated separately below.

Printers: Two slow-speed Xerox 2700 models that print 12 ppm at a resolution of 300 lpi; one high-speed Xerox 5700 model that prints 43 ppm at a resolution of 300 lpi; one 300-lpi page scanner that can handle paper sizes as large as 11-by-14-inch; a Microfiche scanner that requires 98-frames fiche manually positioned with a 24 : 1 reduction with a scanning time of 2 seconds

Optical disk system: One 12-inch optical disk with a capacity of 10,000 to 15,000 pages per side and as many as 100 disks per jukebox (retrieval time is 5 seconds; however, the first retrieved page requires 12 seconds).

Magnetic disk system: Two subsystems that function as an I/O buffer to the optical disk, each of which has an unformatted capacity of 290MB.

Video system controller: Supports 32 peripherals and provides bisynchronous communication to host.

Terminal cluster controller (TCC): Supports buffering and communications to four workstations consisting of an alphanumeric and video terminal and a high-resolution printer; a cable length using RG-11/U (0.375-inch diameter) can be as much as 2,000 feet between the terminal cluster controller and the display terminals.

Workstations: Display 2,000 feet from TCC has both video display mode and an alphanumeric mode, 150-by-300-lpi resolution, and a display size of 8.5-by-11-inches.

Contractors: Xerox (for scanning catalog cards), Sony (for recording video disk), and Integrated Automation (for system development).

5.3.5. National Agricultural Library[522]

Project Name: Text Digitizing Project.

Project Description: The NAL and 44 land-grant libraries planed to use image technology as a means of capturing and distributing textual information. The material is scanned and converted to ASCII text to allow full-text searching and is distributed by CD-ROM media.

522 Andre + [88]

Date and Status: Started a two-year pilot project in September 1986.

Hardware: Ricoh 300-dpi high-resolution scanner; Calera RS 9000 OCR engine; an 80286-based microcomputer with 640KB of RAM, 230MB hard disk, and 1MB video chip for image display; 5.25-inch WORM disk and a 9-track tape drive used for premastering CD-ROM; Laser View 150-dpi monitor; and Ricoh laser printer with 300-dpi resolution.

Software: The operation system is PC DOS 3.1. The system integrator developed most of the software to control scanning, conversion, and to create indexes and hypertext links between indexes, text, and images.

Contractor: Science Applications International Corporation.

Remarks: The automatic conversion involves lots of sophisticated problem, the project is still running for further improvements.

5.3.6. U.S. Patent and Trademark Office (PTO)[523]

Project Name: Automated Patent System (APS).

Project Description: Every year the PTO receives 130,000 patent application and 20 million documents have to be examined before the application becomes a patent. APS was designed to replace these paper documents for the purpose of simplifying the process of storage and retrieval.

Date and Status: Pilot study started in 1984 and ended in 1988. Currently being used on a full production basis.

Hardware: Workstation (designed by Gould Inc.) contains seven 32-bit microprocessors performing different functions (such as communication with the host system and decompressing digital image data) to enable the workstation to manage windowing on dual high-resolution screens and manage internal magnetic storage of 300MB; 36 million pages of text are scanned and converted to images (by Computer Microfilm Corporation of Atlanta, Georgia); 3M-supplied optical disks; and three large-scale mainframe processors are used for system communication through digital PBX switches using high-speed, fiber-optic lines.

Software: Full-text search and retrieval database. Also uses CCITT Group 4 fax data-compression algorithms.

Contractors: Planning Research Corporation (for planning the final system architecture), Chemical Abstract System (for most of the software development), National Advanced System (for mainframe computers), Falcon System (for single-spindle optical disk drives); InteCom Corporation (for the digital PBX), Gould Electronics Inc. (for dual-screen displays and workstations), Masscomp Corporation (for the search engines).

523 Huther [n.d.]; Hosinski [88], p. 31

Remarks: The cost of the test bed is estimated to be $181 million and the final system will cost about $581 million. According to Thomas Giammo, PTO's assistant commissioner for information systems, a lot of mistakes were made because this imaging system was one of the first to be designed.

5.3.7. Veteran's Administration[524]

Project Name: Folderless File System (FFS).

Project Description: The VA's division of vocation and education at the Saint Louis branch adopted an optical disk system (FFS), which allows incoming paper documents to be digitized and stored on accessible electronic folders. These images are scanned, verified indexed and placed on an overnight batch system to be processed the next morning.

Date and Status: The pilot started in 1985 and is still in progress.

Hardware: A 64-disk jukebox (total capacity of 140GB) with four optical disk drives are in use, 3 scanners, 26 workstations, 2 laser printers, and and Ethernet LAN.

Software: FileNet's Workflo.

Contractor: American Management System (AMS).

Remarks: The goal of this system is to handle 20 million claims a year; however, it is currently handling a small fraction of that. Total cost of this system was approximately $3 million with a yearly maintenance of $200,000 a year.

5.3.8. Other Organizations

5.3.8.1. Syracuse University[525]

Project Name: Kellogg Library and Archives Retrieval System (KLARS).

Project Description: Using WORM disk technology to store a large collection of adult and continuing education manuscript materials. The system is expected to have automatic conversion and free-text searching ability.

Date and Status: Project started September 1986, phase one hardware installed December 1987, phase two installation of jukebox and OCR conversion in December 1988.

Image System: Plexus.

Hardware: Plexus P-95 data server with 8MB of RAM, Plexus' Turbo Informix Data Manager, 572MB disk storage, and Optimem 12-inch disk drive; two Fujitsu model 3094A scanners with various sizes and resolutions; rwo Fujitsu model M3727 laser printers with 300-dpi resolution; four Plexus XDP workstations with 19-inch high-resolution monitors; and Cygnet jukebox model 3070 (added at phase two).

Software: Unix 5.2 operating system; Calera 9000 OCR server is expected at phase two.

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524 Chase [88], pp. 34–35; Altman [88], pp. 24–32

525 Keenan [88]

5.3.8.2. United Service Automobile Association (USAA)[526]

Project Description: Store and retrieve text and graphic forms for daily transaction. Currently 130 workstations are in use with a simulation being run to test the MVS system's ability to handle 650 workstations simultaneously. The ultimate plan is to support 1200 users.

Image System: IBM Image Plus.

Hardware: Two IBM 3090 mainframe hosts and one IBM 4381 working in conjunction with IBM application software; a 64-platter jukebox with four drives and two SCSI connections

Remarks: The file-management scheme has documents managed at the object level rather than page level. All documents stay on magnetic media for 30 days then migrate to optical disk on a batch run.

526 Kempster [89]

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ADG [86], doc 266

Account Data Group, "Guide To Local Area Networking," 1986, pp. 1–29.

This guide contains a brief, concise overview of local area network (LAN) technology. It lists and defines the components of a traditional LAN, various topologies, access methods, and transmission mediums. It contains a brief discussion of various LAN offerings by IBM (Token-Ring), AT&T (StarLAN), Novell (NetWare), 3Com (Ethernet), and Banyan (VINES). The guide has a review of the issues and concerns in LAN implementation as well as the factors involved in LAN planning and justification. **(PL)**

Adobe [n.d.], doc 120

Adobe Systems Incorporated, "The PostScript Language," pp. 1–5.

This document describes Adobe's PostScript, a page description language (PDL) for laser printers. The document contains a list of PostScript's benefits, the types of documents that can be generated using PostScript, PostScript-supported applications, and how PostScript is constructed. **(JEE)**

AGA [88], doc 323

Advanced Graphic Applications Inc., 90 Fifth Avenue, New York, New York 10011-7696

Specification sheet for DICSUS rewritable optical disk drive model DR650. **(EL)**

Ahlgren+ [89], doc 161

David R. Ahlgren and H. Gadjali, "The Optimal Compression of Digital Images Using Graphic Signal Processors," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 148–156.

This paper contains discussions of compression systems based on compression schemes that use the Graphic Signal Processor (GSP). These systems can reduce image file sizes by a factor of more than 8 : 1 with only minor detectable image degradation. GSP is now an integral part of display control. The need for separate and expensive DSP for Discrete Cosine Transform (DCT) computation is eliminated. The type of images discussed are natural images as opposed to machine-generated images. The resolutions, which range from 256-by-200 to 4096-by-4096, are television-quality images. The images produce are primarily for viewing as opposed to printing. **(EL)**

Aldus [88], doc 267

Aldus Corporation, "Aldus PageMaker Reference Manual," Seattle, Washington, 1988, pp. 2-22–2-27.

This manual contains a description of the ways PageMaker can place and manipulate a scanned image. It has some detailed discussion about how to create a scanned image and choose the proper scanning resolution. The manual also has a description of PageMaker's image-control options (lightness, contrast, and screen size, angle, and frequency) are also described. **(PL)**

Aldus/Microsoft [88], doc 82

Aldus Corporation and Microsoft Corporation, "Tag Image File Format Specification," Seattle, Washington, August 1988.

Describes Version 5.0 of Tagged Image File Format (TIFF), a format for storing images using tags to identify graphic elements. Originally developed for desktop publishing to promote the interchange of digital data, TIFF is emerging as a standard for scanned images. TIFF identifies the image bitmaps so that the images can be either printed, converted to another file format or used in a desktop publishing package. TIFF allows storage of multiple-resolution bitmaps and storage and compression of gray-scale and color images. The majority of the specification deals with the structure of a TIFF file and its tags. **(PL)**

Alphatronix [89], doc 312

Alphatronix, Research Triangle Park, North Carolina 27709-3687.

Specification sheets for the INSPIRE erasable optical mass storage systems for DEC, Sun, IBM PC, and jukebox. **(EL)**

Alter [88], doc 91

Allan E. Alter, "The Unpapering of America," *CIO Magazine*, October 1988, pp. 16–26.

Optical disk technology is replacing cumbersome paper storage. A 12-inch optical disk can replace half a million pages of text and retrieval of any document on this system can take less than 30 seconds. Also, 450 sites in the U.S. and 4,000 in Japan are converting to optical disk. Some of these sites are CAP International, Maine Medical Center, Glaxo Pharmaceuticals, ICI Pharmaceuticals, U.S. Food and Drug Administration, General Electric, and McDonnell Douglas. **(JEE)**

Altman [88], doc 37

June Altman, "Veterans Administration Benefits from Optical Storage," *MIS Week*, December 12, 1988, pp. 25–42.

Describes a prototype system developed in 1985 by the Veterans Administration (VA) Department of Veterans Benefit (DVB) Claims. This system handles benefit claims relating to one particular veteran's benefit bill—the Montgomery GI bill. For example, when a veteran phones the VA with an inquiry about benefits related to the Montgomery GI bill, the file can be accessed through an optical disk system (while the veteran is on the line) and the inquiry can be responded to immediately. Such an inquiry would normally take several days for the veteran to receive the information. By September 1989, a cost-benefit study should be completed that will determine how optical storage can be applied throughout the DVB.

The system, which cost three million dollars, was purchased from FileNet. The hardware includes 2 scanners, 32 workstations, 1 optical disk jukebox, 1 laser printer, and an Ethernet network that ties the system together. American Management System (AMS) performed the software development and integration. Maintenance for the entire system cost $200,000 for the first year; however, training expenses were relatively insignificant because the system is easy to use. Among DVB's requirements for the optical disk system was that it operate compatibly with its Wang word processing system and its Honeywell claims payment system. AMS developed software to make this compatibility possible. Using the system's windowing capability, a DVA claims processor can call up a veteran's benefit application in one window, call up the veteran's financial report from the DVB's Honeywell system in a second window, and type a customized response to the claim in a third window. **(JEE)**

Anderson, K.+ [87], doc 38

K. L. Anderson, F. C. Mintzer, G. Goertzel, J. L. Mitchell, K. S. Pennington, and W. B. Pennebaker, "Binary-image-manipulation Algorithms in the Image View Facility," *IBM Journal of Research and Development*, Volume 31, Number 1, January 1987, pp. 16–31.

The authors discuss the design considerations, algorithms, and implementation of algorithms to compress/decompress, enlarge/reduce, and rotate images in IBM's Image View Facility. The article contains illustrated discussions of both Modified Read (MR) and Modified MR (MMR) compression schemes from CCITT. The presentation of scaling (enlargement/reduction) algorithms offers perspectives on the trade-offs between quality and speed, between visually demanding output devices (such as printers) and visually forgiving output devices (such as displays), and between customized and generalized approaches. **(GMVTS)**

Anderson, L. [89], doc 232

Lester Anderson, "Write-once Optical Disk in Nonstandard Imaging Applications," *IMC Journal*, March/April 1989, pp. 15–16.

"Conventional image and document management systems are not the only applications for the write-once optical disk." (p. 15) Other possibilities include satellite data collection and seismic data management in the geophysical community. **(GMVTS)**

Anderson, L.+ [89], doc 245

Lester Anderson and Brian Rezach, "Local Area Networks: Tying the Office Together," *Inform*, March 1989, pp. 10–11, 31.

Gives a brief overview of what a LAN is from the perspective of an office environment. The various topologies, different communication media, and different access methods are all briefly discussed. The effect of transmitting images over a LAN is also mentioned. Design of the network and carefully chosen components are specified as the critical issues to the successful implementation of a LAN. **(PL)**

Anderson, W.+ [83], doc 189

William H. Anderson, M. A. Tarlton, K. S. Hensley, A. W. Templeton, and S. J. Dwyer III, "Implementation of a Diagnostic Display and Image Manipulation Node," SPIE: *Picture Archiving and Communication Systems (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 225–232.

The number of image systems are growing at a fast rate in the medical field, especially for diagnostic examinations. The article discusses the amount of data that requires displaying from various digital examinations, such as computed tomography scanners and nuclear medicine cameras, and the required interactive graphic functions necessary to display and manipulate the images. Like many image systems, highly utilized pages are kept on-line for a short period while low demand pages are archived off-line for long term storage. The image workstation must have the ability of displaying any image the system contains as well as the ability to transfer an image to or receive an image from any other node on the system. The interactive image processing functions that should be able to be done are presentation functions (split-screen function, choosing any image to display), manipulation functions (3-D display or the zoom function), and quantification functions (pixel value read out or histogram analysis). For proper storage and retrieval, the database must be carefully designed. B-tree structures are often used because of their high guaranteed space utilization, rapid searching, expansion limited only to the disk size, and rapid insertion and deletion times. **(PL)**

Andre+ [88], doc 308

Pamela Q. J. Andre, Nancy L. Eaton, Judith A. Zidar, "Scanning and Digitizing Technology Employed in the National Agricultural Text Digitizing Project," *Proceedings of the Conference on Application of Scanning Methodologies in Libraries,* pp. 61–75.

The NAL and 44 land-grant libraries planned to use image technology as a means of capturing and distributing textual information. The material is scanned and converted to ASCII text to allow full-text search and is distributed by CD-ROM media. Both bitmap image and ASCII text are stored on WORM disks and linked with each other. The integrator SAIC developed most the software for scanning, conversion, indexing, and linking. **(EL)**

ANSI/AIIM [88], doc 268

American National Standards Association (ANSI)/Association for Information and Image Management (AIIM), "Recommended Practice for Quality Control of Image Scanners (Standard MS44-1988)," Silver Spring, Maryland, 1988.

Provides procedures for the ongoing control of quality within a digital document imaging system. The principles of quality control are explained and procedures and frequency for testing are given. Samples of three test targets (IEEE Facsimile Test, AIIM Scanner Test, RIT Process Ink Gamut Chart) are provided, as well as detailed descriptions concerning various portions of the test targets. Appendixes are provided to explain how to produce a test target, suggestions for scanning, and explanations of resolution, thresholding, and color scanning. **(PL)**

Arps+ [88], doc 214

R. B. Arps, T. K. Truong, D. J. Lu, R. C. Pasco, T. D. Friedman, "A Multipurpose VLSI Chip for Adaptive Data Compression of Bilevel Images," *IBM Journal of Research Development*, Volume 32, Number 6, November 1988, pp. 775–794.

This paper describes the application of very large scale integration (VLSI) chip for data compression. The compression is based on a general-purpose adaptive binary arithmetic coding (ABAC) architecture. The specific version of the adapter/coder used herein is Q-coder. The hardware implementation is in a single HCMOS chip to maximize speed and minimize cost. The coding scheme significantly outperforms nonadaptive CCITT Group 4 standard. Q-coder is good for conventional text files and halftone images. **(EL)**

Arps+ [89], doc 155

Ronald B. Arps and R. C. Pasco, "Improvements to the PCS Algorithm for Binary Images," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 107–113.

Progressive coding for images holds the data for a digital image as a sequential compressed file. These files contain incremental information needed to represent the image at progressively higher resolution. By improving the application of adaptive binary arithmetic coding (ABAC), some improvements can be made to this PCS scheme. This paper summarizes and compares those. **(EL)**

Arrington [88], doc 67

Major Curtis H. Arrington III, "Use of Optical Disk Technology at the Air Command and Staff College," Report 88-0130, Air Command and Staff College, 1988.

This paper reviews the history of written information storage, the specifics of optical disk (CD-ROM) technology, educational applications for CD-ROM, and specific application possibilities at the Air Command and Staff College. Primary uses foreseen are for improved audio-visual support, as a research tool, for interactive tutorial programs, and for database acquisition and development for manuals, maps, educational materials, etc. (GMVTS)

Assmann+ [83], doc 195

K. Assmann and K. H. Höhne, "Investigation of Structures and Operations for Medical Image Data Bases," SPIE: *Picture Archiving and Communication Systems (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 282–286.

Traditional approaches to database management system applications with images address the large size of image files. There are larger issues, and they go beyond simply enriching an image file with formatted data in a coordinated database structure. Working with the Hamburg University Hospital from their base in the Institut für Mathematik und Datenverarbeitung in der Medizin, the authors defined some basic data additions required to be maintained in a relational DBMS:

- o "data describing the image content
- o origin of the image (image source, hardware details, date and time...)
- o contents of the image (organ, possible diagnosis,...)
- o update status of the image (which graphic, text, image,...has been derived)
- o data describing the image form
- o type of image (graphics, sequence, 3D-image,...)
- o kind of representation (compression type, pixel depth,...)
- o physical storage (number of frames,...)
- o Data describing the presentation of images (which graphic, text, image,...has been derived)
- o hardware details of a workstation (resolution, storage capacity)
- o description of the current contents on screen
- o description of the currently performed operation with the images on screen
- o the images themselves" (p. 284)

They extended SQL, the widespread data manipulation language, to provide needed image-specific operations. (GMVTS)

ATG [88], doc 321

ATG Gigadisc Inc., 400 West Cummings Park, Woburn, Massachusetts 01801

Specification sheets for ATG 12-inch WORM disk optical disk system Gigadisc TM 6000, and TM 1002. **(EL)**

Bagg [87], doc 233

Thomas C. Bagg, "Digitizing Documents: Guidelines for Image Quality," *Inform*, November 1987, pp. 6–9.

At a normal reading distance of 14 inches, the human eye can distinguish at most about eight line pairs per millimeter (pairs/mm). Readability can be quantified by the Quality Index, measured in line pairs/mm, and can be scaled as follows: 3 = Character barely decipherable; 3.6 = Marginal quality; 5 = Quite legible, but serifs and fine detail may be lost; 8 = Excellent quality with serifs and fine detail resolved. (pp. 6–7)

Scanning resolutions, measured in dots per inch (dpi), correspond approximately to line pairs/mm as follows: 100 dpi ≈ 2 line pairs/mm; 200 dpi ≈ 3.9 line pairs/mm; 300 dpi ≈ 5.9 line pairs/mm; 400 dpi ≈ 7.9 line pairs/mm; 600 dpi ≈ 11.8 line pairs/mm. (p. 8)

The authors experience suggests that approximately 30-percent higher resolution than that generated by this model is required with CCD scanning, because the spatial quantization introduced by digital scanning virtually never coincides with the layout of fine detail in scanned originals. **(GMVTS)**

Bainbridge [84], doc 137

R. C. Bainbridge, "Keynote Address: The Role of Standards in the Emerging Optical Digital Data Disk Storage System Market," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 27–28.

Discusses the National Bureau of Standards (NBS), which provides technical support for government and industry in the effective use of information technology and setting standards. Standards are important for interchange of data between computers and networks. **(JEE)**

Baumann+ [89], doc 126

Keith Baumann and Jake Widman, "The Full-color Desktop," *Publish!*, May 1989, pp. 50–59.

The authors characterize the color results one obtains from color printers: "...the color your get from those printers is adequate for rough proofing or for quick presentations at best. For published color photos of the quality you've come to expect from magazines, brochures, and even newspapers, you need to turn to four-color printing." (p. 50) The authors executed several software products to product digital color separations. The results were not as good as photographically produced separations, but the authors thought they were good enough to be used in many typical color applications—and they were cheaper. **(GMVTS)**

Baxter+ [83a], doc 180

Brent S. Baxter, M. P. Zeleznik, and G. Q. Maguire Jr., "What Type of Standards Would Be Useful in PACS Activities?" SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 146–150.

Discusses the importance and dependence of the interconnection and successful use of multiple electronic equipment of a digital storage and retrieval system. This system is used for diagnostic image information in a large medical center. A picture archiving and communication system (PACS) network becomes necessary for standardizing procedures. Benefits mentioned for use of standards are new equipment can be added to the old system without the entire system becoming obsolete, the archived image material will not be affected by the new equipment and simplifying communication between medical centers. **(JEE)**

Baxter+ [83b], doc 130

Brent S. Baxter and M. P. Zeleznik, "Communication and Storage Protocols for PACS," *IEEE Computer*, Volume 16, Number 8, August 1983, pp. 31–36.

New and improved standards are needed to ease the expansion of digital image utilization in medicine. New equipment cannot necessary process the images of the equipment being replaced. Different equipment items often produce incompatible images. Even equipment connections are sometimes configured to different standards. **(GMVTS)**

Berglund [88], doc 68

Anders Berglund "SGML, a Brief Introduction," *ISO Central Secretarist*, Geneva, Switzerland, November 16, 1988.

Standard Generalized Markup Language (SGML), ISO standard 8879, specifies a language for document representation. SGML has the following design aims: making the structure of a document separate from its style of presentation, being independent of the text formatting system, and multiple processing of the same source document. The information in SGML is identified by tags and the structure is rigidly specified by the application designer. **(EL)**

Blackford [89], doc 96

John Blackford, "The Exotic World of Optical Storage," *Personal Computing*, March 1989, pp. 277–278.

Introduces the technology of erasable optical disks. Discusses the basic technologies of erasable optical disk and the restraints it has now. **(EL)**

Blair [85], doc 51

David C. Blair and M. E. Maron, "An Evaluation of Retrieval Effectiveness for a Full-Text Document-retrieval System," *Communications of the ACM*, Volume 28, Number 3, March 1985, pp. 289–299.

A series of experiments in an operational environment of litigation support demonstrated that inverted file technology supporting Boolean retrieval strategies delivered an average of 20-percent recall and 75-percent precision. These results conflicted seriously with the performance assumptions of the legal users who had been relying on retrieval tools to support their case work. During the experiments, searches were executed until requestors were satisfied with results, both requestors and intermediaries conducted searches, and individual searcher variations were considered. The authors review problems in full text environments that contributed to the perceived poor retrieval performance. The authors argue the superiority of manually indexed schemes over full text systems for some applications. **(GMVTS)**

Blum [89], doc 110

Greg Blum, "High-Resolution Printers: How much is Enough?," *PC Publishing*, April 1989, pp. 16–22.

Discusses high resolution printers and typesetters. Blum points out that cost per page for the high resolution printer is a lot higher than the average 300-dpi prints. Another important fact brought forth is that the cost of high resolution. Printers has decreased in the last few years and have become affordable. A comparison chart is provided comparing different high-resolution printers, their prices, resolution and other important factors. **(JEE)**

Bodson [85], doc 81

Dennis Bodson, "Simulation and Evaluation of the AT&T Proposed Pattern Recognition Algorithm for Group 4 Facsimile," National Communication System, 1985.

Evaluates the pattern recognition algorithm proposed by AT&T for CCITT Group 4 fax. The algorithm recognizes recurring patterns and transmits a short ASCII-like code to represent such a symbol. Three test documents with four different resolution are tested. The result shows that the pattern recognition algorithm has a significant increase in compression ratio over Group 4 MRC II algorithm, especially with higher resolution. A detail coding algorithm is included in Appendix B. **(EL)**

Boeing [88], doc 1

Boeing Computer Services, "Space Station Technical and Management Information System (TMIS)," Report prepared under Contract NAS 9-17797, July 29, 1988.

This report describes the technology behind optical storage and the role it can play in solving the future storage and archival needs of the Technical Management Information System (TMIS), which is being used by both NASA and non NASA users. A technical issue of TMIS is how the massive amounts of data (such as documents, files, drawings, and programs) generated in support of the Space Station Program (SSP) will be archived and stored in a timely and cost effective manor, over the life-cycle of the program.

The report also included informative tables and graphs, some of the tables discussed the following:

- o Advantages and disadvantages of alternate Mass Memory Technology which include magnetic and thin film technology, optical storage disk, and Optical Read Only Memory (OROM).
- o Advantages and disadvantages of Write Once Read Many (WORM) and Write Many Read Always (WMRA).

- o Advantages and disadvantages of alternative Mass Memory Technologies such as Magnetic tape and Negative Metal Oxide.
- o Information on different SCSI Host adapters.
- o TMIS capabilities mapping.
- o List of manufacturers and their products capabilities.
- o Information on optical disk formats.

The second half of this report is SPIAM Assessment of alternatives supporting archival storage, which consists of graphs and charts fo strategic planning, estimated cost for the project and typical site configurations. **(JEE)**

Bonsall+ [88], doc 127

G. W. Bonsall, T. R. Edel, A. W. Griffee, Y. Hadeda, Dr. B. J. Shepherd, J. A. Stark, V. D. Tucker, J. W. Wing, *Architecture for Object Interchange*, IBM Corporation, November 1988.

This book is divided into two sections. The first contains a description of the structure of a consistent set of architecture for Object Interchange. The second section contains a discussion of the Mixed Object Document Content Architecture (MO:DCA), which is a file format developed and used by IBM. MO:DCA classifies a document or object as containing what is referred to as presentation data. Four of these Object Content Architectures (OCAs), which are discussed in detail, are Image OCA (IOCA), Presentation Text OCA (PTOCA), Graphic OCA (GOCA), and Font OCA (FOCA). **(JEE)**

Braid [86], doc 48

J. A. Braid, "Electronic Document Delivery—A User's View," *Space Communication and Broadcasting*, North-Holland, Volume 4, 1986, pp. 399–406.

The British Library Document Supply Centre (BLDSC) processes approximately three million requests per year for scientific and technical documents. They consider 300 dpi necessary to produce an acceptable image from digital scanning of document pages. Document delivery experiments with CCITT Group 3 fax equipment began in 1982. The service has since been placed into production, but cost constraints limit it to the BLDSC's wealthiest users. High-capacity ISDN communications facilities are being installed to increase the volume and reduce the costs of this service. **(GMVTS)**

Briggs [88a], doc 2

George Briggs, "Imaging System Added By Wang Laboratories," *MIS Week*, November 7, 1988, p. 30.

Announcement by Wang Laboratories Inc. of the PC/AT compatible Freestyle System, which is "an integrated, microcomputer-based imaging system for office communication and information management." Freestyle, an extension of Wang's Integrated Image System (WIIS) for the microcomputer level, features an electronic pen and a computerized desktop tablet, which allows writing and erasing a screen-based image. Also included is a voice handset, which synchronizes spoken comments with an image. Using icons, Freestyle allows storing images in an electronic file cabinet, reducing and enlarging images and mailing or faxing images. **(PL)**

Briggs [88b], doc 3

George Briggs, "Fibronics Inc. Expands FDDI Family," *MIS Week*, November 7, 1988, p. 22.

Fibronics International Inc. introduced their FX8210 ($24,900) to connect an Ethernet IEEE 803.2 LAN to an FDDI backbone, the FX8400 ($38,000—two required per line) to extend to 25 miles the maximum separation distance, and the FX8510 ($495 per station) Network Management System (NMS). **(GMVTS)**

Bright [86], doc 4

Robert Bright, "Linking Electronics and Micrographics," *Journal of Information and Image Management*, August 1986, pp. 37–38.

Compares electronic systems, in this case optical disk, to microfilm. Bright elaborates on the advantages of an electronic system for engineering environments. Documents can be stored and retrieved much more efficiently and quicker than on film or fiche. **(JEE)**

Brown [88], doc 223

Lauren Brown, "Seconds Per Page Feature Blurs True Scanner Speed," *PC Week*, March 15, 1988, pp. 55–56.

Discussion of why the cited speeds of a scanner are a very arbitrary measure on which to judge a scanner. Usually the seconds per page specification of a scanner only measures the time it takes for the actual scan but does not include communication or storage times. Other factors that affect the speed of the scanning process are the interface to the host, memory of the host, character recognition software if used, the type and quality of the document being scanned, and whether a movable or stationary light source is being used. Each of these factors are fully elaborated on. (PL)

Brownstein [89], doc 299

Mark Brownstein, "Solutions to SCSI Incompatibility Emerge," *Infoworld*, May 1989.

Introduces two new products, one from CSM Inc., one form AGA, both have driver adapter to work with devices from different manufactures. The new developments solve the incompatibility of SCSI devices. (EL)

Buchan [87], doc 63

Ronald L. Buchan, "Computer-aided Indexing at NASA," *Current Trends in Information Research and Theory*, Reference Librarian, Number 18, Summer 1987, p. 269–277.

Describes NASA's computer-aided indexing (CAI) by introducing NASA's Thesaurus and Lexical Dictionary activities. The NASA Thesaurus has 16,835 main terms and 4,000 cross references. The NASA Thesaurus activities include printed thesaurus, on-line thesaurus, retrospective index, and demand index. The NASA Lexical Dictionary activities include subject switching and machine-aided indexing (MAI). Subject switching is using the computer to translate controlled vocabulary, including translating grouping of terms to one or more NASA terms. MAI is the processing of natural language into an appropriate controlled vocabulary. (EL)

Bulatek+ [83], doc 174

David E. Bulatek and S. B. O'Connell, "Working PACS Prototype," SPIE: *Picture Archiving and Communication Systems (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 104–110.

Discusses the Picture Archiving and Communication (PAC) model—used at the University of Kansas—that consists of image acquisition, archival and display nodes, each of which is communicating through Ethernet protocols since it is becoming an industry standard and is available on a multibus PC board. The acquisition nodes are used for interfacing the modalities to the network. The archive nodes are used for storing a large amount of image data on and off line. Finally, the display nodes were used to view and edit images. (JEE)

Burnside [89], doc 328

Mark R. Burnside, "Write-once Optical Storage for Personal Computers, a White Paper," Storage Dimensions, A Maxtor Company, San Jose, California, 1989

This overview of WORM technology provides a brief history and description of WORM drives. The discussion of integration issues presents the built-in differences between WORM drives and the read/write drives expected by standard operating systems. Four basic strategies for dealing with these differences are presented. The paper closes with presentations of the advantages of WORM technology, comparisons to magnetic disks and tapes, and an inventory of potential WORM applications. (GMVTS)

Caere [89], doc 269

Caere Corporation, Los Gatos, California, March 1989.

Specification sheet describing the OmniPage character recognition software product. (PL)

Calera [88], doc 270

Calera Recognition Systems Inc., Santa Clara, CA, 1988.

Specification sheets describing the following products: CDP 9000, RS 9000, CDP 3000XF, TrueScan, PagePro, ReadPro, EditPro, TopScan, and CDP 6000. (PL)

Cann [89], doc 58

Lawrence Cann, "Glitch Turns into Clue in This TCP/IP Detective Table," *Data Communication*, June 21, 1989, pp. 53–63.

McDonnell Douglas Space System/Kennedy Space Center Division (MDSS-KSC) is the payload ground contractor for NASA at JFK Space Center in Florida. The communication network of the task is linking a wide variety of computers from different locations. Currently the MDSS-KSC LAN is based on Ethernet protocols, with protocol conversion at Gateway, and uses a combination of thin, thick and broadband coaxial cable. Because of the heterogeneous mix of computers used in this environment, they need an open system approach to network. The lack of OSI standards let them choose TCP/IP—a widely supported de facto standard that provides a basic level of functionality between heterogeneous processors. From their experiences, they found out that hidden errors exist in current TCP/IP products while partial interoperability between these products also exists. A protocol appears to work does not mean that it fully conforms to a standard. They also learned that ensuring long-term interoperability is a more complex task than merely checking newly installed equipments and softwares with the existing network. **(EL)**

Canon [86], doc 271

Canon USA Inc., Lake Success, New York, 1986.

Specification sheets describing the following image scanners: CS 220, CS 240, IX-8, and the IX-12. **(PL)**

CAT [88], doc 272

Computer Aided Technology Inc., Dallas, Texas, 1988.

Specification sheet describing the CAT Reader character recognition software product. **(PL)**

Cavuoto [89], doc 88

James Cavuoto, "At Last: Image-editing for the PC," *Electronic Publishing & Printing*, May 1989, pp. 73–75.

A software product, *Picture Publisher*, from Astral Development Corporation offers sophisticated picture editing in the PC environment. The editing window displays 64 gray levels, but images may contain up to 254. Gray scales may be defined and mapped onto images. Individual pixels can be edited. Sharpening, smoothing, noise reducing, blurring, and averaging filters are available. Usual drawing and painting operations are supported. **(GMVTS)**

Chadwick [89], doc 124

Terry Brainerd Chadwick, "Dialog Comments on Imaging Capabilities: An Interview with Fred Zappert," *Online*, May 1989, pp. 28–30.

Dr. Fred Zappert is director of Dialog's Advanced Technology Division. In his interview, he reviews current use of imaging in Dialog's TRADEMARKSCAN and HEILBRON products. TRADEMARKSCAN uses vector graphics to produce trademark images; HEILBRON uses raster graphics to produce chemical structure diagrams. Dialog is examining the possibility of providing image conversion utilities to deliver machine-readable images to users in such formats as TIFF. Dr. Zappert declined comment on the wider future of imaging technology in Dialog. **(GMVTS)**

Chase [88], doc 6

Deborah Chase, "The VA Adopts Optical Disk," *Inform*, November/December 1988, pp. 34–35.

Discusses Folderless File System (FFS), the VA pilot image-based optical disk system. The system is composed of a 64-disk jukebox (about 140GB capacity), 4 disk drives, 3 scanner workstations, 26 user stations, 2 laser printers, FileNet's Workflo, and multiwindow screens. **(PL)**

Chauvin+ [84], doc 138

Gilles Chauvin and Michel Picard, "A Document Storage Application: The SARDE Project," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 39–42.

Discusses the experimental French SARDE project, which ran from January 1985 through the spring of 1986. The project was a nationwide electronic document delivery system whose goal was to totally change the manner in which technical information was accessed, stored, circulated, and managed. The system was composed of five subsystems:

Acquisition—	took roughly five million technical pages which were mainly in microform or aperture card form and digitize them with resolutions ranging from 200 to 400 dpi. Image enhancement, compression (CCITT Group 3 and Group 4), and an encoding scheme were all applied to the raw data.
Image Storage—	used Thomson Gigadisc optical data disks. Disk drives, optical disk controllers, and jukeboxes were configured modularly so many devices could be supported and performance could be fine tuned.
Retrieval Database—	modeled after traditional search and retrieval methods. It allowed for a fuzzy search using bibliographic information, a search using links between documents, and historical searches. The goal was for short response time with a high amount of processed queries.
Network—	used 64 kilobit lines with transmissions ranging from 64 Kbps to 2 Mbps. Wide area communications used packet switching transmission following X.25 protocol.
Workstation—	very important component since it is the interface between the end user and the system. Consisted of a high-resolution screen (4 million pixels at 19 inches), local disk storage for local images, decompression ability, cheap raster scanner, interface to the network, and a keyboard. **(PL)**

Chen+ [87], doc 11

Yi-Hsin Chen, F. C. Mintzer, and K. S. Pennington, "PANDA: Processing Algorithm for Noncoded Document Acquisition," *IBM Journal of Research and Development*, Volume 31, Number 1, January 1987, pp. 32–43.

The paper presents a simple, fast algorithm that differentiates between and encodes differently the text and the image portions of gray scale digitized images. A specialized dither pattern that maintains compressibility of the final image with MR and MMR compression techniques is described. Quantization using error diffusion is presented. **(GMVTS)**

Christodoulakis [85], doc 60

S. Christodoulakis, "Issues in the Architecture of a Document Archiver Using Optical Disk Technology," *Communications of the ACM*, 1985, pp. 34–50.

This paper examines the problems of data placement in the optical disk, storage hierarchies, data duplication and version control. Simulation results and analytical results are presented. Some results and conclusions are as followed:

- Clustering documents into smaller files may considerably improve performance.
- The user response time can be reduced by combining the queries of more than one users.
- The order of placement documents of a batch on the optical disk will have to be determined so that the number of documents placed across track boundaries is minimized.
- A document placement scheme is required for having better space utilization and better response time. **(EL)**

Cinnamon [88], doc 210

Barry Cinnamon, "Optical Disk Document Storage and Retrieval System," 1988.

This book was written for people that will be evaluating, purchasing and installing optical disk systems. Cinnamon explains the technology in a step by step approach. First he begins with a short description of optical disk storage and retrieval systems. Next, the hardware and software components are discussed in detail. Finally, tables with different components are available for performance and price references. **(JEE)**

Claffie [84], doc 149

Gerald M. Claffie, "Optical Disk Recorders for Operationally Demanding Mass Storage Applications," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 93–101.

"In the optical disk recording market, RC addresses the specialized user requirements segment that cannot be satisfied on either technical merit or cost effectiveness by recorders intended for the more general-purpose commercial market. Both argon- and diode-laser–based recorders, laser diodes, monolithic laser-diode arrays and monolithic detector arrays have been developed as part of this effort." (p. 93)

"...the Air Force (Rome Air Development Center) has sponsored development programs at RC to demonstrate (1) single-channel recording at user data rates to 50 Mbps, (2) multiple-channel recording at user data rates to 300 Mbps, and (3) data packing densities on the disk surface compatible with achieving 10^{11} user bits per side of a 14-inch disk." (p. 93)

Disks are provided with enough buffer space to accommodate two rotations worth of data. A sustained throughput of 33.3 Mbps per channel is supported with burst speeds at 80 Mbps per channel until buffers fill. Both disk and jukebox technologies are discussed. **(GMVTS)**

Cloud [89], doc 206

K. S. Cloud, "Emerging Digital Data Exchange Standards for the Graphic Arts," SPIE: *Electronic Imaging Application in Graphic Arts*, Volume 1073, January 17, 1989, pp. 128–132.

Discusses various standards including the Digital Data Exchange Standard (DDES) which interchanges color pictures between color electronic prepress system (CEPS) and its related system. Also discussed is the ANSI standard for interchange of line art known as User Exchange Format 0 0 (UEF00) and PostScript, Adobe's page description language used for printing. PostScript is not an ANSI standard but an industry de facto standard. **(JEE)**

Coombs+ [87], doc 53

James H. Coombs, A. H. Renear, and S. J. DeRose, "Markup Systems and the Future of Scholarly Text Processing," *Communications of the ACM*, Volume 30, Number 11, November 1987, pp. 933–947.

Generally discusses markup systems with specific focus on descriptive markup and its effect on scholarly text processing. Six types of document markup are introduced: punctuational, presentational, procedural, descriptive, referential and meta-markup. Also discusses the four possible modes of markup viewing—(exposed, disguised, concealed, or displayed)—as well as the different methods of selecting, storing and processing them. In the latter half of the article, the authors defend their view that "descriptive markup is not just the best approach of the competing markup systems, it is the best imaginable approach." The following advantages of descriptive markup are cited:

- elimination of maintenance concerns;
- solution to the document incompatibility problem for achieving universal document portability;
- minimization of cognitive demands in markup selection to allow focusing on the structure and contents of documents instead of typographic and style conventions; and
- allowance for composition-assistance functions such as alternate views of a document and structure-oriented editing. **(PL)**

Cox+ [83], doc 131

Jerome R. Cox Jr., G. J. Blaine, R. L. Hill, R. G. Jost, and C. Shum, "Some Design Considerations for Picture Archiving and Communication Systems," *IEEE Computer*, Volume 16, Number 8, August 1983, pp. 39–49.

Basic queueing theoretic equations are discussed for the physical layer, picture link layer, and picture network layer of a picture archiving and communication system (PACS). Questions of design goals, responsiveness, modularity, reliability, and efficiency are addressed. The basic network topology choices are reviewed. **(GMVTS)**

Crider [88], doc 207

Bill Crider, "Stars for the Big Screen," *Publish!*, October 1988, pp. 72–81.

Discusses large-screen displays, their popularity today, their high resolution and software compatibility. Crider then reviews various Macintosh and PC monitors and ranks their performance. The highest-ranked PC displays are MultiSync Plus (NEC Home Electronics) and Dual Page Display (Cornerstone Technology Inc.). The lowest-ranked PC monitor is the Viking 10 (Moniterm). **(JEE)**

Croft [86], doc 61

W. Bruce Croft, "Boolean Queries and Term Dependencies in Probabilistic Retrieval Models," *Journal of the American Society for Information Science*, Volume 37, Number 2, February 1986, pp. 71–77.

A method of integrating Boolean queries with probabilistic retrieval models is proposed. Boolean queries are interpreted as specifying term dependencies that can be used to correct the document scores obtained with a basic probabilistic model. Alternative methods of obtaining dependency information, such as user-specified phrases, can also be used in this approach. The experimental results indicate that significant performance benefits can be obtained, particularly when dependencies are derived from term phrases identified in natural language queries. **(author)**

Crossan [89], doc 215

David F. Crossan, "Recognition Technologies and the System Integrator," *Inform*, April 1989, pp. 27–28.

Discusses the changing role and new challenges for a systems integrator, especially in the field of recognition technology. System integration can be defined as the merging of discrete systems, technologies, and management structures such as data processing and telecommunications. Recognition technology can be divided into an automatic identification group and personal identification group. Both groups compete with each other and often there is competition between technologies within a group. Many new products have combined existing technologies. This has helped the systems integrator by providing cost justification such as increased data rates, reduced error rates, enhanced document storage and retention, and maximized security. The biggest challenge for the systems integrator today is to choose the correct device that best fits the application as well as impose a documentation standard that can address the product, application, and interface. **(PL)**

Cummings [88], doc 121

Steve Cummings, "Attention, PostScript Printer Shoppers...," *Publish!*, November 1988, pp. 60–72.

"Because of the complexity of the code they must process, PostScript printers tend to be slow....In practice, you'll never achieve the quoted engine-speed ratings, but you'll come closest when you're printing pages of simple text with few font changes. Based on the evidence of our speed test, however, the engine-speed ratings don't reliably predict even the relative plain-text performance of today's PostScript printer crop." (p. 60) One of the speed tests involved an 8-page newsletter with four TIFF images, one EPS image, and an Excel graph in PICT format. Most PostScript printers delivered the job in 30 to 35 minutes. The fastest were in the 10 to 12 minute range, but they substituted their own fonts for those specified in the newsletter. The article differentiates between white-printing and black-printing approaches to laser printing. Black-printing engines tend to perform well on fine details, but produce blotches or streaks in solid black areas. White-printing engines deliver excellent black zones, but can blur fine details. The authors suggest evaluating not only original printer output, but second or third generation copies to ensure that one will receive acceptable printer output. **(GMVTS)**

Cygnet [88], doc 322

Cygnet Systems Inc., 601 West California Avenue, Sunnyvale, California 94086-4831.

Specification sheets for Cygnet 12-inch WORM disk jukebox featuring Optimem 2400 drives and media, Hitachi drives and media, and LMS drives and media. Also a specification sheet for 5.25-inch WORM disk jukebox. **(EL)**

Cywinski+ [83], doc 170

Joseph K. Cywinski, M. L. Cywinski, and L. Lee, "Medical Image Distribution, Storage, and Retrieval Network: The M/NET," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 74–79.

Discusses M/NET, which is a design of Medinet, developed for medical image distribution, storage and retrieval. M/NET's use of a broadband coaxial cable (CATV) makes it possible to connect remote user station with different imaging devices. It requires less than 10 seconds to retrieve an image and its design is capable to handle over 1.5 million images. **(JEE)**

D'Alleyrand [89], doc 325

Mark R. d'Alleyrand, "Electronic Microfilming, Electronic Image Management Systems Learned Everything They Know from Micrographics," *Inform*, June 1989, pp. 27–34.

Office automation systems are typically justified by productivity improvements or cost savings. Since most offices have been scaled down, it has become difficult to apply cost savings arguments effectively. Productivity improvements are possible, but there are dangers. Imaging systems are more complex and rigid than the manual micrographics operations they are replacing. Accordingly, a greater design effort is required, and the resulting system is comparatively inflexible to modification. **(GMVTS)**

Dangler [89], doc 150

Paul E. Dangler, "CCD Imager Digital Data Processing: Concepts and Hardware," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 2–7.

The author discusses the use of a linear CCD imager and the data path necessary to arrive with the correct digital data in high-quality applications, such as photographic film scanning. The author also describes the operation of a linear CCD film scanner and identifies the following three trouble spots: variations in the illumination source from line to line, variations in the speed of the film transport system, and film quality. The data path of a typical linear CCD imager is analog-to-digital (A/D) conversion, optional pixel summing, correction of dark current from digital data, log conversion of transmission space data to density space data, correction for any gain variations, and optional line averaging to improve the signal to noise ratio. For each function, factors to consider are the bandwidth, width of data, and the complexity (measured by buffer size and number of operations). The Input Master board is a hardware implementation to accomplish many of these tasks at high speed. This board contains a single circuit and interfaces to standard computer buses. The design and operation of the Input Master board is discussed in detail. **(PL)**

Datapro [86], doc 212

Datapro Research Corporation, *Color Processing Basics*, Delran, New Jersey, October 1986.

Discusses color prepress basics, which includes a number of functions required for printing. First, color separation uses subtractive and additive primaries to produce all colors possible. Color correction another technique, could be done either photographically or electronically for printed color improvement. Screening, also known as halftoning, is special technique to fool the human eye into seeing different shades and retouching where part of the image is altered or removed. **(JEE)**

Datapro [87], doc 9

Datapro Research Corporation, *All About Optical Disks*, Delran, New Jersey, April 1987.

Describes the technology behind optical storage and discusses the role it can play in today's computer center. The accompanying comparison charts list 15 optical disk products offered by eight vendors. **(EL)**

Datapro [88a], doc 273

Datapro Research Corporation, *Data Communications: Basic Concepts*, Delran, New Jersey, August 1988.

Summarizes the basic concepts of data communications. Topics include basic principles of data communications (prerequisites for communications, data transmission facilities, accuracy control, error correction), communication networks (communication processors, multiplexers, protocol converters, microcomputers, LANs, PBX), computer network management and control, communication software, and the need for data communication. **(PL)**

Datapro [88b], doc 274

Datapro Research Corporation, *Local Area Networks*, Delran, New Jersey, December 1988.

An overview of the concept of local area networks. Included topics are the marketplace today, the definition of a LAN, applications of a LAN, LANs and their relationships to PCs, advantages and restrictions of LANs, LAN alternatives, LAN technology, and LAN standards. **(PL)**

Davis, H. [88], doc 10

Harry Davis, "Yes, The IRS Is Still Considering Optical Disk Technology," *Inform*, November/December 1988.

Discusses the IRS's on-going investigations of optical disk technology that will lead to the acquisition of the Digital Imaging/Optical Disk Storage System (DI/ODSS) in the late 1990s that will handle 200 million tax returns (about 2 billion pages) per year. The IRS conducted a test optical disk project (Files Archival Image Storage and Removal—FAISR) from 1981 to 1988 that scanned 90,000 images in a 14-hour day using three scanners. Current investigations concern using images to process tax returns (as opposed to archival purposes), using character recognition for keyless data entry, determine appropriate scanning resolution, using automatic indexing for and in documents, using multiple-use workstations (image display, database access, computation and communication tasks), using automated quality control to replace 100-percent visual inspection, using optical disk versus using optical tape, and developing standards for optical memory media. **(PL)**

Davis, M. [89], doc 151

Michael H. Davis, "CCD Based Film Scanner With Extended Dynamic Range," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 8–17.

Usually, fast scanner speed, high scanning resolution, and a wide range of optical density are dependent upon one another and are impossible to achieve because achieving one goal, compromises the other two. Eastman Kodak has developed a pixel summing film scanner that optimizes speed and resolution without compromising the range of optical density. Basic linear CCD architecture and CCD timing are discussed to introduce the concept of pixel summing. Pixel summing is an adaptive realtime summing scheme, which can take place in digital or analog form, depending upon the signal level. Besides the already stated benefits, pixel summing increases the signal-to-noise ratio (SNR) and allows the user to change the scan resolution through software, without adjusting the scanning optics. An example is provided to step through the pixel summing mode decision process. This technique is often used for large format items when multiple CCDs are used. **(PL)**

Dawson [87], doc 234

Benjamin M. Dawson, "Introduction to Image Processing Algorithms," *Byte*, March 1987, pp. 169–187.

This paper describes a general image processing system that users can use to assemble from PC and image-processing or graphic board. This system includes a simple image-processing package (SIMPP), a generic image processing hardware, and software routines that interface the hardware to SIMPP. The SIMPP contains many processing algorithms that can be classified into point process, area process, geometric process or frame process. This paper has examples and detail discussion of each processing algorithms. **(EL)**

Dean [89], doc 123

David Dean, "Blurring Printer Standards," *PC Publishing*, February 1989, pp. 36–37.

The two dominant page description languages (PDLs) used by today's laser printers are Hewlett-Packard's PCL (printer control language) and Adobe's PostScript. "What has been a fairly clear choice—PCL for less expensive, quicker, text, versus PostScript for high-quality scalable fonts and graphics—has been getting fuzzy and is about to get a lot fuzzier." (p. 36) An alliance has been announced between Hewlett-Packard and Compugraphic. The new LaserJet III and its successors may well challenge the quality claims of the PostScript printers. **(GMVTS)**

Depompa [89], doc 334

Barbara Depompa, "EISA Chips in, Users Yawning," *Management Information Systems Week*, Volume 10, Number 28, July 17, 1989, p. 7

The article notes a recent first demonstration of the Extended Industry Standard Architecture (EISA) chip set. EISA is intended by an industry consortium to offer a more AT-compatible bus architecture alternative to IBM's Micro Channel Architecture. Users are seen leaning towards holding on to their AT buses, but they are viewed as simply not interested in bus architecture details rather than as making conscious decisions. IBM is cited as released large sales numbers for PS/2 microprocessors, but the IBM sales number include both MCA and non-MCA machines, so it is difficult to assess the true sales of MCA units. **(GMVTS)**

Derfler [88], doc 275

Frank J. Derfler Jr., "Building Workgroup Solutions: LAN Gateways," *PC Magazine*, November 29, 1988, pp. 92–97.

Gives a historical overview of LAN gateways as well as the components of one. Specific gateway solutions are described with the advantages and disadvantages of each being given. **(PL)**

Desmarais [88], doc 213

Norman Desmarais, "Experiments Increase Optical Storage Densities," *Optical Information Systems* May/June 1988, pp. 120–122.

This paper discusses experimentation with photon-gated material, which permit variations in a laser-beam's wavelength. This permits the encoding of multiple bits of data in the same focal diameter but at different wavelengths. These experiments attempt to color-code data bits and store them in the spectral domain, thus increasing optical storage density by up to one thousand fold. (EL)

Dest [n.d.], doc 276

Dest Corporation, Milpitas, California.

Specification sheets describing the following products: PC 1000 Series scanners, PC 2000 Series scanners, Work-Less Station II, Facsimile Pac, Publish Pac, and Text Pac. **(PL)**

Deverell [89], doc 235

Adele Deverell, "Optical Storage Technology: The Wave of the Future," *IMC Journal*, May/June 1989, pp. 8–46.

This paper discusses three types of optical storage technologies: CD-ROM, WORM and erasable optical. It points out that many off-the-shelf software products were designed specifically with erasable technology in mind. Special file system for using WORM disks are required. Two approaches have been adopted by software developers. One is magnetic file emulation that is inexpensive and easy but only good for low-update applications. The other is a totally new file system that allows the users the flexibility to create files without size limitations and to more efficiently use disk space. It also provides hardware and operating system independence, which is good for data transportability. (EL)

Doebler [89], doc 218

Paul D. Doebler, "OCR: A 'recognizable character' On the EP&P Landscape," *Electronic Publishing & Printing*, March 1989, pp. 50–53.

Gives a short overview of optical character recognition history as well as its strong and weak points. The use of special fonts, such as OCR-A, and special bar codes, such as UPC symbols, are also discussed. The recognition techniques of matrix matching and feature extraction are described and compared. There is discussion of the importance of accuracy to character recognition and how new artificial intelligence technology is being used to improve the output of recognition devices. The various uses of recognition output, such as for page description languages, SGML, or object oriented programming, are also mentioned. **(PL)**

DOD [88], doc 56

Office of the Assistant Secretary of Defense, "Computer-Aided Acquisition and Logistic Support," July 32, 1988.

A report to Congress giving an overview of the Computer-Aided and Logistic Support (CALS) initiative and its status as of July 1988. CALS is described as a combined initiative by the Department of Defense and industry "to enable and accelerate the use and integration of digital technical information for weapon system acquisition, design, manufacture, and support." The program began in 1985 with a goal to be fully implemented by 1990. Quality improvements and cost reductions are expected, such as a reduced acquisition and support costs, improved quality and timeliness of technical information, and improved responsiveness from industry. The CALS initiative is composed of two phases: Phase I will replace paper document transfer with digital file exchange, and Phase II will redesign current processes to take advantage of using a shared database environment. The status of the CALS initiative was evaluated in the following areas:

standards—	for digital data interchange and access
technology—	research, development, and demonstration programs to support CALS objectives and provide transition from Phase I to Phase II
weapon systems—	systems that have incorporated CALS standards and integration requirements
DOD systems—	modernization and integration of the Defense Department infrastructure to receive and access digital data

Appendices are provided with specific details in each of these four areas. **(PL)**

Douglas+ [89], doc 236

Sally J. Douglas and Tracey Capen, "Exposing VGA," *Infoworld*, May 29, 1989, pp. 51–53.

Discusses the Video Graphics Array (VGA) and other graphic adapter boards that have appeared in the market over the past two years. Debuting in April 1987, VGA is the most important graphics adapter for the general business market because of its high resolution (640 x 480 pixels with 16 colors or 64 shades of gray in monochrome mode) and low price. In 1988, extended versions of VGA began to appear with resolutions such as 800 by 600 pixels with 16 or 256 colors or even 1024 by 768 pixels with 16 or 256 colors. To use this higher resolution more memory is needed (512KB instead of 256KB) and to take advantage of high resolutions with 256 colors, special driver software is needed. Speed, which is affected by using a 8- or 16-bit board, is also a factor to consider, especially when scanning or panning in a graphic intense environment. **(PL)**

Dreizen [89], doc 158

Howard M. Dreizen, "Interframe coding via nonhomogeneous progressive transmission," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 124–128.

This paper describes a nonhomogeneous progressive coding method for interframe or intersample (nonconsecutive frame) coding and transmission. The coding method first transmit the most important differences followed by differences of lesser importance. The amount of coded data and the transmission time for each sample difference is proportional to the degree of image change. **(author)**

This coding technique is particularly suited for PCs with limited CPU power and low bandwidth communication channels. **(EL)**

Drexler [83], doc 169

Jerome Drexler, "Drexon Optical Storage for Digital Picture Archiving Applications," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 30–35.

This paper presents an overview of the Drexon family of optical storage products, which includes disks, tapes, cards and labels, with emphasis on product configurations, cost comparisons, and medical imagery applications. **(EL)**

Duerinckx+ [83], doc 128

André Duerinckx and Samuel J. Dwyer III, "Digital Picture Archiving and Communication Systems in Medicine," *IEEE Computer*, Volume 16, Number 8, August 1983, pp. 14–16.

Introduces a special issue of *IEEE Computer* on "Digital Image Archiving in Medicine." See also: Meyer-Ebrecht+ [83], Baxter+ [83a], Cox+ [83], and Perry+ [83]. **(GMVTS)**

Dunham+ [83], doc 187

J. G. Dunham, R. L. Hill, G. J. Blaine, D. L. Snyder, and R. G. Jost, "Compression for picture archiving and communication in radiology," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 201–208.

Discusses two kinds of compression that reduce storage requirements and transmission rates of digitized radiology images. These two compression types are noiseless and noisy compression. Noiseless compression represents perfect reproduction of the image and noisy in this case represents error. **(JEE)**

Dunn [83], doc 186

James F. Dunn, "Recent Developments in Image Recording Technology," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 199–200.

Dunn mentions the development in image recording technology. Some of the equipment mentioned are raster scan film recorder, used with a B-mode Ultra sound scanner and computerized Tomography (CT) used for brain scanning. **(JEE)**

Duston [89], doc 238

Beth Duston, "The Impact of Facsimile Technology on Intellectual Property," *Proceedings of the National Online Meeting*, Learned Information Inc., 1989, pp. 137–141.

With fax technology, moving and transferring information containing pictures and graphics can be accomplished with a telephone line and can bypass the computer entirely. The price of the fax machines are less than $1,000 now. By using a fax board, this information can be stored, modified and manipulated in the user's computer. The technology affect publishers, librarians and other information users. This paper discusses the technology as well as the copyright issues. **(EL)**

Eckstein [89], doc 116

Helen Eckstein, "Four-Color Fundamentals," *Publish!*, May 1989, pp. 44–49.

Discusses CMYK (cyan, magenta, yellow and black), which are the four standard printing colors. The two techniques, which are referred as additive and subtractive, to develop different colors. Eckstein also discusses a common problem for printed images, called moirè, which is caused by improper screen angling. Other problems mentioned are bad ink trapping and bad registration. **(JEE)**

Elnahas+ [89], doc 164

Sharaf E. Elnahas and Zhigang Fan, "Progressive Presentation of Transformed Images," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 193–198.

Discusses a method to implement the progressive processing of digital images that allows an approximation of the image to be shown quickly while the details are gradually added. This technique is often used for the transmission of high-resolution images over limited speed channels. The approach presented revolves around the use of inverted discrete cosine transformed (DCT) images. DCT images are used because they allow linear transformations to be computed in successive steps with the capability of stopping at any time. The transform progressive coding scheme is described in detail on both the transmission end and the presentation end. This method is suitable for applications of interactive image presentation, such as the retrieval of images from massive storage devices in local workstations. **(PL)**

Erdman+ [83], doc 173

William A. Erdman, T. J. Stahl, R. J. Tokarz, G. Q. Maguire Jr., and M. E. Noz, "Development of Digital Nuclear Medicine System," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 100–102.

Discusses a central computer system that archives all gamma camera images on a hard disk. Simultaneous retrieval processing and storage of images is made possible through various parts of the hospital by the use of multiple terminals. **(JEE)**

Erickson+ [83], doc 197

J. J. Erickson, E. A. Eikman, M. I. Shaff, and A. E. James Jr., "Future Directions in Image Management: Medical and Practical Considerations," SPIE: *Picture Archiving and Communication Systems (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 296–300.

This paper examines the philosophy of image storage from the standpoint of the medical, legal and practical questions. A proposal is made that not all images are equal and that some deserve to be archived for longer period than others. The practical problem of using a video display for diagnostic readout , aside from the classical questions of resolution and response time, is discussed. A proposal is also made that two database might be created, one provides fast access time, one requires longer access time but provides detail arrival data. **(author)**

Etherington+ [89], doc 239

Nigel Etherington and Doug Gordon, "An Evolving Industry and Optical Disk Service Bureaus," *Inform*, June 1989, pp. 22–25.

This, the sequel article to Gordon [89], discusses the problems that optical disk systems have. The problems for industry are the absence of an established infrastructure and the lack of a WORM file management standard. Because of the absence of any overwhelming market leadership, ANSI committees have been unable to agree on any standards of optical disk system. For customer , it cause confusion, perception of obsolescence and risks. **(EL)**

Fair-Spaulding [89], doc 240

Judy H. Fair-Spaulding, "Images on DIALOG—Trademarks Come Alive," *Proceedings of the National Online Meeting*, Learned Information Inc., 1989, pp. 155–157.

The TRADEMARKSCAN-FEDERAL, DIALOG's File 226, produced by Thomson & Thomson, has provided access to trademarks registered with the United States on a variety of levels included searching character strings. Now it has the ability to display the actual picture of the trademark. It not only increase the value of the information but also develops new applications. **(EL)**

Faloutsos [85a], doc 49

Chris Faloutsos, "Signature Files: Design and Performance Comparison of Some Signature Extraction Methods," *Proceedings of ACM-SIGMOD 1985 International Conference on Management of Data*, May 28–31, 1985, La Mansiòn Hotel, Austin, Texas, published as *SIGMOD Record*, Volume 14, Number 4, December 1985, pp. 63–82.

Text retrieval methods of full text scanning, inversion, signature files, clustering, and multiattribute hashing are briefly reviewed. Four methods of signature extraction are then defined: word signatures, superimposed coding, compression with run length encoding, bit-block compression, entropy based bound, and variable bit-block compression. The performance of each approach is analyzed. It is found that each has something to recommend it, but that variable bit-block compression combines many of the best features of all the other approaches. **(GMVTS)**

Faloutsos [85b], doc 74

Christos Faloutsos, "Access Methods for Text," *Computing Surveys*, Volume 17, Number 1, March 1985, pp. 49–74.

The introduction reviews the structure of text, cites efforts to incorporate text into traditional database models, and differentiates types of queries. Several approaches to text searching are reviewed: full text scanning, inversion of terms, multiattribute hashing, signature files, several approaches to clustering and cluster searching, and hardware approaches using parallel comparators, cellular comparators, and finite state automata. A brief review follows of approximate string matching and text compression. The data and database structures used to support the alternative techniques are discussed, and the paper is closed with a summary analysis of performance considerations. **(GMVTS)**

Felician [88], doc 12

Leonardo Felician, "Image Base Management System: A Promising Tool in the Large Office System Environment," *Data Base*, Fall/Winter 1987/1988, pp. 29–36.

This paper defines the requirements for an image base management system (IBMS) stored on large magnetic and optical disks. Suitable data structures and the main algorithms to manage an image base are discussed in here. **(author)**

FileNet [89], doc 277

FileNet Corporation, *A Strategic Perspective on Integrated Image Processing*, 1989.

An overview of the FileNet system. Included are sections on the optical storage and retrieval library, controlling document workflow, mainframe integration, optional software, document entry, open system architecture, workstations, print services, distributed system architecture, image communications, image management systems, and image processing. (PL)

Fisher [89], doc 113

Marsha J. Fisher, "Digging Out with Image Technology," *Datamation*, April 15, 1989, pp. 18–26.

Cost savings and paper elimination are inadequate bases on which to found electronic imaging projects. Many implementors of imaging systems are experiencing better functional service and increased throughput from their image systems. Issues of the legal standing of digitized documents are not seen as a serious impediment; legal definitions rely more on incorporation of documents into normal business flows than they do on recording media. A major restriction on further development of imaging systems is the comparatively poor performance characteristics of current LAN systems. (GMVTS)

Fleischhauer [83], doc 35

Carl Fleischhauer, "Research Access and Use: The Key Facet of the Nonprint Optical Disk Experiment," *Library of Congress*, August 1983.

Gives an overview of the nonprint portion of the Library of Congress' optical disk pilot project (1983–1985). Designed by Sony Corporation, the pilot project used off-the-shelf analog technology. The goal of the project was to preserve and allow access to images of photographs, architectural drawings, cartoons, motion pictures, and television programs on analog signal laser video disks. The project had five major areas of interest: technical production and design problems, copyright and gift restrictions, preservation and endurance of the disks, research access and use of disk, and dissemination of information about the project. The author also discusses various retrieval methods for each class of materials. (PL)

Folts [80], doc 77

Harold C. Folts, "Revised CCITT recommendation X.25 — 1980," National Communication System, August 1980.

Contains a draft of CCITT Recommendation X.25 as approved February 1980. X.25 is a standard that describes the interface and procedures for public packet-switched data networks. It is composed of three levels:

Level 1— the physical, electrical, functional, and procedural characteristics which are necessary to activate, maintain, and deactivate the physical link between data terminal equipment (DTE) and data communication equipment (DCE).

Level 2— the link access procedure for data interchange between the DTE and DCE

Level 3— the packet format and control procedures for the exchange of control and data packets between the DTE and the DCE

Two types of circuit operations are usually used: switched circuits, which have connections only for the duration of the call, and dedicated circuits, which are permanent circuit switches between two users through a packet network. (PL)

Frahmann [89], doc 241

Dennis Frahmann, "Standards Drive Publishing Applications: Organizations Strive To Connect Systems, Share Data," *Electronic Publishing & Printing*, May 1989, pp. 54–57

The publishing industry is seen facing critical needs for connectivity standards. The most important areas in need of definition are document representations and raster encodings. Printing formats and color encoding also have serious gaps. (GMVTS)

Freedman [84], doc 146

Jean B. Freedman, "The Institute for Computer Sciences and Technology at the National Bureau of Standards (NBS/ICST) Optical Digital Data Disk (OD^3) Standardization Activities," SPIE: *Applications of Optical Digital Data Disk Storage System*, Volume 490, June 25–28, 1984, pp. 77–79.

Discusses the standardization activities of Optical Digital Data Disk (OD^3). The archive life of OD^3 is tested by organizations such as Federal Council on Computer Storage Standards and Technology (FCCSSAT) and National Bureau of Standards/National Security Agency (NBS/NSA). **(JEE)**

Freese [88], doc 306

Robert P. Freese, "Optical Disks Become Erasable," *IEEE Spectrum*, February 1988

This is a detailed, technical assessment of erasable optical disks. It emphasizes magneto-optical (M-O) erasable disks. **(EL)**

Friedman [88], doc 216

Edward A. Friedman, "Word Management Systems: An Introduction," *Inform*, May 1988, pp. 12–14.

Gives an overview of the fields of character recognition and word management systems and their relationship with each other. Character recognition is defined and a summary of its history is provided. The two technological approaches to character recognition, matrix matching and feature extraction, are also defined and described. Character recognition is compared to manual keystroking and options available for specific recognition devices are also mentioned. Word management systems are described as computer based files in which all words in relevant documents are filed, automatically indexed, and are available for retrieval. String matching and inverted indexes are the two approaches described as a means of retrieving information. Issues affecting a word management system are the time and effort to build the database and the overhead to contain it. **(PL)**

Friend+ [88], doc 263

George E. Friend, J. L. Fike, H. C. Baker, and J. C. Bellamy, *Understanding Data Communications*, Chapter 8, Howard W. Sams & Company, 1988.

Chapter 8 deals with various local area network (LAN) implementations and private branch exchange (PBX) networks. The characteristics of an ideal LAN are presented and contrasted to actual existing implementations. Ethernet, Token Ring, and ARCnet LANs are each discussed in detail as to how they work and as to how they relate to the physical and data link layers of the OSI model. Broadband systems and the existing telephone network are also discussed as possible means of data communications. Standards issued by the IEEE Committee 802 are listed and briefly discussed. **(PL)**

Fruchterman [88], doc 221

James R. Fruchterman, "Omnifont Text Recognition: Linking Paper, Electronic, and Optical Input," *Inform*, May 1988, pp. 17–19.

Discusses the development of omnifont and omniformat recognition devices, which can be used to convert hard-copy data into electronic form. The differences between expensive volume producing recognition devices and cheaper desktop versions are also briefly mentioned. The two major methodologies used by character recognition devices, matrix matching and feature extraction, as well as a hybrid of these two methods are all defined and discussed. The changing role of value-added resellers (VARs) from merely selling equipment to becoming application oriented experts is also mentioned. The article concludes with several examples of character recognition systems currently being used as a cost effective means to electronically store and access any information. **(PL)**

Fujitani [84], doc 14

Larry Fujitani, "Laser Optical Disk: The Coming Revolution in the On-line Storage," *Communications of the ACM*, Volume 27, Number 6, June 1984, pp. 546–554.

Discusses the similarities and the differences between the magnetic-storage devices and the laser-based optical disk technology. Also discusses the benefits, the possible applications and the future trends of the optical technology. Diagrams and detail descriptions of the optical disk drive components and the working mechanism of the read/write head are included. **(EL)**

Gallenberger [89], doc 107

John Gallenberger, "EIM: Electronic Image Micrographics?" *Inform*, April 1989, pp. 14–17.

The terms *electronic imaging* and *optical disk* are not synonymous because micrographics are often integrated into electronic imaging systems. Current technology must be appropriately integrated to solve problems. Low-volume, high-retrieval, short-retention applications tend to favor WORM technology; high-volume, low-retrieval, long-retention applications tend to favor micrographics. Micrographics operations can deliver 2,000 images per hour in manual modes, more with automatic feeding mechanisms; moderately priced scanners deliver 360 to 480. Hybrid systems to take advantages of the relative strengths of each technology need to be explored. (GMVTS)

Garges+ [84], doc 141

Daniel T. Garges and Gerald T. Durbin, "The Impact of Optical Storage Technology on Image Processing Systems," SPIE: *Applications of Optical Digital Data Disk Storage System*, Volume 490, June 25–28, 1984, pp. 55–58.

Discusses high-capacity storage disks and storage devices such as jukeboxes. It also discusses the implementation of an optical disk system. Finally two types of scanning are mentioned: laser scanning and CCD scanning (the most recent and efficient). (JEE)

Geller+ [84], doc 147

Sidney B. Geller, "The National Bureau of Standards Research Program for the Archival Lifetime Analysis of Optical Digital Data Disk," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 80–84.

Discusses the lifetime and reliability of different components of an optical disk system. The lifetime of the storage medium depends the care provided for handling and the room temperature it operates in. The content lifetime which is the length of time the stored information remains retrievable is preserved by producing multiple backups and encoding into a cryptic form. (JEE)

Girill [83], doc 64

T. R. Girill, "Display Units for Online Passage Retrieval: A Comparative Analysis," Lawrence Livermore National Library, September 1983.

A comparison of three methods for displaying information when using an online full text retrieval system. The three display-unit methods are:

structural— the text format or syntactical features (such as paragraphs) determine the retrieval units size and location

functional— the size and location of the retrieval units are determined by the text content and key words

hybrid— unit size of retrieval information is structural but location is functional

Each of these three methods are compared in the following four traditional problem areas of retrieving information:

- finding where the subject is discussed
- linking scattered treatments of the same subject
- assessing how important each treatment is
- exploiting the text's organization

The author draws the conclusion that functional text display units solve the online problems of retrieval better than the other two methods. (PL)

Glass [89], doc 278

L. Brett Glass, "The Light At the End of the LAN," *Byte*, July 1989, pp. 269–274.

Gives a brief description of the Fiber Distributed Data Interface (FDDI) standard. The four components of FDDI are the Physical Medium Dependent Sublayer (PMD), the Physical Sublayer (PHY), Media Access Control (MAC), and Station Management (SMT). Each component is defined and discussed as to how they relate with each other as well as their relationship to the layers of the OSI Reference model. The encoding scheme used by FDDI is also elaborated on. FDDI is compared to traditional Ethernet and Token Ring implementations with the advantages of FDDI being stressed. (PL)

Goldstein [81], doc 242

Charles M. Goldstein, "Optical Disc Technology and Its Implications for Information Storage and Retrieval in the Eighties," *What Should Users Expect from Information Storage and Retrieval Systems of the 1980s?*, AGARD Conference Proceedings, Number 304, 1981.

This paper discusses the potential applications of the optical disk technology, which includes inexpensive on-line storage, random access graphics, complement on-line information systems, hybrid network architectures, office automation systems, and archival storage. **(author)**

Gonzalez+ [87], doc 291

Rafael C. Gonzalez and Paul Wintz, "*Digital Image Processing*" Chapter 3, Addison-Wesley Publishing Company, 1987, pp. 61–135.

Chapter 3 deals with two-dimensional (2D) image transforms and their properties. Two dimensional transforms are used for image enhancements, restoration, encoding, and description. Fourier transforms (both one and two variable) are discussed in detail because they are particularly useful for image applications. Other transforms discussed are the Walsh, Discrete Cosine, Hadamond, and Hough. **(PL)**

Gordon, D. [89], doc 243

Doug Gordon and Nigel Etherington, "What Do Optical Disk Service Bureaus Have to Offer?" *Inform*, May 1989, pp. 21–29.

This, the first of a two-part series which ended with Etherington [89], describes the new services that service bureaus can offer with new optical disk technology. The topics include file folder conversion, engineering drawing conversion, format conversion for manuals and forms, duplication from optical disk to CD-ROM and optical disk transcription. For original paper conversion, indexing and quality controlling are major cost of the service. For microfilm conversion, it is not worthwhile since the low cost of film itself and the low quality of image it contains. This report also delivers a message that the capability now exists to replicate data files from WORM onto CD-ROM in a format that can be read by a PC running under DOS, just as though the files were on a floppy disk. AGA company has developed a format that 3M company now accept for manufacturing CD-ROM disks. **(EL)**

Gordon, M. [88], doc 89

Michael Gordon, "Probabilistic and Genetic Algorithms for Document Retrieval," *Communications of the ACM*, Volume 31, Number 10, October 1988, pp. 1208–1218.

An approach to document storage and retrieval is presented in which multiple indexing representations of the same document are stored in a system which continually assesses how each representation contributes to retrieval hits and modifies the representations to improve retrievability. The modification algorithm is derived from the field of genetics. In a performance experiment with a small database, a 40 generation set of queries resulted in a 25-percent improvement of retrieval performance. **(GMVTS)**

Gordon, M.J.+ [88], doc 92

Martha J. Gordon and Martin Dilon, "Factors Affecting Design For Full-Text Retrieval," *Massachusetts Institute of Technology Conference Proceedings*, March 21–24,1988, pp. 667–675.

Discusses three full-text retrieval systems within a framework of five categories of factors that influence interface design for full-text retrieval. The three systems reviewed are Graph-Text, which emphasizes image representation, Full-Text Access System (F-TAS), which emphasizes information retrieval from full-text systems, and (Electronic Information Delivery On-line System (EIDOS), which emphasizes access to a full-text database residing on a remote host mainframe through telecommunications. The five significant factors regarding full-text systems are:

system context—	deals with hardware constraints such as the physical interface (graphical icon, mouse, or keyboard) and the storage of text (local or remote host)
representation—	representation deals with objects (text, tables, equations, or drawings) being in bitmap or ASCII form in the computer system.
presentation—	presentation of these objects to users involves screen display issues as well as how much information to provide the user at his initial request.

organization— deals with the structure of the document, which can range from no structure at all to very detailed.

access— deals with providing the retrieval functions which can be implemented in the following manners: graphical dialog (such as icons or touch screens), formal dialog (such as menus or command language), natural language dialog, or a hybrid combination dialog approach. Other related issues pertaining to the access of information are the level to which retrieval is provided (chapter, paragraph, or sentence), which indexing scheme to use (n-gram, all words in the document), navigation control so the user doesn't get lost in a document, and to provide for cases where more than one language is used.

manipulation— deals with allowing the user to download information for later use, the writing and erasing of annotations relating to the retrieved documents, and to link information within and across documents.

The design of the interface has two major difficulties. One is the variety of document structures and the interrelationship between the structure and access or presentation factors. The other difficulty is that much of the information contained in documents is simply a sequence of lines and are usually not structured. **(PL)**

Gossieaux [89], doc 203

François Gossieaux, "Softproofing: A display manufacturer's perspective," SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 97–104.

Discusses a new approach to image displays which increases productivity to the graphics and arts industry and provides greater softproofing, an off-press proof for verification and approval of colors. It is done immediately on the image displayed on the monitor. **(JEE)**

Gralla [88], doc 209

Preston Gralla, "High-res Boards Dramatically Transform PCs," *PC Week*, January 1988, pp. 105, 111–112.

Discusses high resolution graphic boards which allow the PC to generate high quality graphics on the display device. Such high resolution boards range in price between $1,000–$4,000. Gralla addresses an important point: High resolution boards have no set standards therefore are not compatible with all monitors or software. **(JEE)**

Greenfield [89], doc 112

David Greenfield, "Files by Fax, Fax Servers Take You from LAN to Fax and Back Again," *LAN Magazine*, April 1989, pp. 45–53.

Fax transmission devices are becoming widespread. Encapsulated on a PC board, they are available at very reasonable cost, but fax boards require that an image already be available in a fax format. Conversion to and printing from fax formats requires more expensive equipment. Also, fax operations require considerable user monitoring; one cannot assume that, just because a page has apparently transmitted correctly, it will be received correctly.

The article reviews the CCITT fax formats and fax servers from seven vendors. The author offers the following questions (pp. 50–52) to consider when selecting fax servers: Does it operate with the LAN's operating system? What fax board does the software use? What file formats are accepted? Does it keep you informed? Is it simple to use? Does it operate in the background? Can users send a fax from within an application? **(GMVTS)**

Greenstein [89], doc 23

Irwin Greenstein, "Imaging and Networks: A Natural Combination," *MIS Week*, June 19, 1989, p. 44.

Gives a brief description on the merging of the image processing and networking fields. The necessity of high speed communication is essential for image processing systems and image applications will provide the demand for new improvements and new products in the communication field. **(PL)**

Greenstein [89], doc 244

Irwin Greenstein, "Imaging System Snafu Snarls California Banks," *MIS Week*, June 19, 1989, p. 1.

The office of the Secretary of State of California attempted to cut over to a new image processing system for the processing of loan applications. The system could not be operated reliably, but there was no recourse because the cutover had bypassed parallel processing. Loan processing by California banks became seriously backlogged, and some institutions were possibly driven close to bankruptcy. The recovery is anticipated to cost over half a million dollars and require overtime duty from over 100 state employees. **(GMVTS)**

Griffin+ [83], doc 179

James M. Griffin and Dale L. Harris, "NCR MODUS: A Data Management Subsystem," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 138–144.

This paper describes MODUS, an intelligent data management subsystem offered by NCR. MODUS consists of the hardware and softwares. It could be used in an image database management system for distributed image data storage and retrieval, archival storage management, image data availability and integrity, and personnel or large database management. MODUS has flexibility in the configuration of nodes and convenient expansion of individual nodes as well as the total system. **(EL)**

Grimm [89], doc 224

Vanessa Jo Grimm, "Postal Automation Strategy Rests on Bar Coding," *Government Computer News*, April 17, 1989, pp. 63–64.

Tells of the U.S. Postal Service's intentions of using character recognition technology in order to read ZIP codes so that bar codes can be automatically produced for hand addressed mail and parcels. The purpose of the bar code is so that all mail will be able to be sorted automatically beginning in the year 1995. Three companies involved in the character recognition of handwriting are AEG Olympia, Bell & Howell, and TRW. **(PL)**

Gunn [88], doc 222

Keith Gunn, "Omnifont OCR Comes of Age," *Rothchild Consultants*, Fall 1988, pp. 1–23.

Gives an overview of character recognition technology. Some cited applications of recognition devices are automated indexing and the contents capturing of both forms and entire pages. The various technical considerations which have a great effect upon the quality of the recognition device's output are listed and described. The process of character recognition is divided into three parts: layout recognition, segmentation, and character identification. The methods of matrix matching, feature analysis, and a combined hybrid approach are all fully described as a means of character identification. A list of current character recognition vendors is provided as well as the results of some sample pages which were read by character recognition devices. **(PL)**

Hall+ [80], doc 62

Patrick A. V. Hall and Geoff R. Dowling, "Approximate String Matching," *Computing Surveys*, Volume 12, Number 4, December 1980, pp. 381–402.

Approximation matching of strings is reviewed with the aim of surveying techniques suitable for finding an item in a database when there may be a spelling mistake or other error in the key word. The methods found are classified as either equivalence or similarity problems. Equivalence problems are seen to be readily solved using canonical forms. For similarity problems difference measures are surveyed, with a full description of the well-established dynamic programming method relating this to the approach using probabilities and likelihoods. Searches for approximate matches in large sets using a difference function are seen to be an open problem still, though several promising ideas have been suggested. Approximate matching (error correction) during parsing is briefly reviewed. **(author)**

Halleen [88], doc 16

Harry Halleen, "Document Retrieval for People Who Don't Care," *IMC Journal*, September/October 1988, pp. 9–12.

Discusses the advantages of microfiche and optical disk document storage over paper document storage which is bulky, expensive and inconvenient for retrieval. The bulk of the discussion is on optical disk. **(JEE)**

Handley [88], doc 70

John C. Handley, "The Feasibility of Document Delivery Through Image Transmission," *Annual Review of OCLC Research*, 1988.

This report describes fax workstations, and the CCITT Group 3 and Group 4 standards for image compression and digital transmission. The CCITT Group 3 transmission standard offers about 204 dpi for both vertical and horizontal resolutions. The Group 4 standard can support 200-, 240-, 300-, and 400-dpi resolutions, but needs an error-free transmission environment, such as packet-switched networks (X.25) or integrated services digital networks (ISDNs). For huge image file, the 9600-bps telephone line is not efficient enough, the 56 Kbps packet switched or 96 Kbps ISDN are preferred. **(EL)**

Hansen [88], doc 57

Wilfred J. Hansen and Christina Haas, "Reading and Writing with Computers: A Framework for Explaining Differences in Performance," *Communications of the ACM*, Volume 31, Number 9, September 1988, pp. 1080–1089.

Studies are reviewed comparing the performance of test subjects working from paper documents versus working from computer screens. In general, reading and writing from screens have been repeatedly shown to be significantly slower than working from paper. The authors develop a conceptual model of nine factors—four primary and five secondary—to explain these differences and to suggest research directions further to explore them. The primary factors are *page size*, *legibility*, *responsiveness*, and *tangibility*. The secondaries (and where they were derived from) are as follows: *directness* (responsiveness and tangibility), *sense of text* (page size and directness), *engagement* (directness), *quality* (sense of text and legibility), *speed* (page size, legibility, responsiveness, directness, and engagement).

Four experiments performed by the authors are reviewed in terms of these factors. Computer performance is consistently lower than paper. Some experiments show computer results approximating paper when higher speed RISC workstations with high-resolution displays are used. **(GMVTS)**

Hasekamp+ [84], doc 133

A. J. L. R. Hasekamp, V. Hoekstra, J. W. Klimbie, "The Optical Digital Data Disk for the Storage of Images of Original Documents," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 2–5.

Philips, the Netherlands-based recording media manufacturer, developed Megadoc—a computer system based on the digital optical recorder. Used in office automation applications, Megadoc can store and retrieve millions of documents. The authors describes the modularity and expansibility of the system Philips foresees at the early development stage of image base management system (IBMS). **(EL)**

Helgerson [87], doc 225

Linda W. Helgerson, "Introduction to Scanning Technology," *Association for Information and Image Management*, 1987, pp. 1–30.

Gives a detailed overview of current scanning technology. After giving a historical overview of scanning, the mechanics of a scanner are discussed. Arers discussed are illumination and light sources, detectors and transducers, and various document holders. Different output options and image enhancement capabilities are also mentioned. Scanning devices are broken down into categories of optical character recognition devices, raster image scanning devices, and vector image scanning devices. The advantages and disadvantages of each category is discussed. Also included is a section on requirements analysis which briefly covers the topics of system configurations, user requirements, and product and system specifications. **(PL)**

Helgerson [88a], doc 304

Linda W. Helgerson and Fred P. Meyer, "CD-ROM Publishing Strategies," *PC Tech Journal*, Volume 6, Number 10, October 1988, pp. 52–63.

Developing a CD-ROM publication involves many steps in both the planning and production phases. First, marketing and feasibility studies must determine whether this is the proper medium for the data. Then, data must be prepared in machine-readable form and in a format acceptable to the mastering operation. One approach to the preparation step, described in this article, is a microcomputer-based authoring and premastering system. **(BA)**

Helgerson [88b], doc 305

Linda W. Helgerson and Harvey G. Martens, "In Search of CD-ROM Data," *PC Tech Journal*, Volume 6, Number 10, October 1988, pp. 66–75.

The storage capacity of CD-ROM makes it an attractive publishing medium. The format for optical media, however, is very different from the media for magnetic disk storage. Database developers need to understand the differences and use indexing-and-retrieval techniques optimized for optical formats. **(BA)**

Hendershot [89], doc 237

Gary Lee Hendershot, "The Next Video Plateau: IBM's 8514/A and Its Competitors," *Infoworld*, May 29, 1989, p. 52.

Discusses IBM's 8514/A video board. The 8514/A is an extended VGA board with a resolution of 1024-by-768 pixels showing 256 colors. While IBM has implemented this graphic board even with an interlaced video screen (the monitor scans the screen twice), some competitors, such as Dell or Compaq, use a noninterlaced screen which produces a flicker-free screen at the expense of higher cost. **(PL)**

Henderson [83], doc 175

B. Earl Henderson, "Prototype for an Electronic Document Storage and Retrieval Program," SPIE: *Picture Archiving and Communication Systems for Medical Applications*, Volume 418, May 22–25, 1983, pp. 112–115.

Due to its continuously increasing collection of paper (18 million pages per year) and the rapid deterioration of its existing 3 million item collection because of the acid content of paper, the National Library of Medicine (NLM) developed the Electronic Document Storage and Retrieval (EDSR) system in 1983. This paper discusses phase one of the system which is composed of the following four functions:

scanning— capture pages at 200 dpi using linear CCD array technology and transfer image to temporary storage.

storage— transfer image from temporary storage to magnetic disk storage system.

retrieval— transfer image from magnetic disk to temporary storage at the rate of one page per second.

display— transfer data from temporary storage to either softcopy or hardcopy form with a resolution of 200 dpi.

Other factors studied were a trade-off between resolution and contrast, handling documents with diverse contents, quality control techniques, data compression, human factors, automatic indexing, on-line search and retrieval, and archival storage. The article gives a detailed description of the actual implementation of phase one. Phase two of the system added optical disk storage and jukeboxes. Phase three of the system will integrate the entire image system into the existing communications network at the NLM. **(PL)**

Herther [89], doc 227

Nancy K. Herther, "A Database on Every Desk: the CD-ROM Solution," *Information Center*, May, 1989, p. 32–37

Discusses CD-ROM (Compact Disk, Read Only Memory) that is taking over the publishing and computer industries. It offers researchers a huge database without the cost of the telecommunication or mini/mainframe programming of data from magnetic disks. This disk, which costs $100 and holds 550 to 650MB, is causing a revolution in information distribution. A CD-ROM drive and interface are also needed. The International Standards Organization (ISO) established a file-format standard for CD-ROM (ISO 9660). This standard allows any CD-ROM disk to operate on any CD-ROM drive. **(JEE)**

Hewlett-Packard [88], doc 279

Hewlett-Packard, Cupertino, California, December, 1988.

Specification sheet describing the ScanJet Plus (HP 9195A) scanner. **(PL)**

Hindin [89], doc 228

Eric M. Hindin, " 'Hefty' Servers Seek a Niche in the LAN Environment," *Data Communications*, June 21, 1989, pp. 17–22.

Discusses the integration of LANs and minicomputers, which was only made available recently. LANs could benefit with I/O throughput from the minicomputer. On the other hand, minicomputers can benefit from LANs since LANs have been proven to be cost-effective and minicomputers have not. **(JEE)**

Hitachi [85], doc 324

Hitachi America, Ltd., 950 Elm Avenue, Suite 100, San Bruno, California 94066

Specification sheet for Hitachi 12-inch optical disk subsystem 301 series. **(EL)**

Hofmann [89], doc 205

Georg Rainer Hofmann and Detlef Kromker, "FTCRP: File Format for the Device-independent Transfer of Colored Raster Pictures," SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 122–127.

Discusses a digital image format called file Format for Transfer of Color Pictures (FTCRP) which transfers raster images and can handle color images. It reflects the special application area and the features of the technology and hardware devices. A mathematical model is implemented and the geometry of pictures and rasters are described. **(JEE)**

Holladay [89], doc 156

T. M. Holladay, "A Performance Evaluation of LZ and CCITT Compression Techniques" SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 114–117.

This paper briefly describes two compression algorithms Lempel-Ziv (LZ) and CCITT Group 3 and Group 4 and compares compression results from 51 different images. The experiment show that the method giving the best compression ratio can be predicted from a calculation based on the zero order statistic of the image. The LZ algorithm seems work better for images which appear busy or have a more complex structure visually. **(EL)**

Honan [89], doc 13

Patrick Honan, "What's New in Optical Storage," *Personal Computing*, February 1989, pp. 111–118.

Introduces new products of 5.25- and 12-inch WORM disks, disk drives, and CD-ROM disks. Compares the materials, functions, and prices between several disk manufactures. It carries quite a lot of up-to-date information. **(EL)**

Hopkins [87], doc 103

M. E. Hopkins, "A Perspective on the 801/Reduced Instruction Set Computer," *IBM Systems Journal*, Volume 26, Number 1, 1987, pp. 107–121.

The paper reviews the historical trends of IBM computers leading to the System 370—a series of ever more powerful general-purpose engines, each supporting an ever increasingly elaborate set of machine instructions. Instruction traces on these machines demonstrated that five percent of available machine instructions accounted in practice for two-thirds of the processing done on these machines. Reduced instruction set computers (RISCs) derive from the notion that overall computing speeds can be increased by building computers to offer a smaller number of basic instructions which have been engineered to execute as rapidly as possible. As evidenced by projects such as the 801 architecture described in this paper, the strategy works. The paper reviews a number of programming scenarios and describes the coding trade-offs needed to achieve the benefits of RISC computing. **(GMVTS)**

Horii+ [83], doc 192

S. C. Horii, G. Q. Maguire Jr., M. P. Zeleznik, and M. E. Noz, "Broadband coaxial cable image viewing and processing for radiology," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 247–253.

Discusses an implementation for digital image processing and viewing network in a large radiology department which uses a broadband coaxial cable network. The major goals for this network are storing, retrieving and transporting images, capability of viewing and editing images and consultation functions. **(JEE)**

Hosinski [88], doc 59

Joan M. Hosinski, "Agencies Urged to Ease Into Optical Disk Applications," *Government Computer News*, December 19, 1988, p. 31.

Discusses the investment of the Patent and Trademark Office (PTO), an optical disk system. "Do not devote money, resources and time into an information system that must work by a set date" said Thomas Giammo the PTO's assistant commissioner for information systems. Agencies should start with small applications whose operations are not vital. One of the first imaging systems, PTO's Automated Patent System, began to be installed in 1984. It had encountered some problems because its existing system was not adequate to meet the increasing demands placed on its examiners. PTO had to match Japanese and European systems and could not delay installing the system. Also standards for the systems were not sufficiently developed. **(JEE)**

Hosinski [89], doc 229

Joan M. Hosinski, "Agencies Watch Progress of PTO's WORM System," *Government Computer News*, January 9, 1989, p. 10.

The Patent and Trademark Office's Automated Patent System (APS) is seen as one of the most visible optical disk efforts underway in the U.S. government. Some agencies, like EPA and NARS have their own efforts underway, but many await results from APS. Acceptance of optical disk technology is not helped by the lack of effective standardization, and no remedy is foreseen—especially for the 12-inch media. **(GMVTS)**

Howtek [88], doc 280

Howtek Inc., Hudson, New York, November 1988.

Specification sheet describing the Scanmaster color scanner series.

Huang+ [83a], doc 185

H. K. Huang, N. J. Mankovich, Z. Barbaric, H. Kangarloo, and C. Moler, "Design and Implementation of Multiple Digital Viewing Stations," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 189–198.

Discusses a multiple digital viewing station being designed and implemented. This prototype involves four phases. The first phase allows the researcher to study the technical aspect of a viewing station. The second and third phases use two viewing stations. The first is used to retrieve images of the VAX-11/750 and the other is for use in medical consultation and conferences. The final phase consists of the evaluation of the previous phases. **(JEE)**

Huang+ [83b], doc 193

H. K. Huang, Z. Barbaric, N. J. Mankovich, and C. Moler, "Digital Radiology at the University of California, Los Angeles: A Feasibility Study," SPIE: *Picture Archiving and Communication Systems for Medical Applications*, Volume 418, May 22–25, 1983, pp. 259–265.

Discusses a feasibility study done by the Department of Radiological Sciences of UCLA Medical Center to convert their film based operation into a digital based operation. The feasibility study was divided into the following four parts:

facility study—	details the existing inventory of devices
operating procedure and cost—	deals with a three-year breakdown of current expenses for staff, maintenance, operation, film, and storage
cost-effective analysis—	details the actual cost for conversion
digital-based operating system—	possible operational flows of information for a digital-based system

The study on operating costs showed that half the present expenditures were on the film alone, with the other major expense being the personnel necessary to care for the film in the film library. The cost effective analysis showed that $400,000 could be saved a year with a digital system besides the non-dollar benefits of ease of record keeping, no loss of information, and savings in retrieval time. The digital based system would consist of the following four image parts:

acquisition—	either in analog or digital form.
archiving—	consisting of the storage media, the mechanism to transmit the image to the storage device, and the means of image retrieval.
viewing—	workstation with large memory, video output control, and powerful image processor.
communication—	means of distributing the images in several areas.

Three different prototype systems were established to study different implementations as well as to study the unknown psychological factor an image system would have on people. **(PL)**

Hughes [83], doc 176

Simon H. C. Hughes, "Picture Archiving and Communication Systems (PACS): Introductory Systems Analysis Considerations," SPIE: *Picture Archiving and Communication Systems for Medical Applications*, Volume 418, May 22–25, 1983, pp. 122–126.

Discusses various design factors and how each affects the components of a Picture Archiving and Communication System (PACS). The four design factors discussed are data volumes and rates, cost, modularity and upgradability, and human factors. Each of these concerns are discussed in relationship to communications, the archiving medium, the data acquisition system, the display console, and the software. Though the article was presented with a medical image system in mind, points which apply to general image systems are:

- o digital data is increasing in usage due to newer and better digitizing devices and because density and resolution are improving.
- o typical system configurations consist of magnetic tape for long term storage where slow speed is acceptable and fast magnetic disk storage for short term access.
- o short-term storage is subject to statistical variations and daily pattern usage and therefor must be considered very carefully.
- o the actual transmission of data on a network is usually only about one tenth of the capable sending speed.
- o typical users expect the response of an interactive computer to be no more than two or three seconds.
- o workstations should have local storage.
- o if a low-speed network is used, each workstation should have its own display features and manipulating ability but for a high speed network, image processing functions could be performed by a central image processor.
- o each data capture device usually has its own slow speed interface to the image system.
- o because technology changes so fast, a layered approach should be used and all software should be function oriented instead of specific device oriented, so it is easy to interchange equipment. **(PL)**

Huther [n.d.], doc 17

Bradford Huther, "The Automated Patent System: A Potential Architecture for the 1990s," *U.S. Patent and Trademark Office*.

Discusses the U.S. Patent and Trademark Offices' proposed Automation Master Plan, a computer system capable of processing both character encoded text data files as well as digitized images of U.S. and foreign patents. The Automated Patent System was discussed with respect to its architecture, testing and evaluation, international coordination efforts and public policy considerations. **(PL)**

IBM [84], doc 230

IBM Corporation, *Introduction to Local Area Networks*, Rye Brook, New York, 1984.

Gives an overview of the history of LAN development and LAN technology. The benefits and disadvantages of using different media, access protocols, and topologies are all fully described. Special emphasis is placed on the token ring LAN in order to explain how it works and the advantages it has over other LAN implementations. **(PL)**

IBM [87], doc 117

IBM Corporation, *Image Object Content Architecture: Concepts and Structures*, Rye Brook, New York, October 1987.

This technical book covers the concepts and file structure of IBM's Image Object Content Architecture (IOCA), which is one of the Object Content Architecture used for the interchange and processing of image information. **(JEE)**

IBM [88a], doc 302

IBM Corporation, *Advanced Function Printing Software, Third Edition*, Rye Brook, New York, April 1988, pp. 1–31.

This manual discusses Advanced Function Printing which is a collection of licensed programs when used with IBM printers produce a nicer printed output. The IBM printers that use this software are capable of addressing any point on the page which is a process called *all-point addressability.* **(JEE)**

IBM [88b], doc 281

IBM Corporation, Rye Brook, New York, 1988.

Reference manual for the ImagEdit (Version 2.0) image processing product. **(PL)**

IBM [89], doc 332

IBM, "A Closer Look at IBM PS/2 Micro Channel Architecture," IBM Report G320-9782-00, 1989

This collection on the Micro Channel Architecture contains 15 articles reprinted from *Byte Magazine*, *Computer Reseller News*, *Computer Systems News*, *InfoWorld*, *PC Magazine*, *PC Tech Journal*, and *PC Week* as well as reprints of two IBM publications. The articles praise the MCA and criticize EISA (primarily for not yet existing). Since IBM selected the papers for reprinting, their emphasis is not surprising. Comparatively little of the data needed to support an effective queueing model of the architecture are present. **(GMVTS)**

Idnani [88], doc 83

Govind G. Idnani, "Survey of Optical Disk Technologies," MITRE Corporation, NASA Contract NASW-4348, December 1988.

The purpose of this report is to document and examine the characteristics of the optical disk technologies (ODT) and the products currently available in the market place. This documents organized into seven sections and 11 appendices. Section 1 provides the background, purpose and the scope of this document. Section 2 provides detailed descriptions of the media and drives for different types of optical disks. Section 3 briefly describes the jukebox systems. Section 4 provides brief descriptions of new ODT that are under development. Section 5 presents a comparative analysis of the currently available ODTs in a tabular format. Section 6 describes the technologies required for implementing an ODT based system. Section 7 describes the future trends in the area of the ODTs. Appendices include survey of different size of WORM disk drives, survey of CD-ROM drives, lists of data preparation and service companies, lists of jukebox manufacturers, software vendors, and technologies for WORM recording, CD-ROM recording and erasable optical disks. **(EL)**

IEEE [87], doc 282

Institute of Electrical and Electronic Engineers Inc., *Facsimile Test Chart* (IEEE Standard 167A-1987), 1987.

Test target for fax machines. Includes continuous tone photographs, gray scale, precision measurement marks, resolution charts, and test characters. Comes with a pattern description sheet to explain various portions of the test. **(PL)**

Imnet [n.d.], doc 283

Imnet Corporation, Pine Brook, New Jersey.

Specification sheets describing the following input devices: page scanners (SCN-430 and SCN-304) and microfilm camera (FLM-126). **(PL)**

Intergraph [89], doc 285

Intergraph Inc., Chelmsford, Massachusetts, 1989.

Specification sheet describing the Optronics 5040 scanner. **(PL)**

IRLA [89], doc 307

"Optical Disc Technology Notes" IRLA march 1989, pp. 3–4

NASA's Langley Research Center awarded Aquidneck Systems International a contract for 15 OAS 150tm optical system in the U.S., Canada, and Europe. The NASA will use the system to distribute satellite data for the Earth Radiation Budget Experiment. The cost saving from new system will pay for the new equipment in around 30 months. **(EL)**

Jantz [88], doc 122

Richard Jantz, "Amazing Grays," *Publish!*, Volume 31, Number 8, August 1988, pp. 57–63.

This article focuses on halftones—what they are and how they are captured. Jantz includes the following formula for deriving number of usable gray levels:

$$\boxed{\left(\frac{dpi}{lpi}\right)\times\left(\frac{dpi}{lpi}\right)^2 = 1}$$

The two ways to produce halftones mentioned are dithering and scanning with gray-scale scanners. **(JEE)**

Jantz [89], doc 119

Richard Jantz, "The LaserJet's Sharper Image," *PC World*, February 1989, pp. 74–75.

Discusses Visual Edge, Intel's new printer enhancement software that not only improves the LaserJet's (series II) printing by 300 percent, but also speeds up the process. This product costs $695 and comes with two boards (one for the PC and the other for the LaserJet Printer) and a connecting cable. **(JEE)**

Kaebnick [88a], doc 18

Gregory E. Kaebnick, "FDA proceeds with Full-Scale Optical Disk Systems," *Inform*, November/December 1988, pp. 24–25.

Discusses the pilot optical disk system that the Food and Drug Administration (FDA) acquired for testing and evaluation purposes. This FileNet system, known as Optical Storage and Retrieval (OSAR) is installed in FDA's Center for Devices and Radiological Health (CDRH) at Rockville, Maryland. The pilot system consists of a 200-dpi business scanner; two 20-inch screen workstations, one connected to the scanner; one server containing all system software, databases, files, and temporary memory; a 64-disk jukebox; two terminals for communicating with the operating system software; a magnetic tape drive for creating periodic backup of software and installing new software; Ethernet cabling and communication a 1200-bps modem for systems maintenance conducted by FileNet field offices and a 400-dpi laser printer. By spring of 1989, 150 modified PCs will be serving as workstations which will be connected by T-1 lines. Ten years worth of documents will be scanned into the system. The separate centers will all share one fax standard CCITT group 4 and should be mutually compatible.

Some of the advantages uncovered by the pilot system are:

- o file integrity is maintained (documents are never lost or out of order)
- o file updates are immediately available
- o linking an optical disk image-based system with existing electronic databases on mainframe computers considerably enhances the databases value since the database can now contain document images
- o editing operations are improved
- o space saving is significant.

Some of the areas that could be improved:

- o scanning did not always function smoothly when several sheets are fed into the hopper simultaneously—especially if the sheets are of different thickness
- o image rotation is not possible after the image is stored

- o access is slow (20 seconds)
- o remote transmission is not possible
- o a mix of several hundred workstations and printers could not be supported. **(JEE)**

Kaebnick [88b], doc 19

Gregory E. Kaebnick, "Systems: More with LSS," *Inform*, November/December 1988, pp. 13–14, 36.

Introduces Licensing Support System (LSS) a system designed by Application International Corporation for the department of energy. This optical disk system will produce up to 10,000 documents, which will be needed for the licensing review that the department of energy is trying to gain for building a site to store radioactive waste. This site was to be built in the state of Nevada, however; the project is being contested by the state and some environmentalist group. The optical disk system should be running in 1991; however, the actual processing of the licensing application will begin in 1995. LSS will have nodes in Washington D.C., Nevada, and Texas. By 2009, access to will be possible in 10 other cities. LSS will contain 40 million pages (including headers and full text), bitmapped images with reproduction at the central station, and on-line printing at workstations. Some other LSS features are multiple document capture scanning, text conversion, corrections, cataloging, and workstations displaying ASCII text. **(JEE)**

Kaebnick [89], doc 105

Gregory E. Kaebnick, "CALSthenics: Warm-up for Total Digital Document Handling?" *Inform*, April 1989, pp. 12–46.

The Department of Defense (DOD) effort on computer-aided acquisition and logistic support (CALS) is designed to standardize the movement of technical information within the defence community. Phase I is to permit the submission of technical documents and specifications in digital rather than in paper form. Scheduled for completion in the early 1990s, standards and guidelines to be issued during the phase include:

- o Initial Graphics Exchange Specification (IGES), MIL-D-28000
- o Standard Generalized Markup Language (SGML), MIL-M-28001
- o Automated Interchange for Technical Information, MIL-Std-1804A
- o Raster graphics, MIL-R-Raster
- o CGM application profile, MIL-D-CGM
- o CALS implementation guide, MIL Handbook 54

Phase II will continue by focusing on information management issues. **(GMVTS)**

Kalthoff [88], doc 20

Robert J. Kalthoff, "Issues, Operational Users and the Current State of the EIM Industry," (Keynote address, IMC Document Management Systems Conference, May 1988, Stockholm), *IMC Journal*, September/October 1988, pp. 13–18.

"EIM (Electronic Image and Information Management is already on its way to becoming part of the global economy." (p. 13) Initial users are operations, and it wasn't easy. Optical disk technology has been essential to EIM success, but isn't synonymous with it. User acceptance is growing, but too optimistic assumptions have led many industry analysts to forecast much greater market growth than has actually occurred. Key storage alternatives are in place, 5.25-, 12-, and 14-inch CD-ROM, and erasable optical media, but standards lag in all but the 5.25-inch formats. The industry is maturing, but not mature. "The user must have the time to go through all steps required in the acquisition and implementation and ongoing upgrades of EIM technology—including correction of judgement error." (p. 17) **(GMVTS)**

Kanazawa+ [84], doc 135

Yasunori Kanazawa, M. Ito, and S. Abe, "Development of Large Capacity Optical Disk," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 12–19.

Introduces Hitachi Maxwell's jukebox. Describes in details of structure and data format of Hitachi's disks. Includes diagrams of disk structure and specification tables. **(EL)**

Karsh [89], doc 219

Ariene Karsh, "OCR Comes of Age...Again," *Electronic Publishing & Printing*, March 1989, pp. 56–64.

Briefly discusses recently released devices that have greatly improved character recognition abilities which can be used for both high throughput and desktop scanning applications. Some of the cited reasons for the recent interest in character recognition are the widespread use of computers, the recent proliferation of scanners, new technological advancements which allow for differentiation between text and graphics, the efficiency of character recognition, and most importantly the lowering of prices. Previous unacceptable error rates from recognition devices have been improved through trainable devices, the use of artificial intelligence, context processing, and dictionaries, as well as the ability to give a best guess. Advancements to scanning technology and improved resolution have also improved character recognition's accuracy. Various uses of a recognition device's output, such as a word processor, spread sheet packages, or SGML packages, were also discussed. The article concluded with a discussion of specific device, giving their strong and weak points. (PL)

Keblusek [89], doc 93

Maryann Keblusek, "Service Bureaus: Opening Doors to New Publishing Technology," *Publish!*, February 1989, pp. 30–35.

Discusses services provided to Desktop publishing technology and how they have changed throughout the years. Some of these services are black and white/color output film or paper, camera-ready art and documentation, color separation, stripping, proofing, color and photo scanning. Other creative services are offered such as illustrating, page layout and hardware maintenance. Keblusek emphasizes the importance of investigating the service bureaus before choosing the appropriate one. Among the categories to consider are experience, company policies, quantity and discounts. (JEE)

Keenan+ [88], doc 309

Terrance Keenan and Elizabeth Carley Oddy, "Developing an Optical Disk System for Adult Education Manuscripts: The Kellogg Project at Syracuse University," *Proceedings of the Conference on Application of Scanning Methodologies in Libraries*, pp. 79–95

The KLARS project at the Syracuse University use Plexus image system to store a large collection of adult education manuscripts. The host use Unix 5.2 operating system and 12-inch Optimem disk drive. The system expected to add OCR engine to have auto ASCII file conversion and allow for full-text search. (EL)

Kellis [88], doc 22

Mark Kellis, "CD-ROM Revolutionizes Information Distribution in the Federal Government," *Micro User's Guide*, Fall 1988, pp. 14–16.

Discusses CD-ROM technology. Compact Disk Read Only Memory (CD-ROM) has been used for many applications in the federal government. CD-ROM drives use laser beams to read information contained on 4.75-inch compact disks. One single disk will fold more than 600MB of information and as the word read only implies, it could only be read from but not written to. With the interface to a personal computer and personal software, CD-ROM democratizes the world's largest and most valuable databases to the PC users. (JEE)

Kemezis [89], doc 125

Paul Kemezis, "Fax-to-LAN Increasingly Popular, But Users Are Awaiting a Solution to the Routing Problem," *Data Communications*, June 21, 1989, p. 24.

The marketplace has done a good job of delivering fax transmission and of moving faxes to LAN-based fax servers. There, however, a problem has developed—how to distribute the faxes to their intended recipients, as opposed to piling up the faxes for addressees to pick up when they visit the fax server. IBM has introduced a system that requires an individual to attach electronic mail addresses at the fax server. Other proprietary solutions are nearing release. A standardized solution interests some in the marketplace, but many fax vendors are reluctant to sacrifice header space in the CCITT standards for addresses (they use them currently for their own purposes), and they fear that such an approach would render existing hardware obsolete. Existing fax and OCR technologies do not appear to deliver sufficient recognition quality to solve the routing through an OCR strategy. (GMVTS)

Kempster [89], doc 26

Linda Kempster, "IBM Struts their Stuff for NCC AIIM," *AIIM National Capital Chapter*, February 1989 pp. 1–2, 10.

This report describes two IBM optical storage system from a videotape viewing. The IBM Image-Plus workstations installed in Citibank use Bell & Howell Scanner, display image at 100-by-100 resolution, and cannot rotate image from screen. The 85 workstations in Citibank supported by two LANs, four IBM 5360, one 64-platters jukebox, and a 5363 controller. Both IBM system in USAA and Citibank store documents on magnetic disks first and batch them to optical media days later. **(EL)**

Kendall [89], doc 172

Kendall Preston, Jr., "The Abingdon Cross Benchmark Survey," *IEEE Computer*, July 1989, pp. 9–18

The widely differing applications of imaging applications and the widely differing computer architectures available for performing image processing make performance benchmarks very difficult to achieve. Traditional benchmarks fail to characterize image processors. A special image has been devised, the Abingdon Cross, which embeds the image of a symmetric, square cross (such as that on the Swiss flag) against a noisy background. The benchmark task is to determine the medial axis (that is, the center line which is to resemble a plus sign, "+"). Vendors were free to apply whatever algorithms were considered to be the best application of their hardware to the stated problem. The intent of the benchmark is to test "(1) input/output, (2) matrix and/or vector operations, (3), Boolean operations, (4) filtering, and (5) cellular logic." (p. 12) Results from 39 commercial and 12 noncommercial systems are reported. The testing has revealed quality factors scaled from 10^0 to 10^5 and price performance factors scaled from 10^{-1} to 10^3. "The almost 1,000 : 1 ratio of PPFs for these systems is nothing less than astounding and illustrates the enormous increase in performance per dollar that has occurred over the past decade without a sacrifice in speed." (p. 17) **(GMVTS)**

Kerr [88], doc 231

Susan Kerr, "Document Interchange Reigns at DOD," *Datamation*, November 15, 1988, pp. 81–84

The computer-aided acquisition and logistic support (CALS) initiative at the Department of Defence is reviewed. It is seen as providing impetus to a number of ongoing standardization efforts, including product data exchange specifications, and CCITT Group 4 compression. **(GMVTS)**

Khairy+ [79], doc 39

Salah A. Khairy and George C. Miller, "Document Storage and Retrieval," *ACM/SIGIR Second International Conference on Information Storage and Retrieval*, Dallas, Texas, September 27–28, 1979, pp. 78–82.

Describes a PDP-11/45-based image storage-and-retrieval system operational at the Arab Organization for Industrialization (AOI) in Cairo, Egypt, since February 1978. Scanning was done at 400 dpi vertically and 200 dpi horizontally in two seconds per page. Microprocessor-based compression/decompression routines were present in the scanner and each display device. Designed by E-Systems to achieve a 15 : 1 compression ratio, the compression algorithm typically delivered 20 : 1. Of particular use to system users were the language-independence conferred by the image approach and the teleconferencing possibilities inherent in fax transmission. Storage media appear to have been magnetic, documents corresponded to images, and a handful of specific index attributes were manually entered into the system. **(GMVTS)**

Kleinschrod [89], doc 246

Walter A. Kleinschrod, "Optical Disk: Growth Spurts in an Emerging Technology," *Today's Office*, June 1989, pp. 44c–44n.

This paper discusses the potential of the optical disks system and integration with existing microfilm system. Two trends stand out in today's optical disk industry. One is that systems are being scaled down in size for smaller users. The other is that products from different vendors are being linking together. **(EL)**

Kong [89], doc 286

Zak Kong, "Tracking IBM's Gateways," *Computerworld*, January 23, 1989, pp. 81–85.

Discusses Gateway PC and 3174 Controller approaches for linking LANs to mainframes. The benefits and disadvantages between the two are elaborated on. IBM's System Application Architecture (SAA) and its NetWare-compatible product are also discussed, with the emphasis on their relationships towards LAN gateways. **(PL)**

Kotera+ [89], doc 165

Hiraki Kotera and Katsuhiro Kanamon, "The New Color Image Processing Techniques for Hardcopy," SPIE: *Digital Image Processing Application*, Volume 1075, January 17–20, 1989, pp. 252–259.

Discusses new image processing techniques for color printing. The three necessary requirements mentioned are reproducing continuous tones, getting the correct color rendition and adjusting the colors as needed. **(JEE)**

Krell [88], doc 310

Kenneth Krell, "Experience with an Optical Disk System at FDA," *Proceedings of the Conference on Application of Scanning Methodologies in Libraries*, pp. 113–118

Center for Devices and Radiological Health (CDRH) of FDA evaluates FileNet OSAR system for their image system pilot test. The system is mainly designed for documents management, storage and retrieval. The results showed that the image system can solve most paper management problem they have, and there is no need for a central or standard system throughout the agency. **(EL)**

Kriss+ [89], doc 247

Michael Kriss, Ken Parulski, David Lewis, "Critical Technologies for Electronic Still Imaging Systems," SPIE: *Applications of Electronic Imaging: Critical Reviews of Optical Science and Technology*, Volume 1082, 1989.

Electronic still camera systems are now in the consumer market place. The hardcopy image quality of these systems is poor in comparison with the ever improving photographic film systems. However, the rate at which solid-state image sensor technology, signal processing technology, mass storage technology, and nonphotographic hardcopy technology are advancing indicates that these electronic still camera imaging systems will someday find a place alongside traditional photographic systems. The current and future status of these critical technologies is the subject of this paper. **(author)**

Kunkel [89], doc 171

Gerald Kunkel, " $13,000 Tektronix Phaser Delivers 300-dpi color PostScript/HPGL," *PC Magazine*, March 28, 1989, p. 48

Discusses the Tektronix printer and the enhancements that can be done to the output by installing the Phaser card PostScript/HPGL adapter. This adapter allows the printer to be a combination of both a thermal wax transfer and laser printer to produce beautiful colored output at a resolution of 300 dots per inch. This combination of the board and the printer can be purchased for $12,995. **(JEE)**

Kurzweil [n.d.], doc 287

Kurzweil Computer Products, Cambridge, Massachusetts.

Specification sheets describing the following scanners: K-5000 and Discover 7320. **(PL)**

Landrum [87], doc 248

Craig Landrum, "Digital Document Automation and the Mark of Quality," *Inform*, November 1987, pp. 22–23, 26.

Quality control of scanned images plays an important role in digitizing documents process. But the human inspection requires a lot of manpower. This paper describes an automated quality assurance project, performed by Planning Research Corporation (PRC) for U.S. Patent Office. The object of its research was first to identify image features that quantify image quality, then to develop a set of algorithms combining these features, which would provide a reliable means of rejecting substandard documents. PRC found that image noise was a reliable indicator of image quality. It also used a run-length histogram to separate light images from good images. PRC implemented these techniques in software on a Masscomp 5500 Unix-based system. **(EL)**

LaserData [88], doc 320

LaserData Inc., 10 Technology Drive, Lowell, Massachusetts 01851.

Table of simple specifications for Sony 12-inch and Cygnet 5.25- and 12-inch jukeboxes. **(EL)**

Lewis [87], doc 249

Peter H. Lewis, "Data from Paper? It's Elementary," *New York Times*, November 15, 1987

The release of a complete, machine-readable version of Sir Arthur Conan Doyle's stories of Sherlock Holmes provides an opportunity to review the Compound Document Processor from Palantir (now Calera Recognition Systems). The unit sells for $39,500 and contains five Motorola 68000 chips. (GMVTS)

Lewis [88], doc 250

Peter H. Lewis, "Plugging in Numbers, with Ease," *New York Times*, December 18, 1988, p. 10.

Optical character recognition is described as a technology ready for office use. The article focuses on the Calera TrueScan product for the PC, available in two versions at $2,500 or $3,500 depending on whether landscape orientation can be recognized. Also considered is the Caere OmniPage system ($2,495). (GMVTS)

Lienau+ [84], doc 139

Hans-Joachim Lienau and Karsten Hartmann, "Usage of an Electronic Document Storage System for a Press Clipping Documentation Bank," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 43–48.

One of the world's largest and technically most advanced press data banks is being run as a back-up system four journalists by Grüner and Jahr publishers in Hamburg. The text bank alone now contains two million pages of fax text, each of which can be electronically located and retrieved within a few seconds from automated microfiche reader-printers. Daily input to the system is about 1,000 pages; output is 2,800. Within the next three years the total archive since 1972 is to be converted to electronic storage. The archive then will contain about four million pages. Texts cover all aspects of life, and over 200 top international sources. Digital optical recording (DOR) upgrades the performance of this system. In particular:

- o extend storage space
- o speed up soft document delivery
- o fully mechanize document print
- o improve readability
- o open up almost unlimited possibility of arranging new document collections for distributed use
- o extend the range of document delivery to distant user places. **(author)**

The migration from microfilm to digital storage was justified using the dimensions of quality, speed, and problems of space. The technical characteristics of the optical disk and imaging systems are not discussed. (GMVTS)

LMS [88], doc 326

Laser Magnetic Storage International Company, 4425 Arrows West Drive, Colorado Spring, Colorado 80907.

Specification sheet for Laser Drive 1200/1250E. (EL)

Maguire+ [83], doc 182

Gerald Q. Maguire Jr., S. C. Horii, M. E. Noz, and M. P. Zeleznik, "Message protocols for radiologic consultations over a local area network," SPIE: *Picture Archiving and Communication System (PAC II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 160–171.

This paper discusses the problems associated with consultations in a network environment. With the use of flowchart, a step by step analogy is presented concerning a patient's visit to a doctor's office. Its emphasis is on the division of tasks among each person involved such as the receptionist, the physician, nurse, patient and the role of the LAN such as and its environment. (JEE)

Mamrak+ [87], doc 76

S. A. Mamrak, M. J. Kaelbling, C. K. Nicholas, and M. Share, "A Software Architecture for Supporting the Texchange of Electronic Manuscript," *Communication of the ACM*, Volume 30, May 1987, pp. 408–414.

Discusses the importance of electronic manuscript, a software product that makes it possible for submitting manuscripts on tapes or disks. Also publishers can prepare manuscripts to be published much faster and more economically than with manual keyboarding. With the help of optical scanning text can be captured in electronic format, but this format must be translated to a standard form it will be incorporated into a database. A standard form model which this system is based on, Standard Generalized Markup Language (SGML) specifies a method for describing the contents and structure of an electronic manuscript. (JEE)

Mamrak+ [88], doc 78

S. A. Mamrak, J. Barnes, H. Hong, C. Joseph, M. J. Kaelbling, C. K. Nicholas, C. O'Connel, and M. Share, "Descriptive Markup—The Best Approach?" *Communications of the ACM*, Volume 31, Number 7, July 1988, pp. 810–811.

Response to **Coombs+ [88]**, doc 53, article supporting descriptive markup. Mamrak specifically questions Coombs' claim that "descriptive markup provides an immediate solution to document incompatibility" or that "descriptive markup guarantees a one-to-one mapping between logical elements and markup." Mamrak says that all markup systems may not have the most recent version or have the same hierarchical relationships among logical elements or may even be a functionally mismatched due to lack of some logical elements. The author proposes the adoption of a universally accepted standard with data translators to and from any variant markup form as a means to achieve true compatibility. (PL)

Markivee+ [83], doc 191

C. R. Markivee, W. J. Nalesnik, M. C. Chiang, J. R. Tio, and E. L. Hall, "Determinants of Acceptability of Radiographic Images for Archival Digital Storage," SPIE: *Picture Archiving and Communication Systems for Medical Applications*, Volume 418, May 22–25, 1983, pp. 239–243.

In order to properly scan film, it is important that the images be of optimal exposure quality in order to minimize the loss of information during search and retrieval processes. Because film exposure is subjective to measure, an automated technique is preferred. Using a scanner with a resolution of 128 dpi and a 256 gray-level capture as well as some pre-evaluated training films to be used a a guide, the computer produced a histogram of the filmed image. Using the histogram, the Pearson technique was used to extract the mean, variance, skewness, and kurtosis in order to rate the image in one of five exposure levels which ranged from extremely light to extremely dark. The study showed that the computer was able to evaluate the exposure level within an acceptable range of human evaluation. (PL)

Martin [89], doc 264

James Martin, "ISDN: Telecomm Information Network of the Future," *PC Week*, March 13, 1989, p. 60.

Integrated Services Digital Network (ISDN) is a digital network which will support text, voice, video, and data information and can transmit at 144 Kbps. It is often described as 2B+D to refer to it having two 64 Kbps information channels and one 16 Kbps control data channel. The various existing and future international standards of ISDN are also mentioned. The article concludes with telling the impact ISDN has and will have in the communication fields. (PL)

Maxtor [88], doc 327

Maxtor Corporation, 211 River Oaks Parkway, San Jose, California 95134

Specification sheet for Maxtor Tahiti family 5.25-inch erasable optical disk drive, with 1GB or 650MB media. The 1GB media use Zoned Constant Angular Velocity (ZCAV) recording method. (EL)

McFall+ [89], doc 163

John D. McFall, J. L. Mitchell, and W. B. Pennebaker, "Displaying Photographic Images on Computer Monitors with Limited Color Resolution," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 179–184.

Discusses the problem of displaying continuous tone color photographic images on CRT monitors with the ability of displaying only certain colors simultaneously. An algorithm is provided that can generate a limited number of colors and a method is given for a full color image display using these colors. (JEE)

McNaul [88], doc 220

Jim McNaul, "Scanners Bring Gray-scale Processing to Desktop Publishing," *Micro Users Guide*, Fall 1988, pp. 27–30.

Discusses the role gray-scale information plays in the scanning process. Resolution and gray scale are described as the two main scanning parameters which can affect the quality of the scan and the storage space of the image file. The process of dithering to simulate the gray-scale information and its effects are fully elaborated on. Various image processing functions, such as thresholding, scaling, and image enhancements, are also discussed. Current scanners are able to capture 256 levels of gray and can do more processing of information for a lower cost than earlier models. This improved capability has led to big improvements in many applications, especially in the field of desktop publishing. **(PL)**

Melnychuck+ [89], doc 153

Paul W. Melnychuck and Majid Rabbani, "Survey of Lossless Image Coding Techniques," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 92–100.

This paper compares and briefly describes six lossless compression techniques. Some lossless coding techniques are modifications of well-known lossy schemes, whereas others are new. Traditional Markov-based models and newer arithmetic coding techniques are applied to predictive coding, bit plane processing and lossy plus residual coding. These techniques work for binary images as well binarized gray-level images. The compression ratio offered by these techniques are in the area of 1.6 : 1 to 3 : 1 for 8-bits pictorial images. **(EL)**

Memorex [87], doc 316

Memorex, 611 South Milpitas Boulevard, Milpitas, CA 95035

Specification sheet for Memorex 3682 double capacity disk storage device and 1988 specification sheet for Memorex Telex 3500 optical storage subsystem. **(EL)**

Mendelson [89], doc 69

Edward Mendelson, "Intel Visual Edge, DP-Tek LaserPort Boost HP LaserJet Gray-scale Abilities," *PC Magazine*, March 28, 1989, p. 43.

Using Intel's Visual Edge or DP-Tek's LaserPort add-in boards, it is possible to use HP LaserJet printers to produce newspaper-quality halftones. The boards improve both the speed and the resolution of the underlying print engines, providing dither patters with 64 shades of gray at 70 lines per inch (lpi) or with 37 shades at 100 lpi. Without such boards, the LaserJet delivers 64 shades at 38 lines per inch or 10 shades at 100 lpi. The quality of output from the add-on boards depends partially on the publishing software that drives them; Xerox Ventura Publisher is seen as producing better results than Aldus PageMaker, because Ventura has more sophisticated image support before the board is invoked. DP-Tek has announced a newer board which will deliver 212 lpi with 52 shades of gray—enough gray-scale quality to match the results encountered in book publishing. **(GMVTS)**

Meyer-Ebrecht+ [83a], doc 184

Dietrich Meyer-Ebrecht and Thomas Wendler, "Concept of the Diagnostic Image Workstation," SPIE: *Picture Archiving and Communication Systems for Medical Applications*, Volume 418, May 22–25, 1983, pp. 180–188.

The image workstation is an end user's interface to an image system. It includes the interactive display and any processing systems necessary to allow the user access to pictures, data, and status information by accepting commands and special search keys. The most important function of the workstation is to display the image. To do so, the workstation must solve the two principal differences between soft images (computer display) and hard images (paper or film). One, a soft image is limited very much by spatial resolution, contrast range, and brightness levels. Two, a hard image can be physically moved around. To produce an acceptable workstation, the authors present the following three-step strategy:

- o try to fit the parameters of the soft image to as close as possible to those of the hard image.
- o use the strengths of the soft image to compensate for its weaknesses.
- o invent new manipulation procedures to increase the power of soft images.

The following five areas were identified as conflicting requirements between the hard image and the display:

Spatial resolution—	presenting a high resolution image on a low resolution screen can be corrected by an Overview function or a Zoom function. Presenting a low resolution image on a high resolution screen can be corrected through a Blow-up function.
Contrast—	images with very low or very high contrast can be made to look better by using a Contrast function to select the proper contrast range.
Presentation—	the orientation of a hard image can be changed through the Rotate or Mirror function. The size of a hard image can be made to fit the screen through Enlargement or Reduction functions.
Multiple page—	a comparison between two or more pages can take place through using the Toggle function which switches between the two images or the Cut function which superimposes images on a split screen.
Nonimage information—	users can add text or drawings to an image on the screen by using an Overlay function.

Other image functions can include those for image modification, such as noise cleaning and edge enhancement, and image analysis, such as measuring various parameters of an image. **(PL)**

Meyer-Ebrecht+ [83b], doc 129

Dietrich Meyer-Ebrecht and Thomas Wendler, "An Architectural Route Through PACS," *IEEE Computer*, Volume 16, Number 8, August 1983, pp. 19–28.

Interfaces between models of system users' environments and models of information systems are discussed from the point of view of picture archiving and communications systems (PACS). Specific discussion is presented on three especially important domains, picture storage hierarchies, picture coding for data transmission, and picture processing. **(GMVTS)**

Michie [89], doc 251

Robert W. Michie, "A Fresh Can of WORMs, Those Who Switch from Microfilm to Optical Disk Should Understand the Differences," *Inform*, June 1989, pp. 26–30

Micrographics experience is not seen as an effective model for the production processes of a digital imaging system. Quality control, for example, is more complex, because digital images do not appear the same way on different monitors — they must be printed to obtain an effective quality control base. The author suggests that if access and space utilization are not major concerns, one should seriously consider using microfilm. **(GMVTS)**

MicroMachines [n.d.], doc 331

Micro Machines, "Raster Image Processor," Saratoga, California, no date

This specification sheet describes Micro Machines' Raster Image Processor. The PC/AT-compatible board features inclusion of a 5 MIP RISC chip which is user-programmable. **(GMVTS)**

Microtek [n.d.], doc 288

Microtek Lab Inc., Torrance, California.

Specification sheets describing the following scanners: MSF Series (300C, 300G, 300GS, 300Q,300QS, and 400G); MS 300A; LS Series; and OS-300. **(PL)**

Mileikowsky [89], doc 111

Ron Mileikowsky, "Color Output Devices," *Government Computer News*, March 20, 1989, pp. 49–54.

The author discusses the functions of color printers in detail as well as the different types of color printers: plotters, dot-matrix, ink-jet, thermal-transfer, and laser printers. The author provides a table comparing different printer by vendor, model, type, memory, interface, speed, resolution, paper size, colors, emulation, and price. **(JEE)**

Miles [88], doc 73

Charles S. Miles, "Data Conversion Newsletter," *Image Publishing*, November 1988, pp. 4–6.

This article briefly describes a demonstration of the Palantir (Calera Recognition System) Compound Document Processor, which reads a document as fast as 250 characters per second (cps). The scanner handles 10 to 150 pages per day or, if the CDP 9000 system is used, over 300 pages per day. OCR equipment and software vendors are listed on page five. **(EL)**

Miller+ [88], doc 86

George A. Miller, C. Fellbaum, J. Kegl, and K. Miller, "An Electronic Lexical Reference System Based on Theories of Lexical Memory," *CSL Report 11*, Cognitive Science Laboratory, Princeton University, January 1988.

A word dictionary is under construction which will map the English vocabulary according to both the phonological/morphological relationships of words and the semantic/pragmatic relationships of lexical concepts. Synonymy (similarity networks), hyponymy (taxonomic hierarchy), meronymy (compositional hierarchy), phonology (for example, rhyme), and morphology (such as case, comparison, gender, tense, etc.) can be expressed. "As of the end of 1987, the WordNet files included 11,500 different nouns organized into over 7,000 synonym sets; approximately 6,000 different verbs organized into over 3,000 synonym sets; and 9,500 different adjectives organized into over 8,200 synonym sets." (p. 7) Conceptual relations are now being added to the dictionary. **(GMVTS)**

Mitchell+ [88a], doc 329

J. L. Mitchell and W. B. Pennebaker, "Optimal Hardware and Software Arithmetic Coding Procedures for the Q-Coder," *IBM Journal of Research and Development*, Volume 32, Number 6, November 1988, pp. 727–736

The Q-Coder is an important new development in arithmetic coding. It combines a simple but efficient arithmetic approximation for the multiply operation, a new formalism which yields optimally efficient hardware and software implementations, and a new form of probability estimation. This paper describes the concepts which allow different, yet compatible, optimal software and hardware implementations. In prior binary arithmetic coding algorithms, efficient hardware implementations favored ordering the more probable symbol (MPS) above the less probable symbol (LPS) in the current probability interval. Efficient software implementation required the inverse ordering convention. In this paper it is shown that optimal hardware and software encoders and decoders can be achieved with either symbol ordering. Although optimal implementation for a given symbol ordering requires the hardware and software code strings to point to opposite ends of the probability interval, either code string can be converted to match the other exactly. In addition, a code string generated using one symbol-ordering convention can be inverted so that it exactly matches the code string generated with the inverse convention. Even where bit stuffing is used to block carry propagation, the code strings can be kept identical. **(author)**

Mitchell+ [88b], doc 330

J. L. Mitchell and W. B. Pennebaker, "Software Implementations of the Q-Coder," *IBM Journal of Research and Development*, Volume 32, Number 6, November 1988, pp. 737–752

The design details and experimental performance data of Q-Coder are presented. This paper and its companions present sufficiently detailed information to support implementation of Q-Coder algorithms. **(GMVTS)**

Mitchell+ [89], doc 154

Joan L. Mitchell, W. B. Pennebaker, and C. A. Gonzales, "The Standardization of Color Photographic Image Data Compression," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 101–106.

This paper describes the adaptive cosine transform (DCT) technique which was selected as the basis for the compression and decompression for antral color images. The definition of the inverse DCT, the improvement of the low-bit-rate image quality, the choice of entropy coding technique and the method of achieving graceful progression are important issues as part of the refinement and enhancement process before final selection. Those are also described in this paper. **(EL)**

Mitsubishi [88], doc 315

Mitsubishi Electronics America Inc., 991 Knox Street, Torrance, California 90502.

Specification sheet for Mitsubishi flexible, ridge and optical disk drives. The optical disk drive and jukebox is for 5.25-inch WORM disk. **(EL)**

Mitsuhashi [84], doc 144

Yoshinobu Mitsuhashi, "Standardization Activities for Optical Digital Data Disk Storage Systems," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 71–73.

Discusses the standardization of optical digital data disk (OD^3) in Japan. It mentions the names of the 33 companies that are part of this standards organization. **(JEE)**

Moad+ [88], doc 43

Jeff Moad and Gary McWilliams, "SAA: The Yellow Brick Road to Cooperative Processing," *Datamation*, July 1, 1988, pp. 38–48.

IBM's initial announcement of Systems Application Architecture (SAA) stressed portability; sixteen months later the emphasis appears to be on cooperative processing. IBM's policy on not announcing products until their delivery can be guaranteed within 18 months, has meant a piecemeal approach to announcing SAA components—and considerable confusion over the architecture. The interviewees cited in this article appear to prefer cooperative processing over portability; portability is seen as a somewhat dull objective. IBM's inclusion of IMS and CICS within the SAA framework is seen as indicative of the market pressures to support older products that will erode and dilute the SAA vision in oncoming months. **(GMVTS)**

Moorhead+ [89], doc 157

Robert J. Moorhead, J. S. Ma, and C. A. Gonzales, "Realtime Video Transmission Over a Fast Packet-Switched Network," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 118–123.

Traditional video-compression techniques which are applicable to synchronous, fixed bandwidth channels cannot be applied in packet-switched networks, which can accommodate the bursty and highly variable compressed motion video yet keep a constant level of image quality. This paper presents an effective video compression technique which use interframe DPCM most of the time, but periodically restart by using an intraframe algorithm. **(EL)**

Moran [88], doc 24

Robert Moran, "Choosing an Image Strategy," *Computer Decisions*, November 1988, pp. 57–60.

The author discusses the benefits of an imaging system. The author describes the following components of a compound image system: input devices (scanners, OCR devices), high-resolution workstations, processors, application and system software, image controllers, output devices, and optical storage. The author classifies compound image systems into four categories: large mainframe-based systems, medium mainframe- and minicomputer-based systems; networked microcomputer-based systems, and stand-alone microcomputer systems. The author discusses the issues of database technology, OCR, and communication with respect to imaging systems. The author also gives brief descriptions of IBM ImagePlus, Plexus Extended Data Processing, and Wang WIIS applications. **(PL)**

Mori+ [84], doc 134

Masafumi Mori and Kazuhiko Yamamoto, "High Performance Optical Disk Memory System," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 6–11.

Describes Toshiba TOSFILE3200 optical disk filing system. The paper has detail discussion of functions for each components. The disks have MCLV rotation control, which is combination of CLV and CAV. The electronics portion of disk drive performs signal processing which adds ECC, and modulates when writing; demodulates, separates ECC and sends data to interface when reading. The interface between host and disk drive is GPIB. There are two data block buffers used for read/write data and communication. **(EL)**

Mueller [89], doc 8

Robert Mueller, "Gray-scale Scanning Gains Support from Hardware and Software Advances," *PC Publishing*, February 1989, pp. 14–19.

Discusses the scanner's recent ability to capture gray scale, new software tools for gray-scale editing, and new advancements for printing images with gray-scale information. As scanner prices have dropped, their capability of capturing better images has increased. Earlier scanners commonly only had 16 levels of gray capture but today most scanners have 64 or 256 gray level capture ability. Though capturing the gray levels of an image greatly improves the quality of the scan, storage and printing of gray-scale information provides problems. Halftone dither patterns are one solution for printing, but there usually is a trade-off between the resolution and the amount of gray levels that can be displayed. A new product called Visual Edge is another solution. It allows for gray-scale printing on a standard 300-dpi laser printer. Improved graphic software allows for editing to gray-scale files and new processor chips allow for the processing of data at faster speeds. **(PL)**

Myers **[89]**, doc 104

Edith Myers, "High-density Magnetic Challenges Optical," *Inform*, April 1989, pp. 30–41.

Helical scan tape devices offer 2 to 2.5GB of storage in a pocket-sized tape cassette. In terms of capacity, they may be expected to challenge optical disks in the short run, but their slow data transfer rates and inability to support random access are not expected to sustain such a challenge. The article quotes many industry figures to compare attitudes on optical versus magnetic media. Magnetic media have the weight of traditional acceptance, but optical media are coming along. **(GMVTS)**

Nagy **[83]**, doc 66

George Nagy, "Optical Scanning Digitizers," *IEEE Computer*, May 1983, pp. 13–24.

Though written in 1983, the article gives an excellent technical overview of the mechanics of a scanner as well as the I/O characteristics to be considered when purchasing a scanner. The scanner is used in a wide variety of applications such as OCR, CAD, biomedical applications, geographic data processing, fax communication, printing and publishing, and experimental physical science. The functional components of a scanner are: its scan mechanism (comprised of illumination source, document transport, and transducers) its optical system, and the analog-to-digital (A/D) converter. Each one of these systems is described with the various approaches to each.

The following characteristics need to be evaluated: spatial sampling characteristics (which deal with the resolution of the scanner and the size of the dots), geometric characteristics (which deal with the accurate reproduction of the pixels in the current position relative to one another), photometric characteristics (which deal with the accurate representation of the different shades of gray), and overall system characteristics (which deal with the quality of documents, environment conditions, and ease of interfacing with other devices). Each of these categories are elaborated on with specific factors. Available scanners are grouped into electronic, electro-optical, and solid-state classifications, and the features and limitations of each group is presented. **(PL)**

Neeley+ **[83]**, doc 194

J.P. Neeley, M.W. Vannier, and F.R. Gutierrez, "Practical Considerations in Digital Cardiac Angiography," *Picture Archiving & Communications Systems (PACS II) for Medical Applications*, SPIE Volume 418, 1983, pp. 266–279.

A quantitative assessment comparing digital imaging results with 35mm cineradiographic film. The digital images were found to be comparable in temporal and gray scale resolution; superior in dynamic range, versatility, speed, and contrast sensitivity; and inferior in spatial resolution. It was suggested that 512×512 imaging might eliminate the moiré patterns that appear when 256×256 imaging encounters fine details. **(GMVTS)**

Neubarth [88a], doc 25

Michael Neubarth, "Image Processing: Tools for Offices," *MIS Week*, November 7, 1988, pp. 15 and 17.

Describes the importance of the MIS group in an organization. A project's failure or success depends on the decisions made by the MIS group. Ninety percent of these companies that have installed a document management system were successful. Unfortunately, the 10 percent that failed, had to discard the systems that cost millions of dollars and many man hours. Companies that were successful gained a competitive advantage, improved efficiency and savings in money and space. **(JEE)**

Neubarth [88b], doc 85

Michael Neubarth, "Erasable Optical Drives: An Infant Ready to Soar," *MIS Week*, October 10, 1988.

The market of erasable optical disks has been hold up for having no industrial standards. Quite a few companies has announced their products but the real shipping is very little. Some company, like AGA, try to sell erasable optical drives for PC users. Currently the price of erasable memory is still twice of magnetic memory. It will be a number of years' work for erasable optical drives to catch the data access times and transfer rates of Winchesters. **(EL)**

Neubarth+ [89a], doc 109

Michael Neubarth and Leslie Goff, "Image Processor Files Under Chapter 11," *MIS Week*, March 20, 1989, p. 4.

Tells of Plexus Computers Inc. decision to file for Chapter 11 bankruptcy protection in March 1989 due to the loss of financial backing from venture capital organizations. Plexus plans to restructure from an image processing company to a software only company providing imaging applications and working through original equipment manufacturers (OEMs). The cited reason for filing for bankruptcy protection is that Plexus had overextended itself by being involved in the entire imaging process—software development, hardware manufacturing and value-added resellers (VARs) sales and support. **(PL)**

Neubarth [89b], doc 252

Michael Neubarth, "Plexus Demise Does Not Reflect Imaging Industry," *MIS Week*, April 10, 1989, pp. 17–18.

This report claims the image market is still healthy and growing up even though the third leading image vendor, Plexus, has filed for bankruptcy. There are more big companies and vendors coming into image market. Data base vendors and image vendors are working together to produce better image database products. **(EL)**

NISO [86], doc 36

National Information Standards Organization, "Electronic Manuscript Preparation and Markup," *National Bureau of Standards*, 1986.

Summarizes the Association of American Publishers' (AAP) Standard Generalized Markup Language (SGML) industry standard (ISO 8879). The intent of the standard is to help authors, editors, publishers, and designers create, exchange, and process electronic manuscripts by a variety of devices and for a broad range of applications. Specifically, the AAP standard provides the following:

- specific syntax to be used for tags of document elements and document structures,
- predefined tags for commonly occurring document elements and document types
- a method to represent special characters, symbols, equations, and tabular material using only the standard ASCII character set.

The majority of the document details the three types of generalized markup (descriptive-tags, reference, and declarations) and the structure and definition of the five types of markup declaration (document type, comment, element, entity, and SGML). Provides lists of predefined document type definitions (DTDs), element tags, and reference tags. **(PL)**

NKK [89], doc 319

NKK Corporation, Hieikudankita Building, 4-1-3 Kudankita Chiyoda-ku, Tokyo 102, Japan.

Specification sheet for 5.25-inch WORM or erasable optical disk changer DISC INN N-556W. **(EL)**

O'Malley [89], doc 97

Christopher O'Malley, "What's New In Scanning?," *Personal Computing*, March 1989, pp. 103–110.

Gives a review of the current state of scanners and their capabilities. Both the dithering process and true gray scale are defined and compared. Gray-scale scanners are said to produce better results and provide sharper pictures with much more control of the image. Large file size and long printing times are listed as two drawbacks to gray-scale scanning. Newly created software and improved earlier packages are providing the capability to edit gray-scale images and control their quality. Two new products are described which will allow for the printing of gray-scale files on a standard laser printer. **(PL)**

O'Neill+ [84], doc 7

Sue S. O'Neill and Constance Carter, "Optical Disk Technology, a Brief Guide to Materials in the Library of Congress," *LC Scinece Tracer Bullet*, December 1984

There are no annotations in this 8-page bibliography. It covers books, conference proceedings, LOC materials, abstracting and indexing services, journals, and selected journal articles and technical reports. **(GMVTS)**

OCLC [88], doc 71

OCLC Inc., "Term Weighting in Document Retrieval," *Annual Review of OCLC Research*, July 1987–June 1988.

Two methods are given to improve weighting schemes by using relevance information from a set of queries. The first method estimates parameter values of two independence models in information retrieval: the binary independence model and the nonbinary independence model. The estimated parameters are used to calculate optimal weights for terms in a different set of queries. Performance of this estimation is compared with the inverse document frequency method, the cosine measure, and the statistical similarity measure. The second method is the learn optimal weights of the nonbinary independence model adaptively by a learning formula. For both methods, experiments were performed on three different document collections, CISI, MEDLARS, and CRN$NUL, and results are reported. Both methods show improvements compared with existing weighting schemes. Experimental results show that the second method gives slightly better performance than the first, and has simpler implementation. Principal investigator is Clement T. Yu. **(author)**

Ohr [85], doc 41

Stephen Ohr, "Magneto-Optics Combines Erasability and High-Density Storage," *Electronic Design,* July 11, 1985, pp. 93–100.

This article describes the magneto-optic erasable disk technology, and also emphasizes the relationships among coating defects, error detection, recording density and transfer rate. Introduces the ATG disk format which can be applied to erasable and nonerasable disks. **(JEE)**

Ono [89], doc 199

Yoshio Ono, "High-Definition Color Laser Plotter CLP-300," SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 9–16.

This paper discusses CLP-300, a color laser plotter which uses a rotating cylinder scan method. It permits fast recording of high quality color images and offers various colors and can control the different tones. Finally its resolution is as high as 2,000 lpi. **(JEE)**

Optimem [88], doc 313

Optimem, 297 North Bernardo Avenue, Mountain View, California 94043.

Specification sheets for Optimem disk drives: 4000 series, 2400M, 1000M. **(EL)**

Panasonic [88], doc 289

Panasonic Industrial Company, Secaucus, New Jersey, 1988.

Specification sheet describing the FX-RS505 and FX-RS506 image scanners. **(PL)**

Patterson+ [82], doc 101

David A. Patterson and Carlo H. Sequin, "A VLSI RISC," *IEEE Computer*, 1982, pp. 8–21.

Discusses the Very Large Scale Integration Reduced Instruction Set (VLSI RISC) which explores alternatives towards architecture complexity. This approach is believed to reduce design time errors and execution of individual instructions. Some of the following restrictions placed on this architecture are: only one instruction could be executed per cycle, all instructions should be the same size, memory can only be accessed by load and store instructions and the rest can be manipulated between registers and it could support high-level languages. **(JEE)**

Perry+ [83], doc 132

J. Randolph Perry, B. G. Thompson, E. V. Staab, S. M. Pizer, and R. E. Johnston, "Performance Features for a PACS Display Console," *IEEE Computer*, Volume 16, Number 8, August 1983, pp. 51–56.

For medical purposes, "the display viewing surfaces, or screens, should be approximately 18 inches on a side, or 25 inches diagonally, and have a spatial resolution of 2048 by 2048. There should be at least three screens to hold 16 512-by-512 images (4.5 inches each). **(GMVTS)**

Plasmon [88], doc 311

Plasmon Data Systems Inc., San Jose, California 95134

Specification sheet for Plasmon 471/942 and Plasmon 201/402 5.25-inch WORM disks. The disk use Plasmon's own proprietary "moth-eye" technology and is running by Panasonic disk drive. **(EL)**

Podilchuk+ [89], doc 168

C. I. Podilchuk and R. J. Mammone, "A Comparison of Projection Techniques for Image Restoration," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 303–310.

Compares various projection techniques which are examples of the projection onto convex sets (POCS) method of restoring details to degraded images. Two categories of methods project onto linear subspaces. The first, row-action restoration, projects iteratively on one hyperplane at a time. The second, block-action methods, project onto the center point of multiple hyperplanes for each iteration. The hyperplanes are represented by linear sets of equations that take into account common degradation factors (such as noise and measurement inaccuracies). Image restoration techniques can be extended by incorporating nonlinear constraints (such as nonnegativity). A new signal restoration algorithm, based on both existing methods, is presented and through simulation is shown to produce better results than the older methods. **(PL)**

Popoff+ [84], doc 136

Philippe Popoff and Jean Ledieu, "Towards New Information Systems: Gigadisc," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 20–26.

Introduces optical disks from Thomson-CSF company. It discusses the potentialities of the optical technology. The access times of the Thomson-CSF disk are included in the paper. **(EL)**

Pountain [89], doc 90

Dick Pountain, "Digital Paper," *Byte*, February 1989, pp. 274–280.

Discusses digital paper which is a flexible optical recording medium made from a sandwich of thin polymer films. This film, called Melinex, is made from polyester by Imperial Chemical Industries, one of the largest chemical companies in the world. **(JEE)**

Preston [89], doc 172

Kendall Preston Jr., "The Abingdon Cross Benchmark Survey," *IEEE Computer*, July 1989, pp. 9–18.

The widely differing applications of imaging applications and the widely differing computer architectures available for performing image processing make performance benchmarks very difficult to achieve. Traditional benchmarks fail to characterize image processors. A special image has been devised, the Abingdon Cross, which embeds the image of a symmetric, square cross (such as that on the Swiss flag) against a noisy background. The benchmark task is to determine the medial axis—that is, the center line that resembles a plus sign (+). Vendors were free to apply whatever algorithms were considered to be the best application of their hardware to the stated problem. The intent of the benchmark is to test "(1) input/output, (2) matrix and/or vector operations, (3), Boolean operations, (4) filtering, and (5) cellular logic." (p. 12) Results from 39 commercial and 12 noncommercial systems are reported. The testing has revealed quality factors scaled from 10^0 to 10^5 and price performance factors scaled from 10^{-1} to 10^3. "The almost 1,000 : 1 ratio of PPFs for these systems is nothing less than astounding and illustrates the enormous increase in performance per dollar that has occurred over the past decade without a sacrifice in speed." (p. 17) **(GMVTS)**

Price [84], doc 5

Joseph Price, "The Optical Disk Pilot Program At the Library of Congress," *Videodisk and Optical Disk*, Volume 4, Number 6, November/December 1984, pp. 424–432.

Describes the Library of Congress' critical need for a storage media to reduce storage requirements and to preserve such items as books, maps, newspapers, video recordings, audio tapes and drawings. Early applications of optical disk technology at the Library of Congress are discussed, but the major emphasis is on the optical disk pilot program (1983-1985). The nonprint and print components of the project are discussed in terms of scope, equipment used and matrix management used for evaluating the project. **(PL)**

Prokupets [88], doc 27

Elena A. Prokupets, "Electronic Photoimaging: The Management of Color Images," *IMC Journal*, September/October 1988, pp 44-46.

An imaging system integrator, Edicon, has assembled a system with a video camera, a system unit, and a color video monitor to maintain databases of color images. Experience suggests that 80 percent of an information system's queries can be satisfied with formatted data, but that 20 percent require access to original documents. The document accesses can be greatly facilitated by an imaging system. Potential users of such systems include security and law enforcement agencies, real estate firms, or auctioneers and dealers. **(GMVTS)**

PTO [n.d.], doc 297

U.S. Patent and Trademark Office, Crystal City, Virginia.

Brief description of the Automated Patent System and its system architecture. **(PL)**

Quinn+ [83], doc 188

John F. Quinn, M. L. Rhodes, B. Rosner, "Data Compression techniques for CT Image Archival," SPIE: *Picture Archiving and Communication System (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 209–212.

Introduces a simple compression technique applied on medical images which are 12 bits per pixel. By partitioning the pixel into two groups (bytes) and packing pixel on a byte basis, the technique can achieve as much as 50-percent compression. **(EL)**

Rasure+ [89], doc 152

John Rasure, S. Hallet, and R. Jordan, "A Comprehensive Software System or Image Processing and Programming," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 37–45.

The authors discuss XVision—a research effort to produce a productive and scientific work environment. XVision uses current standards and works on the development of new standards. It also researches different possible user interfaces. Finally, a new programming language is being developed to simplify scientific and research development. **(JEE)**

Reid [85], doc 44

T. R. Reid, "An Inside Look at Computer Memory," *Lotus Magazine*, May 1985, pp. 11, 51–54.

Reid describes six types of memory storage devices: laser disk, tape cartridge, floppy disk, hard disk, microdisk, and memory chip. The read-write mechanism of erasable optical disk is described on p. 11. **(JEE)**

Ricoh [88], doc 290

Ricoh Corporation, San Jose, California, 1988.

Specification sheet describing the RS-312 and RS-320 image scanners. **(PL)**

Ricoh [89], doc 318

Specification sheets for Ricoh RJ-5160 5.25-inch WORM disk jukebox, RS-F series 5.25-inch WORM disk drive, and RO-5030E rewriteable optical disk system. **(EL)**

Rijnsoever+ [84], doc 140

R. C. van Rijnsoever, J. P. J. de Valk, and A. R. Bakker, "A Layered Storage Structure for Images Confronted With the Use of X-ray Images In a Hospital," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 49–52.

Tells of a 1984 study done by a group of Dutch hospitals to help deal with the increasing use of images and the problems they cause, such as the lack of storage space, being misplaced, and only being available one place at a time. Called the IMAGIS project, the study concentrated on the various aspects of a Picture Archiving and Communication System (PACS) which contains a digital storage of images. Issues that were raised concerning a digital image system were the acceptance of change by personnel, the current data flow structure, the communication of images over a very high speed broadband network, and the need of high resolution display stations. Using 256 level gray capture, it was estimated that the total necessary storage after compression was 6000GB. The storage would be handled on off-line optical disks which would be manually placed into a disk drive when necessary. A three layer configuration was considered with the lowest layer containing all disks off-line for long term storage, the middle layer acting as a buffer and containing images on-line which have a high probability of being requested, and the top layer containing images that are constantly used so they are temporarily stored at the local workstations. Various parameters which affect performance are:

- capacity of disk drive and size of the buffers
- access time to the various layers
- transfer rates between the layers
- configuration and protocol of the network
- search method applied
- storage method applied

Since these parameters are dependent upon each other and some are likely to change with time, a simulation model was constructed with adjustable parameters. By using current parameters as the base and then choosing different values as needed, the optimum configuration can be attained. (PL)

Rinehart [89], doc 198

Charles E. Rinehart, "Design Criteria for an Input Color Scanner Evaluation Test Object," SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 2–8.

Discusses the necessity for and the design of a color test target. During the reproduction of a color image, there are three significant problems:

- radical differences in the lightness and darkness dimensions and in color saturation between the original and copy due to differences in material
- significant differences between the ink which produces the original and the printing inks used to make the copy
- the spectral sensitivity of color scanners vary from one to another

By comparing the output of a scanner to a properly designed color test target, the image manipulation functions of a scanner can solve these problems by making the necessary adjustments so that the colors will visually match. A properly designed target will check that the scanner has the ability to do proper grey balancing and is capable of discerning the complete range of colors. A new test target was designed that contains the following scales and patches:

- a 20-step neutral scale which provides a comprehensive visual evaluation of tone-compression effects
- a 12-step color scale for the following colors—cyan, magenta, and yellow; red, green, and blue (CMY-RGB)
- another 12-step neutral scale that is selective in using only the CMY dyes used in the original photographic color material
- 120 color patches, which cover the entire range of colors by having 10 variations in lightness and saturation for 12 different hues
- 12 additional patches to cover the typical flesh tones

A different test target is required for each original color material and for each different set of dyes. (PL)

Rivenbark [89], doc 115

Leigh Rivenbark, "Optical Disk Technology," *Federal Computer Week*, April 10, 1989, pp. 25–26.

The lack of standards is an impediment to Government utilization of 12-inch optical disks, but, due to functional requirements, projects are moving ahead regardless. The Army is pursuing two initiatives, a basic records effort in Sacramento and a personnel file project in St. Louis. The Sacramento project will assess image management in a LAN environment; the St. Louis project will involve microforms. A standardized requirements contract is expected from the Army in about three years that will use experience from both these efforts. The Navy has three projects, one associated with the 1992 recompetition for the Shipboard Nontactical ADP Program (SNAP), one with the 1992 procurement for the Computer-Aided Technical Information System, and the Engineering Data Management Information and Control System (EDMICS). Behind much of the Navy's interest is the concept of the paperless ship—a notion that may ameliorate problems associated with 38 tons of paper on a cruiser, 20 tons on a frigate, and 10 tons on a submarine. The U.S. Mint has a scanner and 12-inch jukebox application in a transaction processing environment, and NASA is organizing a 15 terabyte system to support the Hubble space telescope. **(GMVTS)**

Robichaud+ [89], doc 204

Joseph. L. Robichaud, John P. Hogan, and Robert Gonsalves, SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 105–114.

Analyzes the spacial uniformity of a laser printer called laser writer copy with the use of PC based image processing techniques. The outcome of this analysis produces quantitative values representing a certain frequency interval or obtaining the energy perceived by a human observer. **(JEE)**

Robinson [88], doc 28

Phillip Robinson, "The Paper Chase," *PC/Computing*, November 1988, pp. 164–179.

A detailed discussion on Optical Scanners which covers the difference between graphic scanning and text scanning, different scanner types, importance of resolution, various types of graphic images and the functions of the Charged Couple Device (CCD). **(JEE)**

Robinson [89], doc 217

Phillip Robinson, "Easy Reading," *Byte*, May 1989, pp. 203–208.

Gives a product comparison between Calera's TrueScan and Caere's OmniPage character recognition software packages. The differing capabilities and different technologies used are described. To test both products, nine different sample documents were scanned and then character recognized. The results of the test and the strong points of each software are all fully discussed. **(PL)**

Rosch+ [89], doc 208

Winn L. Rosch and Kellyn S. Betts, "Multiscanning Monitors for VGA and Beyond," *PC Magazine*, May 16, 1989, pp. 94–147.

The authors discuss different multiscanning monitor conventions, including 800-by-600 Super VGA and 1,024-by-768 noninterlaced mode. The authors explain the frequency range of multiscanning monitors and the factors affecting their resolution (bandwidth, dot pitch, and convergence). The authors review 19 multiscanning monitors ranging from $595 to $1,399 in price. The authors also point out that the street price for monitors is typically half the retail price. **(JEE)**

Rothchild [88], doc 300

Rothchild Consultants, "Optical Storage Technology Tutorial Workbook," San Francisco, California, February 1988.

This workbook is a complete, detailed tutorial of optical storage technology. The subjects covered include disk drives, writable optical disk media, key enabling technologies, optical card drives, optical tape drives, system integration issues, and optical disk-based document management system technology. **(EL)**

Russell [87], doc 253

Pam Russell, "Digital Imaging at DARPA," *Inform*, November 1987, pp. 20–21.

Because of the technical complexity of the program, and the geographic dispersal of participants, the project of Autonomous Land Vehicle (ALV) of DOD need the digital imaging system to handle and distribute large streams of text and images. The system includes PC-based work stations, a video camera, an image compression system, hard copiers and a high power, satellite-based teleconferencing system. A special customized color capturing and compressing device also developed by Diversified Technology to get 15 : 1 compression ratio with very minor degradation in image quality. (EL)

Rutherford [84], doc 142

Harold G. Rutherford, "The Differences and Similarities for Archiving Images from Medicine, Document Storage, Satellite Imagery, Seismic Exploration, Astronomy and General Image Processing," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 59–65.

Points out the need for image storage and database management for a wide range of image applications (medicine, document storage, satellite imagery, seismic exploration, and astronomy). The three common problems to all image systems are the acquisition of images, the distribution of images, and the archival and recall of images from archives. Though the actual means of acquisition of the images and the functional use of the digital imagery are each dependent upon the application, concerns such as interfaces to network buses, erasable/nonerasable media, error rates for optical disks, and error correction to maintain accuracy, can all be used identically in different applications. The basic components of an image management system are:

devices—	for analog or digital capture, such as video cameras, CCD cameras, and drum scanners
digital alternator/lightbox—	will display and enhance images on its own parallel bus and not use the host computer bus except to access the database
archive media—	usually very diversified due to the variety of media (cartridge, magnetic tape, magnetic disk, or optical disk), cost of storage per image, and the recall time per image
workstation—	consists of high-resolution display, ability for monochrome and/or color viewing, disk for local storage, and interfaces (such as mouse or touch-sensitive screen)
system—	consists of host, system, and database disks, backup facilities, printers, and terminals
network—	facilities for image acquisition, dissemination of images throughout the system, and transmissions outside of the system

The article describes software components which correspond to each of these hardware components. For example, security and database access are both software issues relating to system hardware. **(PL)**

Sabelhaus [88], doc 40

Linda Sabelhaus, "CD-ROM Use in an Association Special Library: A Case Study," *Special Libraries*, Spring 1988, pp. 148–151.

The American Society for Training and Development (ASTD) replaced their dial-up ERIC search service with a CD-ROM issuance of the same database. They found that installation procedures were documented with an orientation towards computer professionals, but that the process went reasonably well notwithstanding. They were more satisfied with CD-ROM searching than with dial-up use. Response times were better, the connect-time clock wasn't operating, and the system was available whenever it was desired. More searching is being done, and the higher search volume is cheaper on CD-ROM than would be the equivalent dial-up searches. The user community has appeared satisfied by the new service arrangements. (GMVTS)

Salton+ [83], doc 55

Gerard Salton, E. A. Fox, and H. Wu, "Extended Boolean Information Retrieval," *Communications of the ACM*, Volume 26, Number 12, December 1983, pp. 1022–1036.

A new, extended Boolean information-retrieval system is introduced that is intermediate between the Boolean system of query processing and the vector-processing model. The query structure inherent in the Boolean system is preserved, while at the same time weighted terms may be incorporated into both queries and stored documents; the retrieved output can also be ranked in strict similarity order with the user queries. A

conventional retrieval system can be modified to make use of the extended system. Laboratory test indicate that the extended system produces better retrieval output than either the Boolean or the vector-processing system. **(author)**

Salton [86], doc 52

Gerard Salton, "Another Look at Automatic Text-Retrieval Systems," *Communications of the ACM*, Volume 29, Number 7, July 1986, pp. 648–668.

This paper is a response to Blair+ [85]. Alton argues that the Blair and Maron results fit within the spectrum of experimental results developed over several decades of studying retrieval system performance and that the results should not have been characterized as poor. Major exception is taken with the Blair and Maron conclusions on the superiority of manual indexing approaches over automated indexing systems. System techniques are reviewed that might be used to alter the performance characteristics leading to findings such as cited in the Blair and Maron study. **(GMVTS)**

Santos [89], doc 201

Richard P. Santos, "Update on Ink Jet Proofing," SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 88–93.

Discusses ink-jet printers manufactured by a company called Iris Graphics Inc.—the leading supplier of continuous ink jet systems. The printers discussed are the 3000 series. **(JEE)**

Scan-Graphics [n.d.], doc 292

Scan-Graphics Inc., Broomall, Pennsylvania.

Phone conversation to discuss the CF-500 and CF-1000 engineering drawing scanners. **(PL)**

Schaphorst+ [82], doc 79

Richard Schaphorst and Steve Urban, "Measurement of Compression of the Modified Read Code II," *National Communication System*, November 1982.

The article describes the works of measuring compression ratio and scan line statistics for the Modified Read Code II (MRCII), a prime candidate for use in the CCITT Group 4 equipment. The MRCII is the same as the code defined in the CCITT recommendation T.4 with the following exceptions: the K-factor is infinite; the minimum scan-line time is zero; no end-of-line (EOL) code appears between scan lines; two EOL codes appear at the end of a transmitted page. When comparing Group 4 MRCII to Group 3 standard, the compression ratio improves 70 percent, and the average bits/line and total transmitted bits decreases 37 percent. The compression ratio increases linearly as a function of resolution and decreases as document complexity increases. **(EL)**

Schatz [89], doc 106

Willie Schatz, "Patent and Trademark Office Finally Sees the Light," *Datamation*, March 15, 1989, p. 72–76.

The imaging system at the Patent and Trademark Office is seen as having solved most of its technical problems and as being ready for forward progress. Major issues with cost overruns, missed schedules, system failures, configuration management, and I/O errors are under control. Remaining obstacles are primarily in the area of workstations which have never met specifications and are now becoming obsolete. **(GMVTS)**

Schnaidt [89], doc 75

Patricia Schnaidt, "X.25 Exposed, Low-profile X.25 is a Cost-effective Way to Connect Remote LANs," *LAN Magazine*, January 1989, pp. 80–88.

CCITT's X.25 standard on wide-area packet-switched communications has been widely used in Europe, but it is only starting to gain popularity in the United States; reliable and less expensive leased lines have been available in the United States. Several advantages of X.25 are earning wider usage in the U.S.: 100-percent connectivity, international connection, any-to-any connection, cost, transparency, data integrity, access control, and speed. Fifteen commercially available X.25 gateways are compared; they range in price from $550 to $15,000. **(GMVTS)**

Seikosha [n.d.], doc 303

Seikosha America Inc., 1988, pp. 1–4.

This is a company specification sheet that discusses the Seikosha VP-3500 video analog printer. (JEE)

Sharp [88], doc 293

Sharp Electronic Corporation, Mahwah, New Jersey, 1988.

Specification sheets describing the following scanners: JX-450, JX-300, and JX-100. (PL)

Shatzer [83], doc 181

Robert R. Shatzer, "Local Area Network Upper Level Standardization," SPIE: *Picture Archiving and Communication System (PAC II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 151–159.

Discusses data communications and computer networks standards. Some of the standards committees mentioned are International Organization for standards (ISO), American Standards Institute (ASI) which are both working on Open System Interconnection (OSI). These standards and protocols allow character echoing, error control, source addressing and encryption. (JEE)

Sherer [88], doc 15

Paul M. Sherer, "OCR Makers, Users Faces Numerous Challenges," *PC Week*, November 21, 1988, pp. 101–102.

Discusses some of the present challenges of character recognition and some of the possible future improvements. The specific cited problems were text recognition due to kerning, ligatures, and proportional spacing; columns of text; graphics intermixed with text; and dot-matrix or laser printed type. The areas of improvement to character recognition include trainable character recognition software to recognize new fonts, faster microprocessors to reduce character recognition speed from 40 to 15 seconds, and neural networks to allow good recognition of handwriting. (PL)

Shoch+ [82], doc 100

John F. Shoch, Y. K. Dalal, D. D. Redell, and R. C. Crane, "Evolution of the Ethernet Local Computer Network," *IEEE Computer*, Volume 15, Number 8, August 1982, pp. 10–26.

The history and design decisions leading to the Ethernet specification are reviewed. The paper includes the Ethernet 1.0 Technical Summary and discusses each component of an Ethernet network. (GMVTS)

Silver [89], doc 84

David Silver, "The PC Puzzle: Soon to be Solved for Document Image Processing," *Inform*, June 1989, pp. 14 and 53.

Silver, the president of Kofax Image Products, argues that the fundamental hardware technologies to deliver integrated document imaging systems are in place. "The compression and decompression, scanning, printing, and display components have been reduced to board-level products designed around industry-standard AT and Micro Channel platforms." (p. 14) The missing link to unlock the potentials of this technology is software. A threefold need is seen: software libraries, and environment standard which appears to be being met by Microsoft Windows, and a database standard which is expected within the year. (GMVTS)

Simpson, D. [89a], doc 254

David Simpson, "Is Write Once the Right Choice?" *Systems Integration*, May 1989, pp. 42–48

This informal survey article quotes several systems integrators on the salient features of WORM technology integration. Hardware integration is seen as very straightforward, and software integration is viewed as involving significant difficulties. The critical factor is the management of seek times. Slow access times continue to reduce the acceptability of optical disks, but many applications do not really need the faster I/O rates. (GMVTS)

Simpson, D. [89b], doc 255

David Simpson, "SCSI-2 Debuts to Mixed Reviews," *Systems Integration*, June 1989, pp. 36–41.

SCSI-2 standards, though not yet formally promulgated, are seen as sufficiently mature, for vendors to have begun implementations. Only a few products are actually being delivered, and there appears to be reluctance on the part of OEMs and integrators to use the new technology. SCSI-2 promises up to 32-bit band widths and data rates up to 40 Mb/sec, but most applications at least learned to live with slower rates sufficiently well that they are not demanding higher speeds. DASD manufacturers may well be the first to use the new interface to provide ganged device controllers for very high speed data access. The article is accompanied by Skinner [89] **(GMVTS)**

Simpson, D. [89c], doc 262

David Simpson, "Real-Time RISCs," *Systems Integration*, July 1989, pp. 34–38.

RISC (reduced instruction set computer) chips are, in general, much faster than CISC (complex instruction set computer) chips. Not all the speed improvements, however, are available to real-time applications. RISC chips rely on cached memories for instruction storage, and it is a question of probability whether or not a particular instruction resides in cache or requires additional memory access time to execute. The resulting variability can mean that occasional executions are too slow for timing-critical real-time applications. Also, the RISC chips make use of a larger number of registers and, accordingly, require a larger effort to change machine contexts. Applications which are not affected by these pressures can achieve markedly better execution times, but other applications must avoid RISCs altogether or they must program RISCs in nonstandard modes which remove some, but not necessarily all, the benefits of RISC computing. Several real-time operating systems or operating system kernels are now being shipped by software vendors, and several more will be implemented and available by the end of 1989. **(GMVTS)**

Simpson, R.+ [87], doc 102

R. O. Simpson and P. D. Hester, "The IBM RT PC ROMP Processor and Memory Management Unit Architecture," *IBM Systems Journal*, Volume 26, Number 4, 1987, pp. 346–360.

The ROMP processor is the microprocessor used in the IBM RT PC. It is a 32-bit processor with an associated memory management unit implemented on two chips. ROMP is derived from the pioneering RISC project, the 801 Minicomputer at IBM Research. This paper describes some of the trade-offs which were made to turn the research project into a product. It gives an introduction to the architecture of ROMP, including the addressing model supported by ROMP's memory management unit. Some of the unique features of the programming model are explained, with high-level language coding examples which show how they can be exploited. ROMP's architecture is extendible, and the fact that almost all programming for the RT PC has been in high-level languages means that the RT PC hardware architecture can be extended as needed to meet future requirements while preserving the investment in existing software. ROMP stands for Research/OPD (Office Products Division) microprocessor. **(author)**

Skinner [89], doc 256

David Skinner, "The Sequel," *Systems Inegrations*, June 1989, pp. 42-47.

This paper, a companion article to Simpson [89b], focuses on the Common Command Set (CCS) which is a part of the SCSI-2 standard. Though a prominent feature in the standard, the CCS is only a part of SCSI-2, and vendors who support only CCS and not the rest of SCSI-2 may represent a danger to unwary users. The proposed SCSI-2 protocols and commands are reviewed. **(GMVTS)**

Smith [88], doc 29

Sally Smith, "Document Imaging: A Promising Prototype at the VA," *Federal Focus*, November 1988, pp. 5 and 18.

Describes an optical disk system integrated at the Veteran Administration's headquarters by American Management System (AMS). AMS recommended Filenet hardware and software for the VA's imaging system. The system is designed so that, using a windowing technique, the adjudicator can view a file at one terminal and then access the accounting system resident on the Honeywell mainframe in Chicago. Using the optical disk system, this paper-bound agency is more responsive and more efficient. The crucial hardware components are the scanners used in the mailroom to create an exact image of each form submitted. The images are stored on optical disks which in turn are stored in jukeboxes. Some advantages to this system are that files can be easily found and quickly retrieved, unlike searching stacks of paper. Also, this multiuser system can queue a workload by priority. **(JEE)**

Sony [88], doc 301

Sony Corporation, "Writable Optical Disk Systems: Sony Century Media," Park Ridge, New Jersey, 1988.

This specification sheet introduces Sony's WORM Disk System. It includes WDM-3DLO Writable Disk (CLV), WDM-3DAO Writable Disk (CAV), and WDD-3000 Disk Drive, WDC-2000-10 Writable Disk Controller, WDA-3000-10 Writable Disk Autochanger. (EL)

Sony [89], doc 314

Sony Corporation of America, 5665 Flatiron Parkway, Boulder,Colorado 80301.

Specification sheets for rewritable disk model EDM-1DA0/EDM-1DA1 and erasable disk and disk drive models SMO-D501, SMO-C501, SMO-S501. (EL)

Spiegelman [89], doc 333

Lisa L. Spiegelman, "EISA Members Demo Chips, Reveal Computer Specs," *PC Week*, July 17, 1989, p. 5.

This article reports the intitial demonstration of the Extended Industry Standard Architecture (EISA) chip set. The industry consortium behind EISA is offering it as an alternative bus architecture to IBM's Micro Channel Architecture (MCA). The demonstration demonstrated that the product is real, but not all features were announced for the session. According to demonstration coordinators, all functions have been implemented and are being tested in sponsor facilities. (GMVTS)

Stahlie+ [84], doc 148

T. J. Stahlie and R. A. Falkenburg, "A Digital Optical Recorder (DOR) for Application in Harsh Environments," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 86–92.

Hoping to move optical disks out of the computer room and office environments, Hollandse Signaalapparaten B.V. has developed a ruggedized version. They have incorporated "full mil-spec [military specification] Signaal multilayer PCBs [printed circuit boards]," "air-bearings for sled-movement and lens-movement," and "shock-absorbing mounts" (p. 88). The disk is a Philips 12-inch using air-sandwich glass and capable of storing 1GB on each of its two sides. (GMVTS)

Stanfill+ [86], doc 50

Craig Stanfill and Brewster Kahle, "Parallel Free-Text Search on the Connection Machine," *Communications of the ACM*, Volume 29, Number 12, December 1986, pp. 1229–1239.

The Connection Machine is a parallel computer consisting of up to 65,536 separate CPUs. Each component CPU has 4,096 bits of memory and processes exactly 1 bit with each machine cycle. Documents are organized as fixed length records using *surrogate coding* (analogous to superimposed coding, multiattribute hashing, or signature files from other contexts), in which each individual term is hashed into a fixed-number-of-bits pattern and the complete set of terms for a document is combined using a logical OR operation. The resulting files may be read sequentially by the parallel processors of The Connection Machine at very high speed. "For a database of 18MB (31,994 documents) on a 16,384-element machine, the measured time to execute a query varies from 0.004 second for a Boolean query with 25 terms to 0.295 second for a Boolean query with 20,000 terms (computer time only). For a 15GB database, the estimated time to execute a query varies between two minutes for a Boolean query with 25 terms to three minutes for a Boolean query of 20,000 terms (compute plus I/O time)." (GMVTS)

Stanton [87], doc 30

Tom Stanton, "Scanners Take Off," *PC Magazine*, October 13, 1987, pp. 185–321.

Describes scanner technology and its relationship to character recognition and fax technologies. Discusses in detail the CCD, image processing, halftones, dithering, gray scale, formats and storage. Reviews more than 30 scanners—the advantages and disadvantages of each. (PL)

Stanton [89], doc 99

Tom Stanton, "Scanners Build a Better Image," *PC Magazine*, March 28, 1989, pp. 187–258.

Gives a brief overview of current scanning technology as it applies to image capture, character recognition, fax, and other evolving applications. After briefly discussing the mechanics of a scanner, the methods of dithering and true gray-scale capture are compared. Matrix matching and feature extraction, the two major methodologies of character recognition, are also described. The article concludes with a discussion of how to choose the correct scanner to fit the application. Some factors to consider are price, paper feed mechanism, need for color or true gray-scale capture, printing concerns, and editing software. Also included is a review of more than 21 scanners from both the image and character recognition markets. **(PL)**

Steele [86], doc 31

George Steele, "The IDMS Factor," *Journal of Information & Image Management*, August 1986, pp. 18–22.

Discusses various approaches to an image-based records management system and the need to allow for an open architecture. The article deals largely with engineering drawing, oil industry, and conventional record management applications. **(PL)**

Stephens [88], doc 265

Mark Stephens, "Back To Basics," *Infoworld*, December 12,1988–February 13, 1989, pp. 1–7.

Series of articles which discuss the basic issues, technology, and terminology of networking. The seven layer ISO Reference model is presented and briefly described. The advantages and disadvantages of coaxial, twisted pair, and fiber optic cabling is also discussed. The bus, star, and ring topologies are each defined with a more detailed discussion of the Ethernet, Token Ring, and ARCnet implementations. The token passing and carrier sense detection access methods are each defined and described. **(PL)**

Stephenson [89], doc 95

Peter Stephenson, "Writable Optical Drives," *Government Computer News*, February 20, 1989, pp. 61–65.

This report has a general description of WORM disks and erasable disks. It points out the problems of data portability between the drives and the computer operating system, and between different manufacture's drives. It also includes a table of specifications and prices for 22 WORM disk manufactures. **(EL)**

Stone [89], doc 226

M. David Stone, "PC to Paper: Fax Grows Up," *PC Magazine*, April 11, 1989, pp. 94–98, 102–103.

Discusses current fax technology. A brief history of fax devices is provided with the focus on the current CCITT Group 3 and Group 4 standards and how they differ. Both fax machines and PC fax boards are discussed in detail and the advantages and disadvantages of both are provided. Fifteen fax packages are reviewed and the highlights of each are discussed. **(JEE)**

Stover [86], doc 32

Richard N. Stover, "Advanced Engineering Drawing Systems," *Journal of Information & Image Management*, August 1986, pp. 10–13, 23, 44–45.

Discusses the necessity of and different methodologies for the efficient digital capture and storage of documents related to CAD/CAM systems. Uses of digital drawings in industry include the fast handling and distribution of documents and the creation of electronic databases. Five intelligence levels of data capture ranging from simple pixel data to a knowledge-based CAD data handling two dimensional drawings are also discussed. Flying spot and flying aperture, the two basic scanning techniques, are described along with their capabilities and their limitations. Pattern recognition techniques are used for both raster and vector scanning to help improve the capture of an image. To produce good vectorization of a raster image data capture, a process including raster pre-processing, interactive raster editing, peeling methods, and vectorization popstprocessing is used. Generally, nonscaled documents, which comprise most of the engineering drawings, require more specialized handling than scaled documents do. The article concludes with a comparison between raster and vector image storage giving the strong and weak points of each. The author suggests that an ideal system may be configured using both techniques. **(PL)**

Stuck [83], doc 108

Bart W. Stuck, "Calculating the Maximum Mean Data Rate in Local Area Networks," *IEEE Computer*, May 1983, pp. 72–76.

Discusses a IEEE subcommittee's method of calculating the maximum mean data rate of a LAN. Traffic analysis focused on message arriving statistics, message length statistics, and three different access methods (token passing ring, token passing bus, and carrier sense collision detection). Formulas and discussion for calculating the access rate for each method are provided. Using tests to simulate both periods of high and low delay and varying amounts of data, each of the access methods are compared and conclusions are drawn. **(PL)**

Sullivan [89], doc 159

James R. Sullivan, "A New ADPCM Image Compression Algorithm and the Effect of Fixed-Pattern Sensor Noise," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 129–138.

High-speed image compression algorithms that can achieve visually lossless quality at low bit-rates are essential elements of many digital image system. Having compact and consuming minimal power are often the additional requirements for some system. This paper describes adaptive differential pulse code modulation (ADPCM) to meet this requirement. The ADPCM can be implemented at very high data rate in a single custom VLSI chip, and has performance at 2.5 bits per pixel. With a variable rate version of the algorithm called RADC, the bit-rate can achieve 1 bit per pixel, comparable to DCT algorithm. It also shown that this algorithm is relatively insensitive to fixed-pattern sensor noise, making it possible to perform pixel correction on the decompressed image. **(EL)**

Summit [89], doc 46

Roger K. Summit, "Technology Advances for Information Access: Prospects and Impact," *27th Aerospace Sciences Meeting*, American Institute of Aeronautics and Astronautics, Reno, Nevada, January 9–12, 1989.

A history from the point of view of the DIALOG system is presented of on-line searching of scientific and technical information. Information retrieval is seen as a critical technology in a period anticipated to be leaner in aerospace funding and more dramatic in competition. Several specific files of use to aerospace research are reviewed. Emerging technologies are briefly considered: personal computers (electronic mail), optical storage (full text), software (hypertext and new searching techniques, such as term weighting and application of The Connection Machine), ISDN (capacity and fax), and AI/expert systems (searching). These technologies are predicted to lead to improved searching, full text databases, incorporation of graphics, CD-ROM distribution, and greater public access through gateways. **(GMVTS)**

Swanson [63], doc 54

Don R. Swanson, "The Formulation of the Retrieval Problem," in *Natural Language and the Computer*, edited by Paul L. Garvin, McGraw-Hill Book Company, New York, 1963, pp. 255–267.

The notion is explored of what it means to express a retrieval request. Issues of synonymity, relatedness, and proximity are discussed. The huge numbers of linguistic expressions possible with natural language vocabularies are seen as a serious threat to the efficacy of word indexing in full text environments. Applications of subject hierarchies and conventional subject-heading structures are discussed in relation to these issues. **(GMVTS)**

Swastek+ [89], doc 257

Mary Rose Swastek, D. J. Vereeke, and D. R. Scherbarth, "Migrating to FDDI on Your Next Big LAN Installation," *Data Communications*, June 1989, pp 35-43.

Wiring topologies of the new 100 Mbit fiber distributed data interface (FDDI) standard are reviewed. **(GMVTS)**

Sweeney+ [83], doc 190

R. Sweeney, R. Hindel, and H. Blume, "Information and Imaging," SPIE: *Picture Archiving and Communications Systems (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 233–235.

The paper presents a hermeneutical (relating to the study of interpretation) discussion of how imaging transforms which, by mathematical definition, remove information from an image succeed in improving the appearance and interpretability of images. The authors argue that, even though such operations as band-limiting remove raw data, they improve the ability of humans to glean information from them by moving the resulting images closer to patterns which humans have been conditioned to or have learned to interpret. **(GMVTS)**

Tanaka [89], doc 162

Hideshi Tanaka, "Full Color Printer of Sublimation Dye Thermal Transfer," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 172–178.

Discusses a color printer that uses a sublimation dye thermal transfer system used for proof printing. The sublimation dye thermal process is described in detail with descriptive diagrams explaining the process. **(JEE)**

Tanenbaum [81], doc 33

Andrew S. Tanenbaum, *Computer Networks*, Chapters 1 and 7, Prentice-Hall, New York, 1981.

Chapter 1 provides an introduction to what the concept of a computer network is. The structures of both point-to-point and broadcast networks are described and differentiated. The hierarchical architecture of a network is explained as well as the various design issues for each layer of a network. The ISO Reference Model is explained in detail and ARPANET, SNA, and DECNET are compared to it. An introduction to public data networks (PDN) is also provided.

Chapter 7 discusses local area networks (LANs) in detail. LANs are defined and differentiated from other types of computer networks. The majority of the chapter focuses on carrier sense networks and ring networks. Carrier sense networks are defined and the issues of collision detection and contention are discussed. The Ethernet protocol and other collision free protocols such as the bit map, BRAP, MLMA, and binary countdown protocols are discussed and contrasted with each other. Various types of ring networks, such as the token ring, contention ring, slotted ring, and register insertion ring are discussed and compared to each other. **(PL)**

TDC [89], doc 294

Terminal Data Corporation, Alexandria, Virginia, 1989.

Specification sheets describing the following scanners: microfiche (ImageScan IS-3000) and paper (DocuScan DS-2600 and DS-4200). **(PL)**

Teleprint [n.d.], doc 295

Teleprint Corporation, Chelsea, Massachusetts.

Description of the <MAGIC> Markup product. **(PL)**

Tenopir [88], doc 42

Carol Tenopir, "Searching Full-Text Databases," *Library Journal*, May 1, 1988, pp. 60–61.

Full-text databases are being added almost every month to many of major commercial on-line systems. They allows every word in the text to be searched and use inverted index file structures. They use some special search and display features as well as some standards which are currently used for searching bibliographic database. Various type of full-text databases require various search strategies. The use of full-text database can be either as a document locater to enhance bibliographic style search or as a document delivery aid to allow a known article to be located on-line and display or print out the interesting part of the text. **(EL)**

Thompson, N. [89], doc 114

N. J. Thompson, "DIALOGLINK and TRADEMARKSCAN-FEDERAL: Pioneers in Online Images," *Online*, May 1989, pp. 15–26.

A user of the imaging capabilities available through DIALOG's implementation of TRADEMARKSCAN reports her experience. The imaging capabilities are viewed as a major step forward; reservations are expressed, but they are minor in comparison to an overall satisfaction with the service. Among the reservations are: that 37 percent of the database records have images and that 30 percent of these have written descriptions, that there is not yet a provision to search the database by image features, and that image transmission is slow and expensive. "Users who access this file with 300 baud modems should plan to take a second mortgage on their homes." (p. 17) **(GMVTS)**

Thompson, T.+ [88], doc 45

Tom Thompson and Nick Baran, "The NeXT Computer," *Byte*, November 1988, pp. 158–175.

Describes Steve Job's new $6,500 machine called the NeXT computer. This computer which is a Unix based system, was designed initially for the higher education market. Nicknamed the Cube, the NeXT workstation is the result of feedback from an academic advisory council that included researchers and professors from schools such as Carnegie-Mellon, Stanford, and the University of Michigan. Some of the components of this system are magneto-optical (M-O) disk drives, which can hold 300 times the capacity of a conventional floppy disk and supports erasable disks; software tools that make it the easiest to program of any personal workstation to date; and a powerful signal processor chip that can act as a modem, play music, or synthesize the human voice. It also offers usual features of popular technical workstations, such as slick graphics, huge memory, and a variation of AT&T's Unix operating system. **(JEE)**

Thurber [89], doc 258

Kenneth J. Thurber, "Getting a Handle on FDDI," *Data Communications*, June 1989, pp. 28–32.

It is anticipated that applications requirements will soon utilize the full 100 Mbit/sec capacity of the fiber distributed data interface (FDDI). Its token-ring architecture is reviewed. Packets up to 4,500 bytes can be passed among up to 500 stations within a maximum perimeter of 200 kilometers (maximum interstation distance is 2 km). Three of the four standards required for full FDDI specification are firm, and the fourth ex expected in six to 12 months. Current FDDI node prices range up to approximately $20,000, but the author expects prices to drop to the $5,000 to $10,000 range within a year. **(GMVTS)**

Toshiba [88], doc 317

Toshiba America Inc., 2441 Michelle Drive, Tustin, California 92680.

Specification sheets for Toshiba 12- and 5.25-inch WORM disk system, includes WM-070 series, and WM-500 series. **(EL)**

Truvel [89], doc 296

Truvel Corporation, Chatsworth, California, 1989.

Specification sheets describing the following scanners: TZ-3C and TZ-3BWC. **(PL)**

Tsai [89], doc 160

Yusheng T. Tsai, "Real-Time Architecture for Error-Tolerant Color Picture Compression," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 140–147.

This paper presents a practical error-tolerant compression algorithm for recording color picture digitally on a tape and provides a real-time architecture such that the processing of picture compression is implemented in a single VLSI chip. The algorithm is based on the principle of block truncation coding (BTC) and the picture is represented in Y-I-Q color space. **(author)**

UMI/Data-Courier [89], doc 21

UMI/Data-Courier, "Scanning Documents Saves Time and Money," *LOG/ON*, January/February 1989, pp. 4–5.

Tells of Data Courier's decision to use scanning and character recognition devices as a means of updating their full-text database. After spending 18 months reviewing scanning equipment and analyzing their needs, they began using scanning in May 1988. Scanning devices replaced off-shore keying companies and has reduced turnaround time by one third. The advantages of scanning are the savings in time, equipment which is more reliable and easy to operate, and giving the company total control over production. (PL)

Urban+ [80], doc 80

Steve Urban and Richard Schaphorst, "Measurement of Compression Factor and Error Sensitivity Factor of the Modified Read Facsimile Coding Technique," *National Communications System*, August 1980.

This article measures the compression factor and error sensitivity factor for the modified read fax coding technique which was chosen as the standard two-dimensional code for CCITT Group 3 fax equipment. Eight CCITT test documents and five other techniques were tested and compared under various combinations of resolution, K-factor, minimum scan-line time, error phase and error transmission file. A detailed description of coding standards is included in Appendix A.

- o Compression Factor is 4.66 for 100 lpi and 5.64 for 200 lpi.
- o The percentage of overhead to coded data bits is 12 percent for 100 lpi and 16 percent for 200 lpi.
- o The error sensitivity factor (ESF) is 45.24 for 100 lpi and 58.70 for 200 lpi.
- o A full-page A4 document uses approximately 90KB after compression. (EL)

Verhoeven [84], doc 145

J. A. Th Verhoeven, "Standardization activities for optical digital data technology in European Computer Manufacturers Association (ECMA)," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 74–76.

This report discusses the findings of a European standard organization, European Computer Manufacturers Association (ECMA). The objectives of the standards are providing a common understanding between manufacturers and the users and establishing industry acceptable standards. (JEE)

Walter [88], doc 87

Gerry Walter, "An Overview: Technology and Application Status of Optical Disk System," *IMC Journal*, July/August 1988, pp. 10–13.

Walter provides the background and present status, and assesses the near term future, of an Optical Disk-based Document Management System (OD/DMS). This article describes the optical media developments and describes various configurations in comparison tables. The other subsystems—scanners, optical direct-access storage devices (ODASD), library ODASD, system and communication controllers, image display workstations and intelligent copier/printers—are discussed. (EL)

Walter [89], doc 259

Gerry Walter, "What Have We Learned From 12,000+ Installations?" *Inform*, June 1989, pp. 16–20.

This paper has a general discussion of the current stage of optical-based document management systems worldwide. This article contains the following important hints:

- o Currently there are 58 vendors whose system integrate with large computers, and 128 vendors offer PC-based systems. Only very massive configurations are still Mainframe controlled, the trend is toward PC-based system for most configurations.
- o The network systems for desktop computers are either Data PBX (private branch exchange) system or LAN system. If total number of terminal in the system is 32 or less, and each terminal nodes have sufficient buffers, Ethernet is a good choice.
- o In image storage phase, the compression is not a limiting factor, but in retrieval phase, the decompression throughput time becomes an important element in the overall image retrieval time. (EL)

Ward+ [89], doc 166

Joseph Ward and David R. Cok, "Resampling Algorithms for Image Resizing and Rotation," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 260–269.

Image resizing and image rotation are two common applications of image resampling. Resampling is actually a two step process which involves reconstructing the continuous signal from digital form and then resampling the signal at the desired frequency. Three interpolation methods (linear interpolation, sine interpolation, and cubic interpolation) are presented and compared to each other. After testing, cubic interpolation was chosen the best compromise. Two different methods of image rotation (nonseparable and separable) were described and after testing, the nonseparable method was recommended as the best compromise. A method called interpolation with coefficient bins was introduced and described as a means to minimize computation time when performing resampling operations. Results of mean squared error analysis using this resampling method is presented. **(PL)**

Wash+ [89], doc 200

Larry G. Wash and John F. Hamilton Jr., "The Design of a Graphic Arts Halftone Screening Computer," SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 26–60.

Gives an in depth and detailed look at the screening process of a scanner. Screening is the process which transforms multiple bit pixels into halftone dots suitable for printing. The requirements of the screening process are:

- o to actually perform the conversion of gray scale information into binary halftone dots
- o the halftone screen should be adjustable in the range of 65–200 lines per inch (halftone dpi) to get the best image
- o the screen should be adjustable at different angles since larger angular differences between dots reduce moirè patterns

To fill these requirements, a parallel pipelined processor was designed. The processor is dependent on a library of separate reference planes, one for each of the possible gray values. Each plane describes the geometric shape and size necessary to output the gray level as a series of halftone dots. The actual processor is composed of the following four major components:

Image handler— uses the image parameters to determine the relationship between the scanning resolution and the output resolution. Through using this information, it regulates the flow of captured pixel information to be converted into a printer ready halftone dot by determining which reference plane to use.

Screen handler— acting independently yet in parallel to the Image Handler, it is responsible for the generating of the correct halftone bit stream by the actual conversion procedure. It does so by calculating the sampling position vectors within the selected halftone reference plane. By using the correct sequence of sampling points, besides achieving the designed screen ruling and screen angle, the output halftone dots will have the correct shape and will be geometrically arranged with respect to each other.

Bit generator— generates the actual raster output through using the information generated from the Image Handler (that is, which halftone reference plane to use) and the Screen Handler (that is, which bit of the selected halftone reference plane is the output to simulate), as well as halftone font information which details the geometric size and shape of each halftone dot.

Control sequencer— initializes the other components, initiates the screening process, and then monitors it through the use of flags.

Each of these four components are further broken down into subpoints and discussed in full detail. **(PL)**

Webster [88], doc 65

John Webster, "Software Lets Scanners 'Learn' Characters," *PC Week*, October 24, 1988, p. 67.

Discusses the recent advancement of character recognition software being able to learn new fonts. The early problems of character recognition software such as variety of fonts, spacing, columns, graphics mixed with text and high cost are mentioned. Recent advancements have turned optical character recognition into intelligent character recognition by using artificial intelligence to allow software to learn new fonts in about ten minutes. **(PL)**

Weibel [88], doc 72

Stuart L. Weibel, *Annual Review of OCLC Research*, July 1987–June 1988, pp. 5–6.

Discusses a project which integrated optical character recognition with document structure analysis. The use of a markup language is mentioned as a method to provide an effective retrieval system for a full text database. To create a high quality database without doing extensive post-processing corrections, it is suggested that the image be pre-processed to segregate the areas upon which the character recognition is to take place. A sample test using these techniques were applied to 96 catalog cards and the results showed high accuracy. **(PL)**

Weisenberger [89], doc 94

Paul Weisenberger, P. Stephenson, L. Cowan, A. Ruster, and D. Black, "Optical Storage," *Government Computer News*, February 6, 1989, pp. 67–73.

This article mentions numerous topics revolved around optical storage. Weisenberger discusses the use of optical disks in the army and its advantages such as reduction in storage space, deleting and erasing fiche, eliminating duplication and integration of images with the data system. Stephenson discusses a different aspect of Optical Disks storage and that is CD-ROM. He emphasizes that the use of CD-ROM, an establishing publishing medium, on LANs is difficult; however, a small computer interface SCSI makes it a lot easier. Cowan discusses the Optical Digital Image Storage System (ODISS) installed July 1988 by the National Archive and records. ODISS was one of the earliest large-scale test of write once storage and retrieval. After all records are scanned their images will be stored on 35 disks each containing 40,000 digitized images. Ruster discusses a concern facing the imaging world which is the lack of a standard for interfacing mainframes and mini computer hosts. Another concern is that software required to run the optical disk system is developed mainly by integrators as a part of their turn key system but is not available by the manufacturer or vendor. Finally, Black discusses multiscanning storage which combine optical disk system and microfiche. Manufacturers of such systems are Eastman Kodak, Wang, Integrated automation Inc., Alameda and Imnet. An advantage to such a system over optical disk alone is that throughput can exceed by a microfilm camera 1,000 pages per hour. After being filmed and placed on microfiche, the film images can be translated to optical disk. **(JEE)**

Wendling+ [89], doc 202

M. W. Wendling and D. L. Morris, "4CAST Digital Color Imager—The Application of Dye Thermal Sublimation Technology as a Graphic Arts Proofing System," SPIE: *Electronic Imaging Applications in Graphic Arts*, Volume 1073, January 17, 1989, pp. 94–96.

Discusses 4CAST Digital Color Imager which is the first application of thermal dye sublimation transfer technology as a pre press proofing system that is developed by DuPont. The 4CAST system consists of an interface 12-MHz microcomputer, a 180MB hard-disk drive and a monochrome monitor. **(JEE)**

Wetzler [89], doc 211

Fred U. Wetzler, *Desktop Image Scanners and Scanning*, AIIM, 1989.

Topics discussed in this book are scanner history, capability of each type of scanner, list of scanner vendors, glossary of scanner terminology, scanner technology, how it works, matching image scanning software to applications formats and bitmapped versus gray-scale scanners. Wetzler concludes this book by listing in vendor name different scanners, their price and capabilities. **(JEE)**

Williams+ [89], doc 167

Leon C. Williams and Ying-wei Lin, "Halftone Processing in the Xerox 7650 Image Scanner," SPIE: *Digital Image Processing Applications*, Volume 1075, January 17–20, 1989, pp. 270–277.

Discusses three different halftone processing techniques of the Xerox 7650 Pro Imager scanner which enable it to produce high quality output on many different printers from a variety of input documents. Automatic contrast adjustment uses histogram sampling, linear mapping construction, and rescanning while mapping to compensate for low contrast input images. Electronic scanning allows a user to choose or create a screen pattern which is used to convert the gray video captured by the scanner into binary form for the printer. Digital filtering uses a two-dimensional (2D) low-pass filter to alter the spatial frequency content of the scanned image. This allows for edge enhancement and halftone screen removal when scanning halftones. Using contrast adjustment while scanning and digital filtering before the application of the electronic screen produces high quality binary output. **(PL)**

Wood [89], doc 98

Lamont Wood, "Gotcha," *Mini–Micro Systems*, March 1989, pp. 66–73.

Gives a short but thorough overview of scanning technology today from the point of view of a systems integrator. A basic understanding of the CCD and resolution as well as the different characteristics of gray scale, color, bitonal and halftone is scanning is presented. Various common interfaces between the host and scanner are mentioned as well as their affect on speed and price. The principal file formats are mentioned and the need for data compression is stated. The article concludes with a short discussion on the state of color scanners today. A table of scanners and their characteristics is also provided. **(PL)**

Xerox [89], doc 298

Xerox Imaging Systems, Mountain View, California, 1989.

Specification sheet describing the Datacopy AccuText scanner software. **(PL)**

Yochum [88], doc 34

Kathleen Yochum, "Optical Disk Jukeboxes: How They Work, What They Can Do," *IMC Journal*, 1988, pp. 50–51.

Gives a short overview of automated disk libraries (jukeboxes). The emphasis of the article was the components of the jukebox: optical disk itself, disk drive, controller, interface to host computer and robotic disk changer. Various jukebox configurations and the advantages of jukeboxes over other media are also discussed. **(PL)**

Yoshizaki+ [83], doc 177

Osamu Yoshizaki, M. Inai, and J. Yoshimura, "Total Medical Imaging System," SPIE: *Picture Archiving and Communication System (PAC II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 127–132.

Discusses a general medical image diagnosis system developed by radiology department in the Sakura Medical Hospital of Tokyo. This system, which is called DR SMIS (Digital Radiology by Sakura Medical Imaging System), is divided in five sections: The manager or image database (which has the central role), image processor, image input port, image hard copier, and network. **(JEE)**

Zachman [86], doc 47.

John A. Zachman, "A Framework for Information System Architecture," Report *Number G320-2785*, IBM Los Angeles Scientific Center, 1986.

The increased design scopes and levels of complexity of information systems' implementation necessitate the use of some logical construct (or architecture) for defining and controlling the interfaces and the integration of all of the system's components. This paper attempts to establish an independent definition of architecture and to map that definition on to the area of information systems. The conclusion from this research is that "there is not an information system architecture, but a set of them! Architecture is relative, it depends upon what you are doing." For a database administrator, it means data design; for an analyst, it means a data flow diagram, and so on. **(EL)**

Zajaczkowski [84], doc 143

J. Zajaczkowski, "Future Standardization Development Projects within the American National Standards Activities," SPIE: *Applications of Optical Digital Data Disk Storage Systems*, Volume 490, June 25–28, 1984, pp. 68–70.

Discusses the importance to develop and maintain standards for optical media. The standards committee mentioned in this paper is the American National Standards Committee and its goals were to identify areas that require standardization, generate a program of work and generate the appropriate project proposals. **(JEE)**

Zeek [87], doc 260

Robert Zeek, "A Wish List for Digital Document Image Automation," *Inform*, December 1987, pp. 31–33.

The paper contains a compendium of digital document imaging systems users "wishes" assembled by the author. Improved communications speeds and performance monitoring tools to manage better the ones currently in place rank highly. The many forms of compatibility continue to be of considerable interest to many users. **(GMVTS)**

Zeleznik+ [83], doc 196

Michael P. Zeleznik, G. Q. Maguire Jr., and B. S. Baxter, "PACS Data Base Design," SPIE: *Picture Archiving and Communication Systems (PACS II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 287–294.

A PACS database must manage three different types of data: structured data, text data, and images. Queries based on the content of text documents content of images as well as structured keys must be supported. This research group models the PACS database as three logically distinct database, each supporting one of these data types, with mapping structures relating all three. Several database systems have been discussed here. **(EL)**

Zeleznik+ [83], doc 183

Michael P. Zeleznik, G. Q. Maguire Jr., B. S. Baxter, M. E. Noz, J. H. Schimpf, and S. C. Horii, "PACS User-level Requirements," SPIE: *Picture Archiving and Communication System (PAC II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 172–178.

Discusses possible functional levels in PACS, including data archiving, data retrieval, interactive data display, image processing/analysis, data output, personal workspace environment, electronic mail, user help, and data security. **(JEE)**

Zelinger [87], doc 261

Sheila Zelinger, "The Optical Disk Jukebox: and Options," *Inform*, December 1987, pp. 34–38.

This paper discusses optical disk jukeboxes about what it contain, how it works and how to select. It also offers three examples to illustrate the influences of several different elements of jukebox in different type of applications. This paper contains the following important hints:

- When considering a system, performance flexibility, security, and service support are as important as capacity.
- If the access files are large, then more drives may be required to achieve performance requirements.
- Jukebox expansibility and upgradability is important.
- The performance of jukebox must be weighed against its cost. **(EL)**

Zielonka+ [83], doc 178

Jason S. Zielonka, R. S. Hellman, and C. M. Kronenwetter, "Distributed Architecture for Image Acquisition, Analysis and Archiving: Application to Local PACS," SPIE: *Picture Archiving and Communication System (PAC II) for Medical Applications*, Volume 418, May 22–25, 1983, pp. 135–137.

Discusses a Star topology network. The host mode of this network acts as a file server and a system resource scheduler. The other nodes act as acquisition, display, and processing nodes for clinical image data. This system described is available and could be useful for either a small or a large hospital. **(JEE)**

ZSoft [88], doc 118

ZSoft Corporation, *Technical Reference Manual*, San Francisco, California, 1988, pp. 1–22

This technical manual was developed by ZSoft to help programmers and users understand the PCX format. Also discussed in this manual is the use of Frieze which is a utility resident in memory that allows the user to save graphic images from other program. The manual includes the file format layouts and a subroutine written in C that is capable of reading data from PCX files. **(JEE)**