Remote text access in a computerized library information retrieval system

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INTRODUCTION

As part of the Intrex experiments with a computerized model library,1 we are developing an experimental system for accessing the full text of the 10,000 journal articles in the Intrex data base. The essential result of the user dialog with the augmented catalog is the identification of those articles selected as relevant to the user's inquiries.2,3,4 The next step in the library-usage process is to retrieve the text of these articles for reading. The convenience, response time, and quality of the text-access system is likely to affect the extent to which the user negotiates with the catalog before requesting full text. The Intrex system will permit experimentation with the complete machine-aided library operation. The purpose of this paper is to outline the text access problems and our approach to them.

The goals of the text-access system are to provide guaranteed, rapid access to full text at remote locations. Guaranteed accessibility implies a controlled, central store where the text always remains in the system and is available to users at all times. Rapid accessibility at remote locations implies transmission of text in electrical-signal form. Remote accessibility of text and catalog information from locations near the user's working area provides more convenient library use, and in addition is a preliminary step toward realization of a network of computer-based libraries coupled together by data communication links.4,5

Textual images differ from the displays commonly encountered in computer-oriented systems. A page from a typical technical journal contains from 5,000 to 10,000 character spaces and is composed from an unrestricted character set including foreign alphabets, mathematical symbols, and sub- and super-scripts, etc. Text frequently contains graphics and pictorial information with several gray levels, and in some instances, with color. Even the text layout and type font may influence the effectiveness of its information transfer.

These special characteristics of textual images restrict the types of displays that are appropriate in a text-access system. The graphics, photographs, and unrestricted character sets in text lead to raster-scanned displays rather than character- and vector-generated displays. The gray levels in photographs require a display with multi-level intensity. The large number of characters and symbols requires a high-resolution display, and much of our early efforts were aimed at establishing quantitative resolution requirements for textual images.6 A high-resolution color display presents a real challenge to the display designer.

A wide variety of systems have been developed for storing, transmitting, and displaying textual images.7,8 Slow-scan facsimile techniques, where the image is scanned and transmitted over common-carrier lines, is frequently used for document transmission. The Alden/Miracode system is an example which uses microfilm storage and slow-scan facsimile transmission. The disadvantage of these systems or our application is that several minutes are required to transmit each page and there is no capability for rapid scanning of documents before requesting hard-copy. Closed-circuit TV has been used in some systems for remote viewing of text. These systems generally operate at bandwidths of 20 MHz or less which limits the resolution of the displayed image. The Remington-Rand Remstar system is an example of the use of closed-circuit TV for transmitting images from microfilm to remote terminals. This system provides a zoom capability for viewing an enlarged section of the image in order to compensate for the resolution limitations. The Ampex Video File is an example of a system which uses magnetic tape for storage with the capability of providing a soft- or hard-copy output.
The storage and transmission methods adopted for the text-access system are pivotal parts of the system design and the considerations leading to microfilm storage and single-frame transmission are discussed below.

Single-frame transmission

A facsimile-like system, where each page is scanned and transmitted only once per request, has two distinct advantages over a system which continually transmits the image, as is done in closed-circuit TV. With the resolution required to display a full page of text, a TV-type refreshed image requires a video-signal bandwidth of approximately 60 MHz for a flicker-free display. Also, a separate scanner and transmission line is required for each simultaneous user. By providing image storage at the receiving terminals, single-frame transmission can be used which permits a trade-off between video-signal bandwidth and the transmission time per page. If the retrieval and transmission times are short compared to the average reading time, the scanner and transmission network can be time-shared among several on-line users. With a transmission time of two seconds, a 2,000 scan-line image requires a bandwidth of approximately 1 MHz. If the average reading time per page is one minute or greater and the total retrieving and scanning time is 2–3 seconds, reasonable service for a number of users could be provided from a single scanner and transmission network. The lower bandwidth and time-multiplexing capability are the key arguments favoring a single-frame transmission system.

Digital versus facsimile storage

Facsimile storage of text implies that the data base is stored as duplicates such as photographs of the original documents. Digital storage implies that the data base is stored in arrays of binary numbers that can be decoded by a suitable algorithm to reconstruct the original document. An advantage of the digital form is that if the text is properly encoded it may be computer processed for such purposes as automatic extraction of bibliographic information and automatic fact retrieval. For materials containing a limited character set, such as typewritten text, digital encoding can be more efficient in the use of storage space than facsimile storage because much of the page image contains little information. Efficient encoding can also reduce the bits per page that must be transmitted, thus saving on communication cost.

At present, textual material is not readily available in digitally-encoded form and the conversion costs are a significant obstacle to digitally-stored text. Further development of optical character readers or the availability of text in digital form directly from publishers could reduce the cost of preparing the digital store. However, the difficulties in the digital encoding of pictorial information, unrestricted character sets, and various layouts is likely to preclude digital storage for full text in the near future, particularly if no machine processing of the information is required.

The Intrex system utilizes digital storage for the augmented catalog (which requires computer processing) and facsimile image storage on microfilm for full text.

The COSATI microfiche format was chosen as the storage form for textual images because suitable retrieval equipment was available for this form and the reduction ratio required to store an entire page of typical journal article text within one frame of the COSATI grid is compatible with the resolution requirements of the text-access system. Each 4 × 6-inch microfiche contains a maximum of sixty frames and each frame contains an image of one page. The frames are located in five rows, and each row contains twelve frames. To facilitate automatic retrieval and scanning, extra care was taken during the microfilming process to achieve minimum tolerances in the location of the individual page images with reference to the COSATI grid.

Resolution

In the initial phase of the Intrex program, it became apparent that some experimental work was necessary to establish the resolution and the number of scan lines required in the text-access system; therefore an experimental image-transmission system was assembled. It utilized a flying-spot scanner to convert a microfilm image into a video signal which was transmitted over a coaxial cable. At the receiver, the image was reconstructed on a CRT and filmed with a 35-mm camera. This system is illustrated in Figure 1.

![Figure 1—Experimental image-transmission system](From the collection of the Computer History Museum (www.computerhistory.org))
The Modulation-Transfer Function (MTF) concept was used for quantitative resolution measures of the individual components and for relating these to the over-all system resolution. Experiments were conducted in which selected text was scanned and transmitted through the system under various MTF conditions and with different numbers of scan lines. Evaluations of the transmitted images demonstrated that a minimum limiting resolution of 1000 cycles/page and at least 2000 scan lines/page are required for reproducing text from typical technical journals with acceptable image quality. Resolutions or raster scans below these limits produced discernible degradation in the images.

The experimental text-access system

Figure 2 contains a diagram of the text-access system and its connection with the complete INTREX system. The primary retrieval programs and data storage for the augmented catalog are filed within MIT's general-purpose compatible time-shared computer utility (CTSS). The buffer/controller (B/C) includes processing capability for controlling the operating modes of the catalog consoles, and directing the data flow among consoles, and the text-access system. The processor in the B/C, a Varian Data Machines 6201 computer, serves as a systems monitor among the elements of the INTREX system as discussed in References 2 and 3.

The B/C is connected to the text-access-system central station via a 300-bit-per-second half-duplex serial data channel. The terminal equipment is designed to interface with a standard dataphone to permit the use of a common carrier. Because of the rather specialized and limited data requirements of the text-access system, computer words, not characters, are transmitted to the text-access central station.

Software

A flexible software package has been developed for the 6201 to control data flow efficiently and to provide linkage to subprograms that provide special services for the user consoles. As the 6201 dedicated to INTREX has only 4k of core memory, the monitor system will have the capability of storing subprograms on a portion of the 128 track magnetic drum which is used to refresh the console displays.

It is anticipated that requests for text access will be a result of a catalog search. After retrieving a document title the user may wish to check on its relevancy by seeing the first page or to read the entire article. This desire will be indicated by activating a button on the augmented-catalog console which will cause the 6201 to fetch the text-access subprogram into core.

This subprogram will permit the 6201 to carry on a dialog with the user during which he will identify the document he wishes displayed. Initially the user will have to type the access number which he retrieved on a previous catalog search, when the 6201 asks for it. This access number identifies the microfiche and frame numbers that locate the document in the text-access files. This rather laborious procedure will be changed as the software interface between the buffer/controller and CTSS is more fully developed. In the future, CTSS will tag the document access number for the 6201 so that the user need only identify this document either by typing its title or pointing at its title as displayed on the augmented-catalog output with a light pen or cursor. The 6201 would then associate the document with the correct access number.

After identifying the document, the user will be asked whether he desired to see the first page of the article displayed on the direct-view storage-tube display terminal or whether he would prefer a film copy of the entire document. This choice will be indicated by typing C for copy, D for display, or pushing a programmable button.

If the display option is taken, the action will shift to the text-access terminal where the first page of the document will appear in a few seconds. The 6201 will remember the access number and page number of the text displayed on the text-access screen. To view succeeding pages or a magnified image of a sector of the current page the user need only push illuminated buttons located adjacent to the text display unit. These buttons, labeled PAGE-FORWARD, PAGE-BACKWARD, REDISPLAY-SAME-PAGE, MAGNIFY, DISPLAY-CHosen-SECTOR, and SECTOR-POSITION (a matrix of 9 buttons), are illuminated in a programmed sequence to guide the
infrequent user. They are connected through the augmented-catalog console to the buffer/controller. Currently the 6201 maintains a queuing routine for the time-shared central station of the text-access system. Even with only one text-display console a queue is likely to form as the user requests film copies of several documents, while continuing to inspect pages of others on the storage-tube display. With several user terminals operating, a copy queue and a display queue will be formed. At first, priority is allotted to the display queue as it is thought that changing pages on the storage display should be a very rapid operation to facilitate browsing.

As the queues are formed, the 620I checks to see that the access number, whether typed by the user or retrieved from CTSS is valid. This procedure avoids sending erroneous data to the text-access system which could result in delay in the operation of the text displays.

Text-access central station

The central station contains the document store, an automatic retrieval device, a flying-spot scanner, and control logic.

Much attention has been given to the problem of communication between the 6201 computer and the Text Access-System Control logic (TASC logic). Flexible operation is desirable with a minimum of information transmission between the devices. The text-access central station is treated as an output device and the TASC logic is a special purpose processor that actually operates the unit. An output request from the 620I consists of one, two, or three 16-bit computer words that contain the fiche number, a frame number and certain procedural data. The format of these computer words was chosen to minimize the number of words required per request and yet not overly complicate the TASC logic. The TASC logic also sends 16-bit status messages back to the 620I after the completion of every text-access request or in the case of a minor malfunction. A more detailed description of the design and construction of the TASC logic is found in Reference 2.

The microfiche-storage-and-retrieval device

The microfiche-storage-and-retrieval device is a Houston/Fearless Compact Automatic Retrieval Device (CARD) modified to be coupled to a flying-spot scanner and to enable it to be controlled by electrical inputs. The basic CARD unit stores up to 750 microfiche with access times of less than five seconds to any microfiche and one second to any frame on the retrieved fiche. Using the COSATI formatted microfiche, approximately 45,000 pages may be stored on the 750 fiche.

Although systems are available that will randomly access any one of \(10^5\) fiche, no automatic storage and retrieval device is commercially available that will adequately store and access the contents of a complete university library containing more than \(10^6\) volumes. The Houston/Fearless machine was chosen for the initial INTREX experiments because it economically met the requirements necessary for accessing the documents in the INTREX collection and its response time for a limited number of user terminals is quick enough to test the principle of on-line browsing. It is anticipated that the partial specifications for a device capable of storing a much larger collection will be among the results of the INTREX experiments.

The transmission subsystem

The transmission subsystem links the user terminals to the central station via a unidirectional coaxial line. The coaxial line is time shared among the user terminals; therefore provision is made for uniquely addressing each terminal. Synchronizing pulses for the entire system are generated by an oscillator contained in the transmitter section of the TASC logic.

The output of the oscillator is divided to produce a basic clock frequency of 280 kHz which is further divided by programmable counters to produce the horizontal-synchronizing pulses. The number of scan lines is determined by a programmable line counter that counts these pulses. The programmable counters provide the flexibility for switching automatically between user terminals having differing scanning parameters.

The horizontal-synchronizing pulses are transmitted continuously to the user terminal. The time between pulses may be occupied by no signal, or an analog video signal corresponding to one line of an image, or a sequence of pulses representing a digital word. Each frame of video is preceded by two 16-bit digital words and followed by one or two digital words. The digital messages are used to control the user terminals. A 6-bit address code is assigned to each user terminal; thus, commands may be sent to any one of 64 possible terminals while others remain idle. The standard ASCII seven-bit code has been chosen for the commands so that a full character set is available. Commands that operate the receiver terminals such as ERASE, ADVANCE-FILM, and BEGIN-VERTICAL-SWEEP were chosen from the ASCII control characters.

The synchronizing signals, digital address and digital command signals, and the analog video signals are
combined in a line driver for transmission to the user terminals over coaxial cable. Presently baseband transmission is used but the signal format need not be changed if it is decided to utilize a modulated-carrier type of transmission.

A matched filter and threshold comparator in the receiver of each user terminal separates the digital codes from the analog video signal. The decoder functions as an address detector and interpreter of the digital commands. A feature of the video circuitry is the automatic gain control which compensates for slow variations in the system gain which might result from temperature variations and/or changes in the separation distances between transmitter and receiver.

**Textual-image displays**

Library users are accustomed to the traditional forms of textual images, such as books and journals, which provide high-quality images and many other features including portability, browsing capability, gray scale, color, etc. Many of these features are difficult to achieve in a remote display and a completely satisfactory device for displaying textual images is not yet available. Although the text-access display may suffer from comparison with the traditional textual forms, this is offset by providing guaranteed, rapid access to full text at a console conveniently located near the researcher’s working area.

The detailed requirements for the Intrex displays have been reported previously and are reviewed in a companion paper at this conference. The single-frame-transmission feature of the text-access system, requiring image storage at the user terminals, has a significant effect on the types of displays that are suitable for this system. The video signal could be stored and used to generate a refreshed CRT display. However, the bandwidth in excess of 60 MHz required for a flicker-free display with adequate resolution is a serious obstacle to this approach. High-order interlaced scanning reduces the bandwidth requirements somewhat, but some brief experiments performed by our group with pseudo-random scanning indicate that sufficient bandwidth reduction cannot be achieved to make the refreshed textual display practical.

Two types of display terminals are included in the initial system. One uses an electronic-storage tube and the other uses 35-mm film for image storage. The cathode-ray storage tube is an erasable, soft-copy display and the film terminal provides a form of hard copy. The soft-copy display permits rapid access to text because the image requires no processing. A browsing capability requires a response time of at most a few seconds between pages. An erasable storage medium is potentially more economical in cost per page because there is no material expenditure for each display request. If the text is always available within seconds from a central store, it is expected that much of the need for hard copy will be eliminated. Unfortunately, there is no existing transient-display device with the resolution and writing speed required for the text access system, but the direct-view electronic-storage tube comes closest among the currently available devices.

Adequate resolution is achieved with the microfilm-facsimile terminal. The output of this terminal is a 35-mm film strip which is automatically processed in approximately one minute and read with the aid of microfilm viewers.

**Storage-tube display**

A block diagram of the storage-tube display terminal is presented as Figure 3. The terminal consists of two main components, the Tektronix type-611 Storage-Display Unit and the electronics for controlling the display and user inputs. It is designed to be self-sufficient in that it requires no external power supplies.

The storage tube terminal is located adjacent to the augmented-catalog console and is intended to provide a quick-look at full text as a supplement to the catalog searching operations. The limiting resolution of the Tektronix eleven-inch storage-display unit is approximately 400-line pairs in its long dimension which is considerably less than the 1000-cycles/page that the image-transmission experiments showed to be a minimum for high-quality textual images. The lack of resolution and gray-scale capability results in an information loss particularly for small symbols for characters, and in pictorial material. In addition the brightness of the Tektronix 611 is marginal for viewing in a well-lighted room. However, the display is not intended for prolonged reading or for detailed text, but it is appropriate for evaluating the usefulness of a
soft-copy, stored display as part of the text-access experiments.

In addition to the input devices at the catalog console, a number of illuminated switches are located at the storage-tube display and are connected to the console. Two of these, PAGE-FORWARD and PAGE-BACKWARD, enable the user to request the following or preceding page in a document by pushing a single button.

A third function switch is used to initiate the magnify mode which is designed to compensate, in part, for the limited resolution of this display. In this mode, an illuminated rectangle with dimensions approximately one-half the full page size appears as an overview on the display. The rectangle outlines the page sector to be magnified and can be moved to any one of nine positions by means of a pushbutton matrix at the display. When the re-display button is pushed, the quarter-page sector outlined by the rectangle is scanned and transmitted. This gives a factor-of-two magnification of that page sector and improves the legibility of small characters which might not be recognizable on the full-page display.

Several indicator lights are included at the storage-tube terminal to inform the user of the status of his request such as FICHE-NOT-FOUND, LAST-PAGE-OF-DOCUMENT, and REQUEST-IN-PROCESS. The pushbuttons and indicators are lighted in a programmed sequence to assist the infrequent user in operating the terminal.

**Microfilm-facsimile terminal**

The microfilm-facsimile terminal, diagrammed in Figure 4, consists of a high-resolution cathode-ray tube with its associated sweep and focus circuitry, an automatic camera-processor, and control logic required to operate the terminal. On command from the central station, the microfilm-facsimile terminal will reconstitute a page of text on the face of a high-resolution cathode-ray tube from the video signal. The automatic-camera and film-processor unit will record on 35-mm film the image of the displayed text and deliver to the user a fully processed strip of film in a convenient form for viewing in a microfilm reader.

A camera-processor unit that satisfactorily met the INTREX requirements was not found to be commercially available. The camera-processor pictured in Figure 5 was manufactured by attaching a modified Kodak film unit to a GAF automatic film processor. This processor utilizes a horizontal straight-line film transport that is self-threading and accepts short strips of 35-mm film. It should be noted that the film processor was designed for films of 12-inches maximum width, and for a much heavier volume of processing than we anticipate. It appeared after a survey of available film processors that the GAF machine comes closest to meeting our needs, at least on a temporary basis.

Initially the request for a film copy, made by the user at the catalog console will result in a film strip containing the entire text of a journal article if the document contains eight or fewer pages. Longer documents will be filmed in 8-page increments. Provision has been made to allow the user to combine short documents on a single film strip.

Approximately 20 seconds is required to complete the filming of an eight-page document after the receipt of a request by the text-access central station. After the filming of the last page in a sequence, a digital command transmitted from the central station initiates...
the processing of the film strip which requires approximately 70 seconds.

User acceptance of the microfilm output is largely dependent upon the convenience of handling and viewing the 35-mm film strips. After emerging from the processor, the film strip is inserted into a transparent jacket which facilitates handling and protects the film. A strip along the jacket edge can be written on with pen or pencil for identification purposes. The film in the jacket is inserted into a microfilm viewer for reading.

An Addressograph Multigraph Model 3000 electrostatic copier is being modified such that 8 1/2-by-11-inch paper copies can be made from the 35-mm film images. There is some degradation in the copying process and these copies lose some resolution compared to the 35-mm film image. However, the modified machine will supply, at locations remote from the central store, a traditional form of hard copy that can be read without the need for a viewer.

SUMMARY

A system for providing guaranteed, rapid, and remote access to the full text of the 10,000 documents in the INTREX collection has been described. Consideration of the more general problem of storing and displaying the textual image has indicated the practicality of facsimile image storage on microfilm and of single-frame transmission from a time-shared central station to the user terminals. In the initial INTREX text-access system, photographic images of text are stored on microfiche which are accessed by a computer-controlled storage and retrieval device. Retrieved fiche are automatically positioned in order that the proper frame may be scanned and transmitted as a single frame of video to either of two user terminals. A direct-view storage-tube display unit, placed adjacent to the catalog console, provides rapid access to text although with marginal resolution and brightness. A microfilm-facsimile terminal provides adequate resolution, but the film-processing time and mechanical complexity of the terminal are significant disadvantages. Document requests are entered through the augmented-catalog console. The processor associated with the catalog buffer/controller maintains the queuing and message-formatting algorithms for the text-access system.

The text-access system is currently operating in the laboratory and is part of the INTREX facilities intended for user experiments. Evaluations of these experiments should provide new insights into the library user's requirements for text-access which will lead into the incorporation of new techniques and equipment.

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