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ABSTRACT

In cooperation with the Commission on Preservation and Access, Xerox Corporation, Sun Microsystems, Inc., and the New York State Program for the Conservation and Preservation of Library Research Materials, Cornell University (New York) studied and established the effectiveness of digital technology to preserve and make available research library materials, evaluated image capture quality in binary scanning, digital computer output microfilm, and extended network access to the Digital Library through a client/server architecture. The main conclusions of the project are: (1) effective access over the Internet to an image-based digital library can be achieved from a variety of workstations; (2) Cornell has defined and will implement a digital document control structure that incorporates the best features of various Xerox prototype systems; (3) digital computer output microfilm that meets national standards for quality can be produced from 600 dpi (dots per inch) binary scanning; (4) binary scanning can reproduce many categories of printed illustrations and archival material in a manner superior or comparable to the quality obtained with standard light lens photocopy and microfilm processes; and (5) the infrastructure developed for library preservation and access activities supports other applications in the electronic dissemination of information. Five appendices cover: the CLASS scanning system; document architecture description; testbed description; "DocuTech-printed" examples; and screen descriptions from digital library UNIX client. (SWC)

The Commission on
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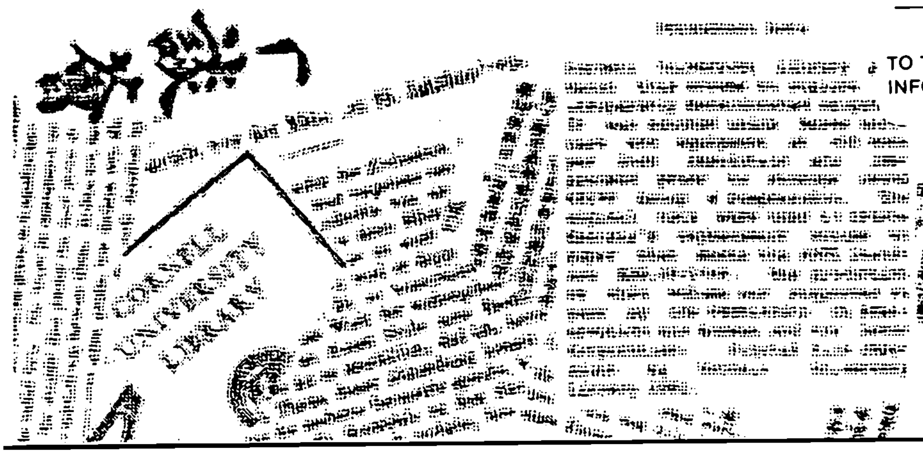
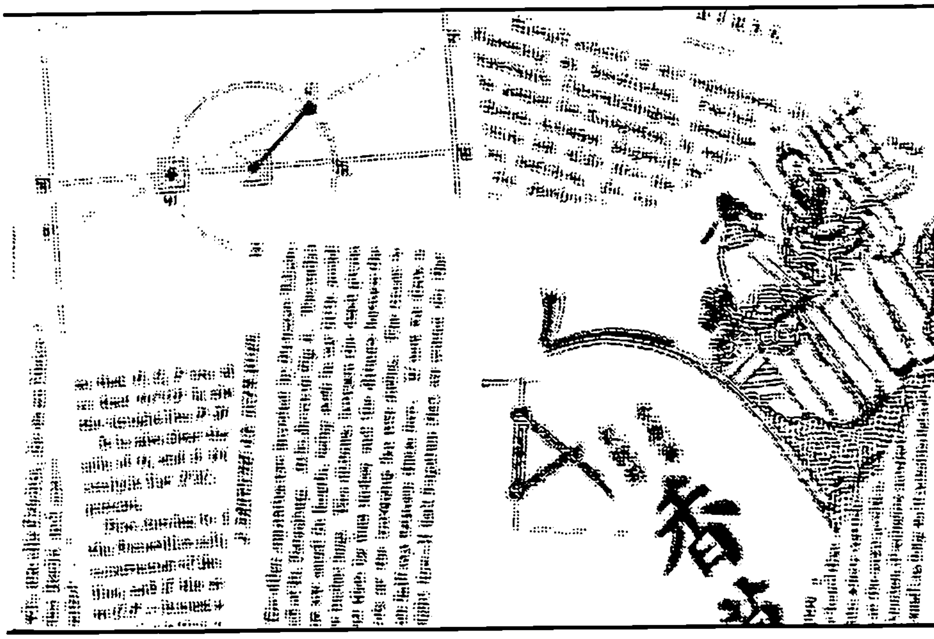


A Testbed for Advancing the Role of Digital Technologies for Library Preservation and Access



Final Report by Cornell University to The Commission on Preservation and Access —October, 1993

Anne R. Kenney and Lynne K. Personius, Project Managers

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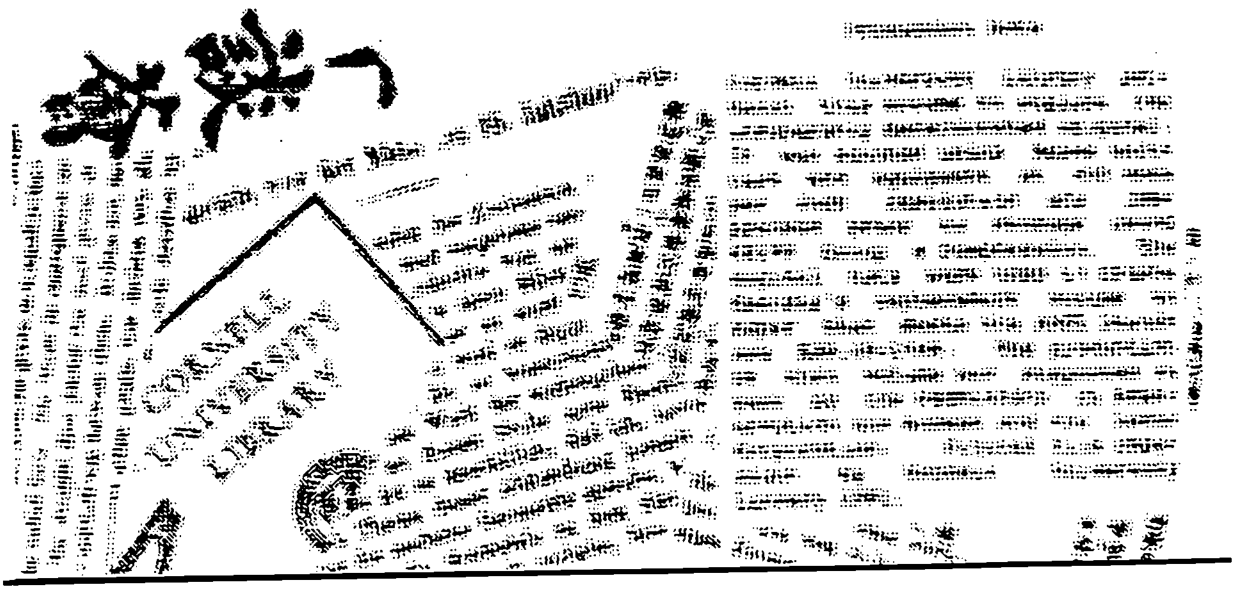

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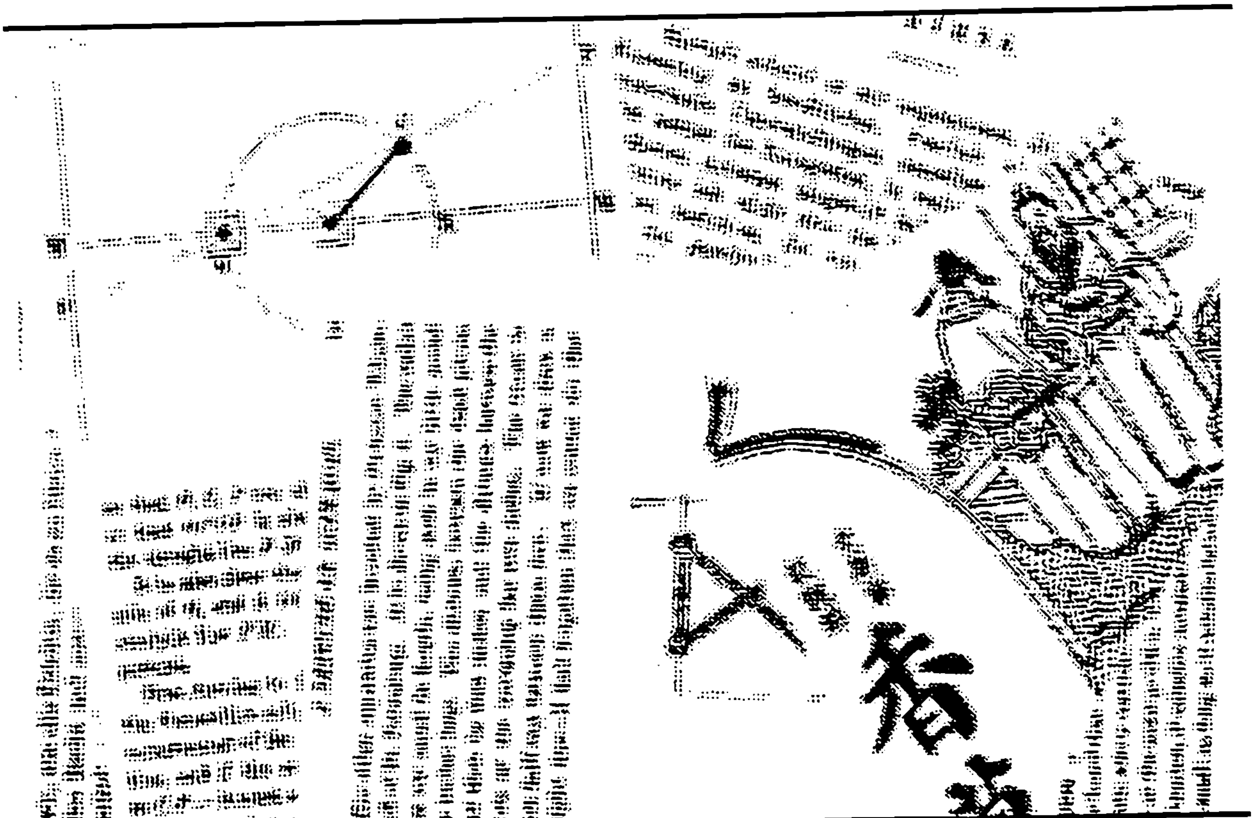

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ACKNOWLEDGMENTS

Cornell University acknowledges the support of the Commission on Preservation and Access and its Technology Assessment Advisory Committee. This support has been critical to the success and recognition of Phase II of the Joint Study in Digital Preservation.

The Joint Study involved the work of many individuals from both Cornell University and Xerox Corporation. Within Cornell, collaboration between M. Stuart Lynn, Vice President for Information Technologies (CIT), and Alain Seznec, University Librarian, both giving the project their fullest support, was crucial to its success. Stuart Lynn's position on both the Commission's Technology Assessment Advisory Committee and Xerox Corporation's University Advisory Panel was critical to bringing this project to Cornell. The support and encouragement of Glenn Alexander, Xerox Academic Publishing Manager, has been invaluable throughout all phases of the project, as has been that of Joe Hoey, Manager, POD/Vertical Applications, Xerox.

Additional administrative support and key advice came from Ross Atkinson, Cornell University Associate University Librarian for Collection Development and Preservation, Catherine Murray-Rust, Associate University Librarian, and John F. Dean, Director of the Department of Preservation and Conservation.

The Cornell portion of the study was co-managed by Anne R. Kenney, Associate Director of the Library's Department of Preservation and Conservation, and Lynne K. Personius, Assistant Director of Cornell Information Technologies for Scholarly Information Sources. William R. Turner, Senior Project Leader in the Library Technology Department, David Fielding and Christopher Stuart, Software Developers designed and developed the digital library server and clients. Their dedication and superb work resulted in a high quality technical environment for the digital library. Michael Friedman and Sue Poucher served as scanning technicians. Their experience with the functioning of the scanning workstation directly affected the quality of image capture for non-textual material. Together they have scanned over half a million pages.

Pete Baker, Computer Operations Supervisor, and Peggy Roberts, Laser Programmer, both of Cornell Information Technologies, were responsible for the operation of the Docutech printer.

Many bibliographers and selectors chose the volumes that were scanned during this project, with particular help coming from G. David Brumberg, History Bibliographer, Library Collection Development in the choice of New York State Material. H. Thomas Hickerson, Director of the Division of Rare and Manuscript Collections, Kroch Library,

Elaine Engst, Curator of Manuscripts, and Mark Dimunation, Curator of Rare Books, selected manuscript material for inclusion in the project. Cataloging the digital library is the continuing work of several individuals in the Central Technical Services division. Edward S. Weissman, Catalog Librarian, Judith Brugger, Authorities Librarian and Elizabeth F. Gamble, Head, Original Cataloging Unit have provided valuable assistance in this process.

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The engineering software team worked with the Cornell group to understand the library application and to create software which provided the required services. Members of the team took a deep, personal interest in the success of the project at Cornell.

The Joint Study was also made possible through the generous donation of computer equipment by Sun Microsystems, Inc. Thanks are extended to William Seawick, Sun Technical Market Development, Katherine Webster, Sun Education/Research Marketing, Tamarah Day, Sun U.S. Field Organizations Connie J. Brobeck, Academic Equipment Grant Program Manager, and James Loedel, Sun Sales Representative to Cornell.

This report represents the work of many of the individuals listed above. The project managers would especially like to thank: Stuart Lynn, Ross Atkinson, Catherine Murray-Rust, John Dean, Jim Harper, and William Turner for their help and encouragement.

I. Executive Summary

Cornell has embarked on a program to encourage the use of digital technology to enhance access to library materials and to provide a new alternative for preservation reformatting of brittle library material. Phase I of this program, a joint study conducted by Cornell with the Commission on Preservation and Access and the Xerox Corporation, led to a number of conclusions regarding preservation, access, electronic technology, and the role of the library. In particular, Cornell established the effectiveness of digital technology to preserve and make available research library materials.

In Phase II, Cornell extended its exploration of the use of digital imaging technology by establishing a **Testbed**, for evaluating both new uses of digital technology for library applications, and new technologies that may advance library preservation and access. The **Testbed**, as in Phase I a collaborative effort on the part of Cornell Information Technologies and the Cornell University Library, has been sponsored by the Commission on Preservation and Access, with additional support from Xerox Corporation, Sun Microsystems, Inc., and the New York State Program for the Conservation and Preservation of Library Research Materials.

At the conclusion of Phase II, a Testbed facility has been established, the quality of image capture capabilities associated with binary scanning further evaluated, the creation of digital computer output microfilm explored, and network access to the Digital Library extended through the development of a client/server architecture.

MAIN CONCLUSIONS

1. **Effective access over the Internet to an image-based digital library can be achieved from a variety of workstations.**

   Phase I demonstrated the feasibility of remote access through the delivery of digital images over the Cornell network for printing and for viewing on a prototype workstation. Phase II development centered on defining the architecture and developing systems needed to support extended remote access to the digital library. Internet access is provided via a digital library server and software "clients" designed to run on standard desktop computers that students and faculty members would commonly have, such as Macintoshes, IBM PC's, and Sun workstations. The client software provides access across the Internet at speeds comparable to what is available locally. Client/server computing is an evolving application architecture that is expected to play a major role in providing network access to digital libraries across the country.

2. **Cornell has defined a document control structure that incorporates the best features of the various Xerox prototype systems from Phase I, and will maintain its digital library in that form.**

   Through the implementation of document control structures, digital technology offers a means to facilitate access and to provide links between the bibliographic record and material located in the digital library. Preliminary experiments with network viewing of digital books has verified the early assumption that information about the internal organization of a document, its structure, is essential for ease of navigation from a viewstation. Cornell has defined a non-proprietary document architecture which incorporates the best parts of the various prototypes from Phase I, and has decided to maintain its digital library in that form.

3. **Digital computer output microfilm that meets national standards for quality can be produced from 600 dpi binary scanning.**

   Cornell University, in cooperation with Image Graphics, Inc., tested the feasibility of producing microfilm from high resolution digital images by means of an electron beam recorder. Cornell evaluated the quality of the resulting film, computed its "digital resolution" based on a formula recently developed by an AIIM technical committee, and compared it to printers' type sizes used by publishers during the period 1800-1950. Based on these analyses, Cornell has concluded that a scanning resolution of 600 dots per inch is sufficient to produce digital computer output microfilm

(COM) that meets ANSI/AIIM standards for image quality for virtually all books published during the period of paper's greatest brittleness.

Although the Cornell experiment demonstrated the technical feasibility of producing preservation microfilm, some of the issues surrounding quality, processing, costs, and vendor services associated with the conversion process have yet to be resolved. Cornell will continue its investigation into the use of digital technology to produce microfilm that meets preservation standards, while also allowing for the flexibility in storage, distribution, and access associated with the technology.

4. **Binary scanning can reproduce many categories of printed illustrations and archival material in a manner superior or comparable to the quality obtained with standard light lens photocopy and microfilm processes.**

   Where Phase I focused on preserving brittle books that were largely textual, Phase II extended the evaluation to include a review of the applicability of digital imaging technology for printed illustrations and a wide array of archival material. Based on this experimentation, Cornell has concluded that binary scanning can result in the production of paper facsimiles for a wide range of material that are superior or comparable to photocopy versions. For some material, and for purposes other than printing, however, gray scale or color scanning may be more appropriate reformatting options. More experimental work is needed to examine the various tradeoffs associated with the use of gray scale and color scanning.

5. **The infrastructure developed for library preservation and access activities supports other applications in the electronic dissemination of information.**

   The infrastructure created to support the Testbed provides the basic components for many electronic publishing applications and is designed to encourage widespread collaboration among institutions. Cornell University is presently conducting several collaborative projects for incorporating other material into the digital library, including current periodicals, dissertations, research reports, and newly-published books. Discussions are underway with other institutions that would lead to the creation of union collections accessible in a common fashion over the Internet.

II. TESTBED PROJECTS

Cornell University has established a testbed environment to evaluate, test, and advance the role of digital technologies in preserving and enhancing access to deteriorating library materials thereby providing a link between prototype technologies and activities and their translation into production services. The testbed is a corporate venture between Cornell University Library and Cornell Information Technologies. A description of the Testbed facilities, staff, and testing methodology is described in Appendix III.

This testbed built upon the *prototype* activities conducted as part of the CLASS Project that was jointly supported by the Commission on Preservation and Access, Cornell, and the Xerox Corporation[1]. Indeed, the activities of the testbed have used the scanned CLASS materials as the archive to test both extended access to a digital library, and to experiment with the production of computer output microfilm that meets national presentation standards. Testbed projects include those with goals of :

- **Improving Access:** Technologies for improving local and national network access to the digital masters were defined and implemented. Software development centered on the creation of a client/server architecture to provide remote viewing of digital material from common computer platforms.

- **Evaluating Storage Technologies:** Technologies for storing scanned digital masters were assessed, including different file formats and compression techniques and storage technologies. Different storage architectures, including document structures and indexing techniques, were developed and tested that enable the storage of extremely large files of information while providing a high degree of precision in recall.

- **Evaluating Scanning Technologies:** In cooperation with the New York State "Big 11" research libraries, Cornell experimented with binary digital technology for image capture of a wide variety of archival material Technicians also tested the CLASS system's capabilities to reproduce a variety of illustrations found in books published from 1850-1917. A third project centered on evaluating the feasibility of creating digital computer output microfilm to meet national preservation standards.

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1 A. Kenney and L. Personius, Cornell/Xerox/Commission on Preservation and Access Joint Study in Digital Preservation Report: Phase I (January 1990-December 1991). Washington, DC: Commission on Preservation and Access, 1992.

A. IMPROVING ACCESS

The digital library from Phase I of the joint study resulted in a prototype networked system for creating, storing, printing, and accessing an electronic library. This system allowed for the distributed scanning, printing , and storing of the digital library to a number of locations served by a high speed network. During Phase II Cornell has expanded access to the digital library both from Cornell locations and over the Internet. The development of a client/server environment permits images to be delivered over networks to a variety of hardware platforms, and facilitates viewing the images of library materials from local workstations.

The components of this portion of the project include:

- Providing a browsing capability from any workstation to descriptive information about digital documents in the Testbed digital library, and facilitate requests for the delivery of printed copies.

- Developing an image delivery server that translates images stored in the Testbed digital library to selected other storage formats and compressions for transmission to a variety of systems.

- Delivering digital images to common workstations including Sun workstations, IBM PS/2 computers, and Apple Macintoshes, and evaluating the quality of interface software and of the onscreen display.

The prototype digital library as developed by the Xerox Corporation consisted of three top level functional modules.

Creation - Documents are added to the digital library at Cornell using a scanning workstation and sophisticated software. The actual scanner and the software are Xerox products. They have been described in earlier reports of this project, and detailed specifications are available from Xerox Corporation. Using this system, technicians scan books and then request that the books be filed into the digital library.

Storage - The Xerox system stores the digital library as TIFF Group 4 image files of scanned material into an image filing system. Cornell has used a test system for this project, which now must be replaced.

Printing - A network connected DocuTech printer provides the ability to create high quality paper facsimiles at high speed from the digital library. Material can be sent to the printer from the creation workstation.

Cornell perceived a need to add two capabilities to the digital library: (1) a browsing capability, and (2) a mechanism to manage the use of the library. The initial features of the browsing capability include:

— The ability for a library patron to read digital books from home or office using the same network-connected workstation that is used for other purposes. No new or specialized hardware should be required.

— The ability to request a printed copy of all or of selected sections of one or more documents.

— The ability to protect the digital library from either accidental or deliberate modification by public users.

The Cornell digital library is based on the client/server model of computation. Initially, Xerox staff worked closely and exclusively with Cornell University Library staff to define the requirements for library preservation and access. These requirements included storing both low- and high-resolution versions of images, so that the low-resolution images could be used for browsing over the network and the high-resolution images could be used for printing and storing. In addition, substantial work was done to define documents with internal structures that could be navigated. As part of the Testbed Project, Cornell developed complementary software to allow library users to browse the documents (including navigating the internal document structure) and request printed copies over the network. The Cornell-developed access software consists of an image delivery server and browsing clients for three common user workstations described below. It is freely distributed to institutions working on imaging projects.

The Image Delivery Server

The largest component of this project has been the development of an image delivery server connected to the campus network which allows images to be read from the image filing system and converted so that they can be sent out in revised formats. The image delivery server is UNIX application running on a Sun SPARCstation workstation.

A significant product of this project has been the definition and implementation of a protocol to be used between the image delivery server and the client software used for viewing digital files.

Many of the functions of the original request server from Phase I have been included in the image delivery server. At the completion of Phase

I, a prototype request server was in place.[2] The image delivery server allows a researcher to make a print request using client software that is now readily available for most workstations.

The digital library clients request information from the server over the network and present it to the users. The Image Delivery Server manages access to the digital library, which includes searching databases, parsing document structures, scaling and rotating images, and finally packaging and sending the desired image or information on to the client. The client/server model allows for unlimited expandability. Servers can be added as needed to support user clients and to communicate with other image delivery servers once appropriate protocols have been developed and implemented.

The tasks for which the server is responsible include image scaling, rotation, decompression and compression. Processing requirements are determined by "handshaking" with the client. The Sun workstation client is capable of decompressing an image, so the images can be sent in compressed form for improved network performance. Clients running on PC's and Macintoshes require more support from the server. Images are stored in a compressed format, and must be uncompressed, scaled or rotated (as necessary), and possibly recompressed before being sent across the network.

Material for included in the digital library is scanned at 600 dpi. The current server software does not support scaling and rotation of images due to memory and processing constraints (the time to rotate and scale 600 dpi images is on the order of minutes). To provide fast access, 100 dpi "thumbnail" images are stored on local magnetic disks. The high resolution images are stored and used for printing facsimiles of documents and for scaling purposes. Thumbnail images are delivered to the clients for browsing and viewing in real time.

The quality of the on-screen display for most of the material scanned was acceptable, with the exception of halftone images. Because of the use of screens, which provide a dot structure to duplicate the original halftone, the scaling down of these images for screen viewing causes a distortion of the images. To achieve a proper viewing resolution, the halftone scanned images would have to be presented at full size, which would be approximately six times the size of a 23" monitor. As is well-

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2 At the completion of the Cornell/Xerox/CPA Joint Study, a prototype request server was in place designed to permit any workstation on the Cornell Campus Network running X-windows software to request a printed copy of a digital image or a set of images by means of a document structue file that provides users with a description of the contents of a volume and the means for requesting specific page sets. The specification for that server is included as Supplement III of The Cornell/Xerox/Commission on Preservation and Access Joint Study in Digital Preservation Report: Phase I (January 1990- December 1991).

known, for viewing purposes low resolution images with some grey scale displayed will provide the best combination for on screen viewing, however, binary formats are best for production printing purposes.

The image delivery server starts a new copy (instance) of the server software for each client that connects. The memory used averages about 1 Mbyte per client. When a client opens a document, the image delivery server parses the document description files and initializes necessary structures. Each document opened requires about 1 Mbyte additional memory, depending on the size and complexity of the document. The maximum number of documents for each client is currently 3, limited by the hardware resources available. Each server requires roughly 3.5 Mbytes (with two documents open). If image rotation and scaling is required, additional memory is used.

The current demonstration system is a Sun SPARCstation 2 with 32 Mbytes of memory, running SunOS and OpenWindows. The Digital Library search database, a Gupta SQLbase server which uses 5 Mbytes of memory, also runs on this machine. After starting OpenWindows and Gupta SQLbase approximately 12 MBytes are available. Under these circumstances the current image delivery server hardware can support only 3 simultaneous users. In the future the digital library will need be upgraded to support significantly more users.

Description of Viewing Clients

Clients access and browse the Cornell digital library, allowing users to search for documents by author, title, or catalog id, and then to traverse the document structure, e.g., by chapter or article. Pages may be viewed from one book, or multiple documents may be opened for viewing simultaneously.

Client capabilities included:

Searching — After starting the client, a document window is visible which includes buttons for searching, printing, and navigating. The magnifying glass button or the Search menu item starts a search. The user is given a dialog box with a popup menu to limit the search to either author, title, or catalog. All the books currently available will be retrieved if the field is left blank, or "Find All" button is selected in the popup menu.

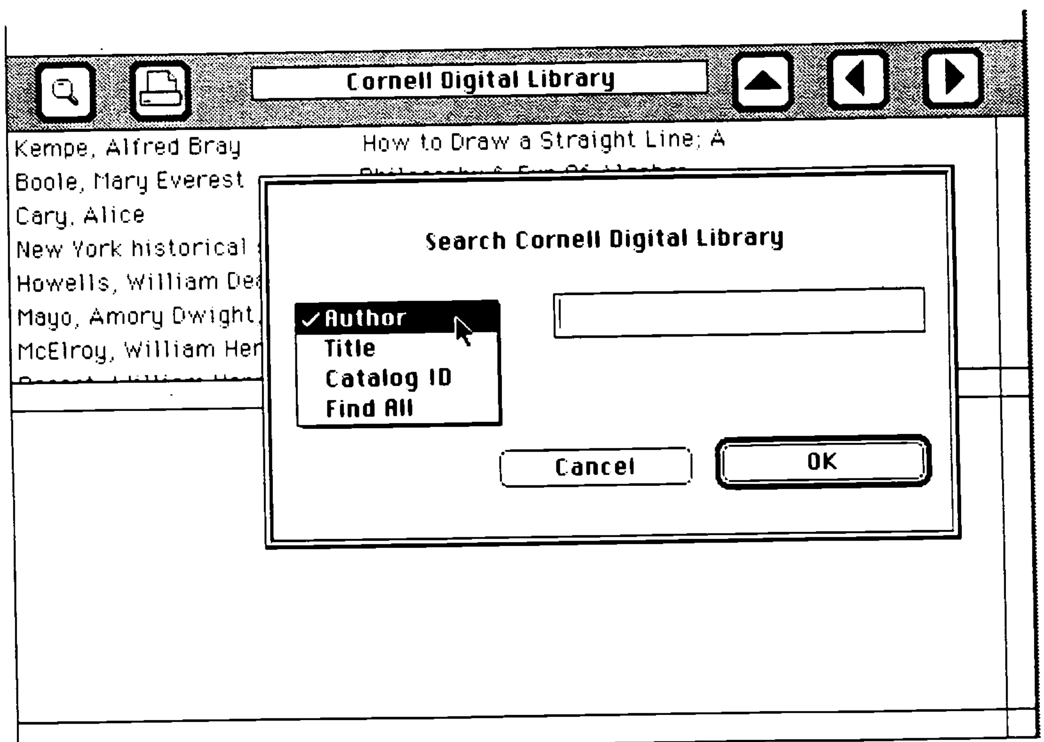

FIGURE 1. SEARCH DIALOG, APPLE MACINTOSH DIGITAL LIBRARY CLIENT

Browsing — Once the search returns a document or list of documents the user makes a selection. The client then retrieves the next level of the document structure which might include chapter headings or pages or other labels depending on how the document has been structured. By traversing successive levels, the user eventually comes to a screen where the first page of a selected section is displayed in the bottom portion of the document window. The user may then browse through the document.

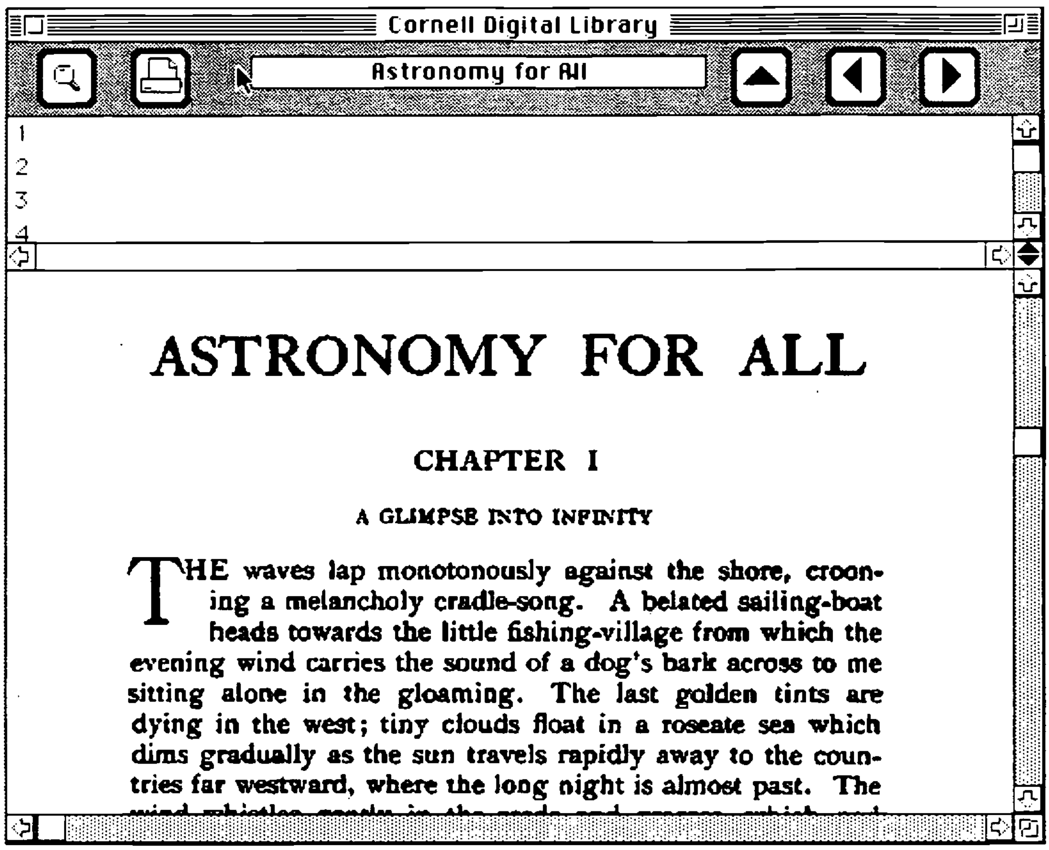

FIGURE 2. ASTRONOMY FOR ALL PAGE DISPLAYED IN BROWSING WINDOW
APPLE MACINTOSH DIGITAL LIBRARY CLIENT

Printing — A user can generate a print request either by clicking on the printer icon in the control area or by choosing the Print menu item. A dialog box will be displayed which informs the user of the number pages selected for printing. For instance, if the user has a chapter heading selected and clicks on the print button, the client determines the number of pages to be printed in that chapter and informs the user of the total print request. The output is then sent to the Xerox DocuTech printer on the Cornell University campus for printing at 600 dpi resolution, and delivered to sites on campus via campus mail.

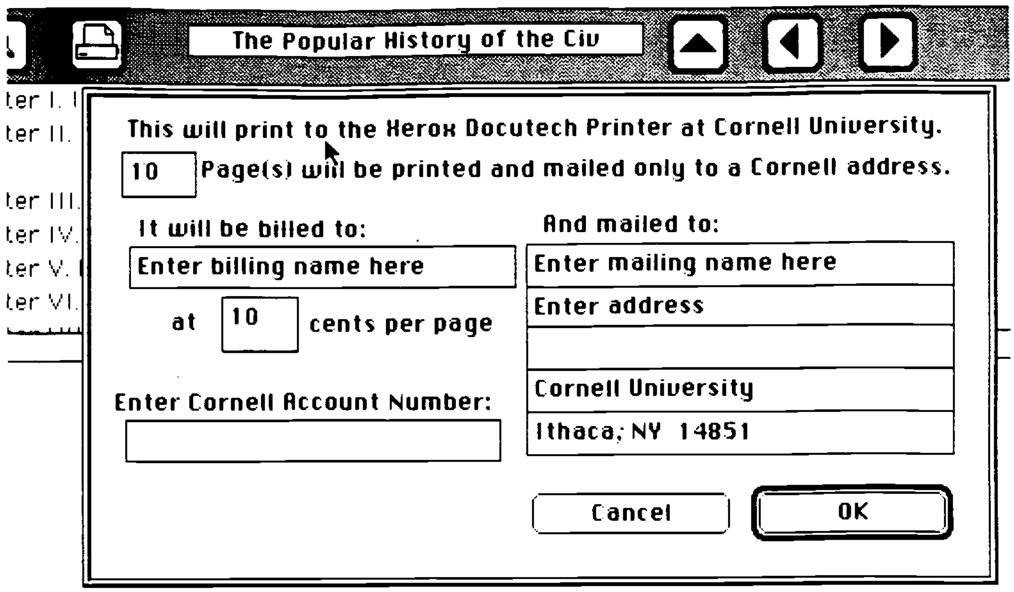

FIGURE 3. PRINT DIALOG, APPLE MACINTOSH DIGITAL LIBRARY CLIENT

An example of printed pages from this book is included as Appendix IV.

Delivery of Images to Workstations

Client software developed for three workstations (IBM-compatible PC's with VGA and running Windows; Macintoshes; and Sun workstations) provides access to the Testbed digital library via the image delivery server. The graphical interface varies from one platform to the next, but the functionality is equivalent. Appendix V contains samples from a digital library session using the UNIX client running on a Sun Sparcstation.

The client software has been tested across the Internet and provides access at speeds comparable to what is provided at Cornell. The client/server architecture is now being tested by the Big 11 Research Libraries in New York State who use the various Cornell developed clients to access books in the digital library and to test the print on demand capabilities.

The Macintosh client includes the ability to capture books as QuickTime movies. QuickTime is a new extension to the Apple Macintosh system that supports the incorporation of animation, sound and video into Macintosh files, and provides image compression capabilities. In the Macintosh digital library client, QuickTime is used for viewing, scaling, and compression of the images, and to save a document or portions of a document as a QuickTime movie for local storage.

Beyond the Testbed—Plans for Continuing Development

As Cornell worked on the design for the digital library, it was anticipated that additional management functions will be necessary to provide a fully functioning digital library. In particular, access to the digital library will need to:

— Record charges for printed copies of material, and to bill the requester.

— Know if a particular book is covered by copyright, and if so, record royalties for the use of that work. The appropriate interface needs to be designed so that charges can be transferred appropriately for use of material.

— For some library material, check that the reader is authorized to view documents. An early example of the need to authorize users was presented by a journal publisher who contracted to provide material, stored in the digital library, to some but not all categories of users.

— Authenticate users. In order to charge readers or authorize them to comply with contractual arrangements, the system must be sure that readers are who they claim to be.

— Track use in order to document how and when the digital library is used. This will assist librarians and scholars in assessing the impact of creating the digital library on the research process.

The next phase of client development will include the addition of a WAIS interface to search text abstracts which will then link to the digital documents. User authentication will be implemented using Kerberos to verify users according to copyright licenses and affiliation with the Cornell community. Bookmarks will be developed so that a user may set a bookmark for fast access to particular locations in a document.

To guide the thinking about new methods of access to Cornell material in the digital environment, two forums have been established. The Cornell University Library Priority Committee, a group composed of the Library's administrative heads and members of the Library Technology Department and chaired by Catherine Murray-Rust, Associate University Librarian, meets regularly to establish policy and determine how resources are to be allocated to technology-related work. The Priority Committee is actively reviewing the opportunities and challenges of adding provisions for digital and electronic resources that are to become part of the collection of the Cornell Library. A white paper is expected later in 1993.

A second University task force is evaluating digital technology as a way to provide access to Cornell collections beyond the library. The members of the Task Force on Digital Access to Cornell Collections, chaired by Tom Hickerson, share an equal concern for the development of systems for the effective management and preservation of collections and for the design and implementation of systems which enhance and broaden access and use of these collections. In the expansion and application of digital technology, new capabilities for high-quality scanning and printing, high-density compression and storage, and high-speed networks offer remarkable new opportunities. The mission of this task force is to explore and capitalize on these opportunities.

B. EVALUATING STORAGE TECHNOLOGIES AND DOCUMENT STRUCTURE

Move from proprietary to UNIX file system

After evaluation and testing both at Cornell and at Xerox's internal facilities, Xerox decided not to use the prototype CLASS system developed and tested with Cornell. However, Xerox has plans for their product to evolve to meet the standards developed for this project. Cornell plans to implement it as soon as:

- An export function is provided so that books can be brought out and put in Cornell format
- The scanner incorporates certain functions that are required for compatibility with the CLASS system.

Cornell is using Xerox software and hardware for scanning, but does not intend to use the Xerox system for archival storage. The Xerox system was not intended for large libraries. The document structure files that associate individual files for pages into logical documents of books, journals, or archival collections are not a widely acceptable standard and not sufficiently accessible to meet the needs of libraries. The Xerox Corporation supported Cornell's evaluation of hardware and software options for the digital library files. A prototype Xerox scanner with associated software has been used throughout the digital preservation study, both Phase I and Phase II. Cornell intends to continue using the prototype because it contains functions that have not yet been included in the product version. However, Cornell has been informed that the product will evolve to include these, and plans to convert to the product as soon as these features are available.

A primary goal of the Testbed was to create and maintain a growing digital library of scanned documents that remains current and broadly accessible in the face of changing technologies, and compatible with *de facto* and *de jure* standards. Keeping this in mind, Cornell decided to use a standard UNIX file system. This provided great flexibility in the choice of actual hardware. Since many types of physical devices are supported by the UNIX operating system, optical storage can be used where appropriate, or magnetic storage as needed for performance. Cornell has supplied mass storage for the digital library.

Cornell has scanned over 1000 books which require more than 30 Gbytes of storage. The 600 dpi images are stored on a magneto/optical jukebox mass storage device, which has great capacity but relatively low performance. To store the 100 dpi images for these books on local disks for good performance will require 5 Gbytes of disk space.

Status of Digital Library Document Architecture

Documents in the digital library are flexible and easy to use in a way analogous to a book. Images are linked together into documents reflecting the structure of the originals. Browsing is greatly enhanced by the use of this structure. Chapter headings, the table of contents, indices and the like can be easily located and used to navigate through the document.

Cornell's intent in establishing a digital library has been to provide wide access and to facilitate experimenting with different means of access. This was accomplished by maintaining a simple and open document architecture to which other software could be easily adapted. A non-proprietary document architecture which incorporates the best parts of the various versions of CLASS has been defined by Cornell. Software was written which would access the digital library without using any proprietary software, resulting in access software which could be freely distributed. Access to documents in the digital library has been provided using such standard network tools such as FTP and Gopher.

Why a Document Architecture?

Just as a conventional library contains books rather than pages, so the electronic library must contain documents rather than images. To organize groups of images into useful documents, a Document Architecture has been defined. This is a critical component of the electronic library, and Cornell recommends that it be further defined and standardized to facilitate sharing of electronic documents among institutions.

During the scanning process, images are automatically linked into documents by creating document structure files that order the image files in the same way the binding of a book orders the pages. Thus, the digital book as currently configured consists of two parts: a set of individual pages stored as discrete bit map image files, and the document structure files which "bind" the image files into a document. In addition, a database entry is made for each digital document which permits searching by author and title (i.e., bibliographic information).

Beyond the order of the pages, the arrangement of a physical book provides information to readers. The title page and publication information come first; the table of contents usually precedes the text;

the text is divided into sections or chapters; if there is an index, it follows the text. The reader often refers to these components of a book when browsing the library shelves, in order to determine whether the book meets their needs. The document structure provides direct access to the components of an electronic document, storing the information that would otherwise be lost when the book is disbound for scanning.

Preliminary experiments with network viewing of digital books has verified the early assumption that information about the structure of a book, beyond what is customarily included in a bibliographic record, is necessary for ease of use. For example, the page numbers printed in the original book must be incorporated into the document structure and correlated with the image files so that a request to retrieve a particular page number can be met with the image with that number printed on it.

The creation and storage of the document structure is critical to the system design. Requirements for the document follow.

Cornell recommends a collaborative process involving other institutions and consortia to define further the application and utility of the document structure and to establish it in a standardized form across the digital libraries of multiple institutions.

Document Architecture Requirements

1. The architecture must be open. "Open" in this sense means that the specification is published and freely available, and may be used by anyone without paying any royalties.

2. The architecture should be as simple as possible. The intent is to facilitate development of products using the architecture.

3. The architecture should assume that data is stored in UNIX file systems.

4. The architecture should not preclude use of the data in other standard ways, such as via FTP and Gopher servers. This means that the files containing the pages of a document must exist in a single directory, and the naming convention used must order them in the standard collating sequence (i.e., the series "0001.TIF, 0002.TIF, ..., 0411.TIF" is acceptable, while the series "1.TIF, 2.TIF, ..., 411.TIF" is not, as the latter would appear as "1.TIF, 10.TIF, 11.TIF, ...)

5. The architecture should provide for storing the same information in different formats. For example, when a page of a document is available at several different resolutions or in ASCII as well as image form, these should be stored as separate files within the same document. In keeping with #4 above, each format may (and perhaps should) reside in a separate subdirectory, so that all image files are together, all ASCII files are together, etc.

6. Low-resolution "thumbnail" images of each page must be stored to facilitate browsing and sharing of data. At present, the desired resolution for thumbnail images is 100 DPI.

7. The architecture must support distribution of files so that similar files may be stored together, permitting optimization of storage use and performance. For example, it must be possible to specify that all 100 DPI thumbnail images be in a certain directory. This also supports use of the data in other ways, as the directory name may be used to describe the format of the data.

8. The architecture must support documents that are composed of references to all or part of other documents. For example, it should be possible to create an anthology by excerpting portions of other documents without making physical copies of the images, and it should be possible to build up a journal from separate articles. Such documents should require only additional document structure files and database entries.

9. The architecture must support documents, components of which are stored on separate servers distributed across the network.

10. The architecture must support not only an hierarchical structure for each document, but the ability to define multiple views of each document. Secondary views should be able to contain pages in different order from the primary view, and should be able to exclude selected pages. However, inclusion of additional pages would mean creating a new document.

11. The architecture should accept, rather than dictate, directory structures in which documents will be stored. This will permit documents created in other ways to be added to the Digital Library simply by adding database information rather than by copying or moving files.

A description of the document architecture recommended by Cornell is included in Appendix II.

C. Evaluating Scanning Technologies

1. Establishment of Digital-to-Microfilm Feasibility

One of the main objectives of the Testbed Project was to determine the feasibility of using digital image technology to produce computer output microfilm (COM) that could meet national technical specifications for preservation. These specifications cover a wide range of issues, including: the preparation of documents; composition of the film stock; quality of image capture as defined by reduction ratio, image placement, resolution, and density; film processing; and storage.[3]

In the fall and early winter of 1991/92, Cornell tested the conversion process for producing computer output microfilm from digital images. Although there are a number of companies in the United States offering digital to microfilm conversion, Cornell located only one, Image Graphics, Incorporated of Shelton, Connecticut, that was prepared to handle high-speed, high-resolution film recording. Since 1974, Image Graphics has become a leading developer of electron beam technology for government and industry. Electron beam recorders (EBR) record directly from digital data to film, and, according to Image Graphics, the EBR provides ten times better resolution, speed, and dynamic range than conventional cathode ray tube, laser, and photomechanical imaging devices.

Document Preparation

Image Graphics agreed to run a test conversion of Cornell's digital images. The files for one volume were copied at Cornell onto magnetic tape along with AIIM Scanner Test Charts (as cited in ANSI/AIIM MS44-1988, "Recommended Practice for Quality Control of Image Scanners). The volume, entitled The Steam Turbine: The Rede Lecture 1911, by Sir Charles A. Parsons, contained halftones and line drawings embedded in text. The volume had been scanned one page/digital image using an early version of the CLASS scanner software at 600 dpi resolution.

Film Stock

The magnetic tape was sent to Image Graphics where the digital images were recorded on a MICROGRAPHICS EBR SYSTEM 3000, an electron

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3 For a fuller account of the digital-to-microfilm analysis, see A. Kenney, "Digital to microfilm conversion: an interim preservation solution," Library Resources & Technical Services, Vol 37, No.4 (October 1993.)

beam recorder used to produce microfilm from high resolution digital images and gray scale. The microfilm output from the digital files was produced on 35 mm, non-perforated Kodak Direct Electron Recording Film, SO-219.

The SO-219 film is a silver-gelatin microfilm designed expressly for use in recorders that expose film by means of an electronic beam brought to bear directly on the emulsion. The film emulsion layer is unusually thin and characterized by extremely fine grains and a relatively high silver to gel ratio; the support is ESTAR base, a clear 4 mil polyester film. Because of uncertainty regarding the longevity of the SO-219 film, Cornell requested that Image Graphics test a film that is in wide use in preservation microfilming. The company was able to produce a sample strip of several images using Kodak ImageLink HQ.

Processing

Image Graphics wet-processed the film in an Oscar Fischer processor, at a speed of five to seven feet/minute. The company used Kodak Ultratek developer at a concentration of ten to one. The film was rinsed with tap water filtered through a one micron filter, then double fixed, using Kodak Rapid Fix with Hardener, and rinsed in a final bath of filtered tap water.

Cornell sent samples of the SO-219 and the ImageLink HQ films to Biels Microfilm Corporation of Buffalo, New York where a methylene blue test (as defined in ANSI PH 4.8-1985) was conducted to determine the amount of residual thiosulfate concentration. If fixing and washing are inadequate, thiosulfates, or silver salts, or both, will be retained by the film. These can break down, especially under poor storage conditions, to produce yellow staining in clear areas and fading in areas containing image silver.

The test results indicated unsatisfactory levels of chemical residue remaining on the film. Concentrations of less that 1.4 mg indicate archival quality. The Kodak ImageLink HQ had an actual concentration of 2.4 mg; the Kodak Direct Electron Recording, SO 219, had an actual concentration of 2.5 mg. Both films failed the methylene blue test.

An inspection of the SO-219 film over a lightbox revealed additional problems associated with the processing of the film. The film was dirty, dusty, slightly scratched, and there were frequent splotches along the edges, indicating that the film had not been properly washed and dried. While the results reveal improper processing of the film on the part of Image Graphics, they do not have a direct bearing on the process of digital-to-microfilm conversion. Once the film is created, the method of processing is identical to that used with conventional film, and, with proper handling, the film should meet standard preservation specifications.

Density, Image Placement, and Reduction Ratio

Image Graphics produced both a negative and a positive version of the film. Density readings taken on the negative averaged 1.21 which falls within the national guidelines for background density ranges for master negatives. However, it should be noted that, unlike conventional micrographics, film density for digital COM is a software-controlled variable within the EBR System 3000 recorder. Image Graphics could have adjusted the density to any level.

Reduction ratio and image placement are also controlled by system software. Prior to recording the digital images on film, Image Graphics had rotated the images for film placement of two images/frame in the cine position at 10X reduction ratio, based on Cornell's specifications. While this conversion was successful, the light box inspection of the positive film revealed that the spacing between frames was too wide, which was attributed to incorrect software calculations for image placement. Further, the white background against which the images were placed made it difficult to discern the edges of individual pages, and this too would need to be addressed by software programming.

Photographic Resolution and Quality Index (QI)

A standard microfilm version, including three generations of film, of The Rede Lecture was prepared by Cornell Photo Services for comparison purposes. The positive copies produced by the two technologies were reviewed on identical side-by-side microfilm readers and compared to the original volume. Staff members who performed a frame-by-frame comparison could discern no difference in the capture of text and line art between the two films. In both cases the images appeared crisp, with sharp contrast between text and background.

Staff members also examined the IEEE Scanner Test Chart under 100 X magnification. The microscopic inspection of the technical targets reproduced there revealed that the resolution readings taken on both the positive and negative versions of the digital COM were identical, indicating no generational loss between copies. The same resolution readings were also achieved when the image of the test target was displayed at 600 dpi on the computer monitor, indicating negligible or no generational loss between the digital file and the COM. In contrast, there was a drop of two readings from the archival master to the service copy in the conventional film.

Quality Index (QI) is a means for relating resolution and text legibility, based on the measurement in millimeters of the height of the smallest significant character, usually the lower case letter "e," as read from the original document. This measurement (h) is then multiplied by the smallest resolution pattern that is resolved on the film (p), and the resultant number is used as the Quality Index (QI), e.g., p X h = QI, or 6.3 X .8 = 5.04. Quality Index is described in detail in ANSI/AIIM MS23-1991. The standard states that a QI of 5.0 is considered medium because all alphanumeric characters are readable without difficulty, but serifs and fine detail may be lost. A QI of 5 has also been determined to be acceptable quality for applying Optical Character Recognition (OCR) software. A QI of 8.0 is considered excellent because serifs and fine detail are resolved. While the ANSI/AIIM standard indicates that a QI of 5 is acceptable, the Research Libraries Group, Inc. requires a QI of 8 for its preservation microfilming projects.

The resolution readings on the digital COM measured 6.3 line pairs per millimeter (lpm) for the equivalent of the third generation service copy, indicating a Quality Index rating of High Quality (8.0) for the master negative for material where the smallest "e" is 1.3 mm (for 6.3 lpm), and a Quality Index Rating of Medium Quality (5.0) for material where the smallest "e" is .8 mm (for 6.3 lpm). Conventional microfilming is superior at capturing resolution: readings on the archival master were 10 lpm, indicating a Quality Index rating of High Quality for material where the smallest "e" is 1 mm high. To achieve the resolving power of standard micrographics would require scanning at about 1,000 dpi.

Digital Resolution vs. Photographic Resolution

Although the resolution reading on the digital COM measured 6.3 lpm, caution should be used in equating digital resolution to photographic resolution. In fact, the ANSI/AIIM MS44-1988 standard, "Recommended Practice for Quality Control of Image Scanners," advises against the use of resolution test patterns for scanners with a resolution less than or equal to 600 dpi because of "(1) the problems associated with the random placement of samples, and (2) the conflicting requirements placed on the threshold."

The February 1992 draft AIIM technical report on photographic and electronic imaging resolution suggests an alternative method for determining Quality Index for digital imaging that takes into consideration the probability of misregistration. The proposed Quality Index equation for digital resolution (Rd) of a scanner is:

$$Rd=[(2 \times QI)/(h \times .039)] \times 1.5$$

In this equation, the traditional QI, which assumes resolution units of line pairs per millimeter, was doubled because digital resolution measures just dots or lines. The height (h) of the smallest "e" is defined in inches in the tutorial. To convert millimeters to inches, the figure h is multiplied by .039. To compensate for possible misregistration in the scanner, the total figure is increased by 50%, or multiplied by 1.5.

To determine the height of the smallest "e" that can be resolved digitally, the formula becomes:

$$h=[((2 \times QI)/Rd)/.039] \times 1.5$$

The digital resolution (Rd) of the CLASS scanner used equals 600, and if the QI were to equal 8, the maximum height that can be resolved would be:

$$h=[((2 \times 8)/600)/.039] \times 1.5$$

which equals 1 mm.

If a QI of 5 (medium) were acceptable, the height of the smallest "e" that can be resolved would equal:

$$h=[((2 \times 5)/600)/.039] \times 1.5$$

or .6 mm.

Practical Application for 600 DPI Scanning

Given the CLASS scanning system's technical capability to capture text, one must then determine its practical application in a preservation context. The question becomes, is 600 dpi scanning adequate to capture the range of printing found in brittle books? One way to answer this is to translate Digital Quality Index requirements into printing type size for material published since the mid-nineteenth century.

One hundred and five measurements of the height of the smallest "e" at 9, 10, 11, 12, and 14 points were taken for a variety of typefaces used in the nineteenth and early twentieth centuries. These point sizes were commonly used for printing the body of texts. Typical x-heights in the 9 to 14 point sizes ranged from 1.34 mm to 2.15 mm, which are easily rendered by 600 dpi scanning. The x-height of the main text in The Rede Lecture 1911, for example, measured 2.1 mm, which would require a scanning resolution of 300 dpi to achieve a Digital QI of 8.

Some charts, formulae, diagrams, illustrations, advertisements, and footnotes are printed in smaller types, and to be captured successfully will require higher scanning resolutions. Modern phototypesetting, introduced in the mid-nineteen sixties, offers a range of standard sizes from 4 or 5 points to 72 points. By contrast, items printed in the nineteenth century and first half of the twentieth century—the period during which most brittle books were published—were set by hand or by casting (monotype or Linotype), using metal type. With metal type, the ink has a tendency to spread, making the edges of the letterforms uneven, and so there was a limit to how small a typeface could be effectively printed or letters spaced. Metal type was commonly produced in sizes ranging from approximately 5 point to 72 point, with 6 point being the smallest point size for most typefaces.

In a sample of 26 type faces used from the mid-nineteenth century on, the x-height for 6 point type ranged from .9 mm to 1.4 mm, with the average measuring 1.17. Ten examples of 5 point text were available, and the x-height measured from .9 mm to 1.1 mm, with the average being .98. In The Rede Lecture 1911, the x-height measured 1.5 mm for captions and .9 mm for text used in diagrams and charts. Based on these figures and the Digital Quality Index measurements noted earlier, 600 dpi scanning should render the complete range of metal type in common usage from the nineteenth century to the mid twentieth century.

Visual Inspection

While the Digital Quality Index provides a useful means for translating between digital and classical resolution, the authors of the tutorial on photographic and electronic imaging resolution recommended strongly that users verify the quality of image capture by visually examining the scanner's output. Samples of the 5 and 6 point type were scanned, printed on paper, and examined both with the naked eye and under an eye loupe. The quality of the reproductions was uniformly high. All were easily readable, with serifs and fine details rendered.

Some modern technical literature is printed at 4 point type, and some charts and diagrams used in books from the past century and a half contain handwritten characters that are below 5 point type in size. Measurements of 8 typefaces at 4 point ranged from .6mm to .9mm, with an average of .72 mm. The height of the smallest handwritten character in a line drawing from The Rede Lecture measured .55 mm, and was legibly produced. According to the Digital Quality Index rating for 600 dpi scanning, 4 point text will be rendered with medium quality (QI=5). An examination of a number of scanned samples of 4 point type under magnification revealed that while all alphanumeric characters were clearly readable and distinct, some type with serifs or in italic was more difficult to capture than sans serif or Roman type.

Based on these experiments, it appears that the resolution power of 600 dpi binary scanning will produce film that meets RLG's specifications for excellence (QI=8) for most text printed at 5 point type and larger, and it can be used to produce microfilm that meets the ANSI/AIIM MS23-1991 standard for acceptable quality (QI=5) for text printed at 4 point type and larger.

Given the CLASS scanning system's technical capabilities and the widespread use of typefaces 5 point and above in the printing of books between 1800 and 1960, Cornell has concluded that 600 dpi scanning and the production of digital COM can serve as a viable means for capturing and preserving brittle books. Obviously, higher resolution scanning would offer some improvement, and 900 dpi production scanners may be practical before long. However, a guiding principle of the Cornell project was that the use of digital technology must result in products of sufficiently high quality and must be cost effective to be considered viable for the preservation of deteriorating library materials. Higher resolution scanners are currently available, but because the scanning time is very slow, the cost of image capture would be prohibitive.

Costs and Availability of Digital COM Service Bureaus

There is great potential in using digital technology to capture brittle material and to produce microfilm as a preservation backup. However, there are many issues that remain to be resolved before this becomes a practical alternative. The first issue concerns costs and the availability of service bureaus to record the computer output microfilm. To date, Cornell knows of only one company, Image Graphics, that is prepared to offer this service. According to the Marketing Manager for the company, Image Graphics' primary interest lies in marketing the Micrographics EBR System 3000, However, the company realizes that many institutions cannot afford to purchase their system and the company is thus offering a scanning service. As has been reported, Cornell experienced some concerns about the quality of the processing of the film and the use of the SO-219 film base. While both concerns could be adequately addressed by Image Graphics, or by having the processing subcontracted to another service bureau, there would be a period of adjustment and some costs associated with meeting ANSI/AIIM standards.[4]

4 In a letter of December 5, 1991, Putnam Morgan, Marketing Manager for Image Graphics, quoted a price per book for the production of digital COM of $50 for the Kodak SO-219 and $25 for Kodak HQ Imagelink, with the price differential attributed to the cost of the film stock. Image Graphics would also have charged a one time set-up fee of $5,000 for "non-recurring engineering and coordination," and would have preferred to convert to the use of HQ Imagelink slowly over time. These charges were based on an average of 300 pages/book and 2,400 pages per

Conclusion

The results of this study show that preservation quality microfilm can be produced from 600 dpi scanning and recommends that this option—including costs, vendor relations, and large scale conversion—continue to be explored. Cornell had initially considered converting a large number of digital books to microfilm in 1992 but decided against this for several reasons, the primary one being that there was a considerable delay in the development of the document structure software that will be required for merging microfilm targets with digital page images and for reel programming. The document editing software has recently become available from Xerox Corporation. Additional software programming would be required to extend it to cover the merging of digital images with the requisite targets and to create microfilm reel contents. In June 1993, Cornell submitted a proposal to the National Endowment for the Humanities to conduct an end-to-end demonstration project to create digital COM for 1500 volumes. Support is also sought to assemble a technical advisory committee to address issues of quality, performance, and the development of draft guidelines for use by both research libraries and service bureaus.

Definitions of quality must be developed for the use of digital technology as a preservation alternative. Micrographic standards are not totally transferable to digitally-produced microfilm, as the problems of using resolution test patterns attest. Because film density is a software-controlled variable in the production of digital COM, it may have less bearing on the image quality than it does in conventional microfilming. Also, micrographics standards are based on defining quality for the preservation copy (film) and not the use copy (paper). This is problematic given the degradation caused by converting from film to paper via a reader/printer. Fourth, unlike micrographics,

roll of film for film lengths of 120 to 125'. A discount price was also given for a high volume of work (1,000 to 2,000 volumes/month was $20; 2,000-3,000 volumes/month was $18). The per frame charge, exclusive of the one time fee would be close to $.17/frame or $.083 per page.

This cost may seem high, but it should be remembered that it reflects start up costs for a new service, which should come down over time. Moreover, the cost may compare favorably to the cost of converting film to digital images. Estimates for this conversion run from several cents/frame to $1.50 per page for the creation of digital images from 35mm film. The range in price may reflect additional costs associated with indexing the digital images. In addition, much of the work in film-to-digital conversion is being done for banking and financial applications and is limited to 16 mm microfilm. A recent contract for converting 35 mm film to 500 dpi digital images was $.35/page.

quality standards for digitally captured material could vary according to the type of document being scanned (gray scale vs. binary) and the medium of the use copy (paper, film, on screen image). Quality standards for digital COM would assist in the knowledgeable use of digital technology as a means to preserve and make available deteriorating library materials.

2. Image Capture for Illustrated Texts and Archival Material

The Cornell/Xerox CLASS System was designed primarily to capture printed text, and as the Final Report for Phase I of Cornell's project indicates, the system can be used to produce a paper facsimile of comparable quality and lower cost than photocopy. From February through August 1992, scanning technicians experimented with the CLASS system's capability to capture a wide variety of hand printed or machine-produced illustrations, including line drawings, etchings, engravings, halftones, and continuous tone photographs that were present in fifty illustrated volumes published between 1850-1917. In September, the technicians began a six-month project to test the system's capability to reproduce a wide array of archival material. This latter project was conducted on behalf of the eleven comprehensive research libraries in New York State and partially funded by a Cooperative Preservation Grant through the New York State Program for the Conservation and Preservation of Library Research Materials.[5]

Because no guidelines existed to assist the technicians in determining how best to treat illustrations or archival material, much of their time was spent experimenting with various combinations of scanner settings, including filters, screens, and tonal reproduction curves. The challenge posed by this material was further compounded by changes over time in printing processes and in the media used to create manuscripts (from quill pen to laser-printed documents). With older published material, for example, scanner settings would have to be adjusted several times through the course of scanning a book because of the variations in the ink applications on the printer's plates.

Photo mechanical processes for illustrations included letter press, halftone, photogravure, and collotype etchings or engravings that utilized the cross hatching of straight lines to produce the illusion of tone. The process of creating halftones has changed over time. Early halftones from the mid-to-late nineteenth century varied from twentieth century halftones in the resolution of the printing screens

5 The findings and representative samples of this second project of the Testbed are presented in the final report Preserving Archival Material Through Digital Technology.

used to determine the frequency of the dots. Early halftones employed a more widely spaced dot pattern, resulting in a coarser image.

These changes required the technicians to apply different scanning settings for similar image types. The technicians also grappled with the question of fidelity: should their scanned representation be faithful to the process used to create the original or should they strive to capture the essence of the image? In the end, the answer was to try to capture the image, even if it meant representing a fine line etching as a halftone (see examples K & L).

Binary scanning can reproduce many categories of printed illustrations and archival material as paper facsimiles that are in most cases superior or equal to the quality of photocopy versions. This was true for most-machine produced documents, including typescript, offset printing, and letterpress printing. Digital technology effectively captured most handwritten documents (including a broad range of ink and paper colors) and line art, including woodcuts, line drawings, graphs, and other simple edge-based representations. In some cases, the scanned version actually improved the legibility of the original document although a 600 dpi resolution is insufficient to capture all the detail present in some fine line etchings and engravings. Binary scanning also proved superior to photocopying for reproducing the depth of tonal range present in continuous tone and halftone images.

The major distinction between binary scanning and photocopying for capturing photographs centers on a tradeoff between resolution and tonal reproduction. Photocopying can achieve extremely high resolution and can capture fine lines but it sacrifices detail in the highlights and the full range of shading.

Perhaps digital image technology's greatest advantage over light lens processes is in capturing text cum image, where the illustration can be windowed and treated separately from the printed text in a manner that optimizes the capture of both. A description of the CLASS scanning system is located in Appendix I.

The following chart and examples depict the capability of binary scanning in general and, the CLASS system in particular, to capture a wide array of illustrations commonly found in books published between 1850-1917.[6]

6 A similar description for archival material is included in Preserving Archival Material.

XEROX WG-40 SCANNER SETTINGS USED FOR ILLUSTRATIONS FOUND IN BOOKS PUBLISHED FROM 1850 TO 1917

ILLUSTRATION TYPE	SCANNER SETTINGS	COMMENTS/EVALUATIONS
LINEART/TEXT Line Drawings Text Charts/Diagrams	Lineart with enhancement filter and threshold at 50-120, with the majority falling in the 85-110 range. Threshold was increased for faint text while thresholds as low as 45-50 were used to capture material on darkened or colored paper.	These are generally the easiest categories of printed material to capture. Because of the simplicity of the images, very little manipulation of the scanner settings were required and the settings were generally consistent throughout the entire book. Image editing can be used to eliminate stains and to reconstruct damaged or missing text. (Compare Examples C and D.)
LINEART/TEXT Non-Latin Text	Lineart with enhancement filter and threshold at 50-120.	The factors that made languages such as Hebrew, Chinese and Sanskrit more difficult to capture were the varying line widths contained within each character, poor quality printing, and the darkness of the pages caused by their brittleness. The use of enhancement filters improved the capture of non-Latin text. (See Example A.)
LINEART/TEXT Mathematical Formulas	Lineart with enhancement filter and threshold at 50-120.	The relatively wide characters found next to the tiny superscripts found in mathematical formulas posed more of a challenge than regular text. In addition, many of the math books were hand written and the characters found in the formulas as well as the text varied widely in line width and density. The choice of threshold and filter affect one another, particularly for capturing a combination of fine line and coarse line material. (See Example B.)
MANUAL PRINTS Relief Wood Engraving Line Block Intaglio Steel Engraving	Lineart with enhancement filter and threshold at 50-100.	Generally for all of the Manual Prints that we encountered, if the engraving did not include very fine detail, using Lineart with an enhancement filter was sufficient to capture the image. However, in cases where the details of the image were created by very fine lines closely spaced, we used the Halftone or Photo Mode to attempt to capture the detail. This resulted in capturing the detail but losing the "feel" of the original. (See Examples E, F, and G.)

ILLUSTRATION TYPE	SCANNER SETTINGS	COMMENTS/EVALUATIONS
PROCESS PRINTS Relief Halftone	High Frequency with descreening filter, screen, and TRC map.	Halftone are created using a variety of screens, from the 80 line screens used in newspapers to the 150 line screens used in fine art books. This variation necessitates the use of different descreening filters and TRC maps to capture the contrast and details of the original. (See Example H.)
PROCESS PRINTS Intaglio Mezzo Type Photogravure Machine Printed Photogravure	Photo with screen and TRC map.	Photo Mode captures the details and "feel" of the original adequately. The system is able to capture process prints better than it can capture an original photograph because there are fewer tonal gradations in the photogravures. (See Examples I and J.)
PROCESS PRINTS Planographic Photolithograph Collotype	Low Frequency using an enhancement filter and Moiré Away with a threshold at 40-120.	The originals may vary a great deal in their density and detail which requires adjustment of the threshold and moiré away to find the right balance for capturing the variations in the original. (Examples K and L show two ways of capturing a photolithograph.) (Example M represents a reproduction of a collotype.)
Photograph	Photo with screen and TRC map.	Photo Mode allows for the capture of an original photograph with most of the detail found in the original. The continuous tone image is changed into an image composed of a series of dots which can only be black or white in binary scanning. (See Example N.) (Examples O and P represent a CAMI scan and the final image selected.)

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אֶל־בְּנֵי־חֵת לֵאמֹר: ד גֵּר־וְתוֹשָׁב אָנֹכִי עִמָּכֶם תְּנוּ לִי אֲחֻזַּת־קֶבֶר עִמָּכֶם וְאֶקְבְּרָה מֵתִי מִלְּפָנָי: ה וַיַּעֲנוּ בְנֵי־חֵת אֶת־אַבְרָהָם לֵאמֹר לוֹ: ו שְׁמָעֵנוּ ׀ אֲדֹנִי נְשִׂיא אֱלֹהִים אַתָּה בְּתוֹכֵנוּ בְּמִבְחַר קְבָרֵינוּ קְבֹר אֶת־מֵתֶךָ אִישׁ מִמֶּנּוּ אֶת־קִבְרוֹ לֹא־יִכְלֶה מִמְּךָ מִקְּבֹר מֵתֶךָ: ז וַיָּקָם אַבְרָהָם וַיִּשְׁתַּחוּ לְעַם־הָאָרֶץ לִבְנֵי־חֵת: ח וַיְדַבֵּר אִתָּם לֵאמֹר אִם־יֵשׁ אֶת־נַפְשְׁכֶם לִקְבֹּר אֶת־מֵתִי מִלְּפָנַי שְׁמָעוּנִי וּפִגְעוּ־לִי בְּעֶפְרוֹן בֶּן־צֹחַר:

למימר: ד דייר ותותב אנא עמכון הבו לי אחסנת קבורא עמכון ואקבר מיתי מן קדמי: ה ואתיבו בני חתאה ית אברהם למימר ליה: ו קבל מננא רבוננא רב קדם יי את בינגא בשפר קברנא קבר ית מיתך אנש מננא ית קבריה לא יכלי מנך מלמקבר מיתך: ז וקם אברהם וסגיד לעמא דארעא לבני חתאה: ח ומליל עמהון למימר אם אית רעוא בנפשכון למקבר ית מיתי מן קדמי קבילו מני ובעו לי מן עפרון בר

רש"י

ומתה: (ד) גר ותושב אנכי עמכם. גר מארץ אחרת ונתישבתי עמכם. ומ"א אם תרצו הריני גר ואם לאו אהי' תושב ואטלנה מן הדין שא"ל הקב"ה לזרעך אתן את הארץ הזאת: אחזת קבר. אחוזת קרקע לבית הקברות: (ו) לא יכלה. לא ימנע כמו (תהלים מ) לא תכלא רחמיך. וכמו (לעיל ח) ויכלא הגשם: (ח) נפשכם רצונכם: ופגעו לי. לשון בקשה כמו (רות א) אל תפגעי

שפתי חכמים

שאמר לה שלא נבהלו ר"ל שטה מועטת קודם לכן נבהלה כל כך מדבריו ופרחה רוחה ונשמתה. מהרש"ל: י וא"ת והלא כפ' לך לך כתיב והכנעני והפריזי אז יושב בארץ ופס פרש"י ולא זכה בה אברהם עדיין ש"מ דעדיין לא היה לאברהם חלק בה וי"ל דלעיל לא היה עדיין זרע לאברהם אבל עתה הי"ל זרע ולכך נקט הכא שאמר לו הקב"ה לזרעך אתן וגו' ועתה יש לי זרע ולכך לכל הפחות תנו לי אחוזת קבר אף שעדיין אין זרעי ראוי לרשת את הארץ כיון שעדיין מועטים הם: כ דק"ל דהאי לשון אחוזה נופל אלא בדבר שיש בו ממש לא על קבר שהוא כיר חלול לכן פירש"י אחוזת קרקע לקבר ואחוזה קאי אקרקע. והרא"ם פי' דאחוזה שייך על קרקע שהוא תחת רשות האדם לא כן קבר שהוקלה נמת לכן פי' שיתנו לו קרקע לאחוזה לעשות הברות: ל [ממ"ש] אע"פ שזה כסוף כה"א וזה כאל"ף מ"מ שוין בפירושו אבל אין פירושו ל' כליון כמו עשי כלה כלה ונחרלה שהם בה"א לבסוף כמו הכא לא יכלה דכאן אין לו שום משמעות

אור החיים

אברהם והיא איך ישאל מתנת חנם ויאמר תנו לי אחוזה לזה הקדים ואמר לאמר פי' לבבו לא כן יחשוב אלא מפיו אמר הדברים ודעתו לבא בטענה כאשר אבאר בסמוך:
גר ותושב וגו'. טעם טענתו גר והושב ע"פ מה שכ' רמב"ם בפ"ז מהל' זכיה ומתנה וז"ל יכול ליתן מתנת חנם לגר תושב שאתה מצווה להחיותו דכתיב גר ותושב וחי עמך ע"כ ויש לך לדעת כי כל תורתינו הקדושה היא שכליות ובפרט בענייני הנהגה הארצית וכמו שאנו מתנהגים בגר היושב עמנו כמו כן יתחייב שכליות יושבי הארץ להנהיג ביניהם להיות אדם שהוא גר ותושב עמהם ולתת לו מתנת חנם והיא טענת אברהם גר ותושב אנכי תנו לי ודקדק לומר גר ולא הספיק לומר תושב המכוין לומר שהגם שאני גר ואיני מכם אף עפ"כ הריני תושב עוד טעם אומרו גר כי חש לומר על עצמו תושב בעה"ז והוא הפך מדת הצדיקים לזה הקדים לומר גר:
ואקבריה וגו'. פי' שלא יעכבוהו עוד נתכוין לימר להיות שעתיד הוא לגלות דעתו כי חפץ בשדה עפרון
דין

כלי יקר

ונותן בה ממון עתה יאמרו מה ראה אברהם לתת כולי האי בסדל' דארעא הלא דבר הוא ודאי שראה בו דבר גדול שישוה בכפלי כפלים לזה הקדים לומר ואקברה מתי לקוברו מלפני פי' זה הוא שמכריחו שלא לחוש על ממונו ואם לא הי' מתו לפניו לא היה קונה דבר ומעתה הגם שיקנה שדה עפרון בכל ממון שבעולם יתלו שהוא מקום מובחר לקבורה ולהם אין בכך כלום:
ויענו וגו' לאמר לו. פי' לגד כי לא רבים ידברו לו"א לאמר לו כי אחד יאמר אליו בעד כולם. עוד נתכוון לומר שלא הסכימו ביניה' על הדבר האמור בתשובת' אלא לאמר לו וכמו שגילה סופם על תחילתם בכסף מלא:
שמענו וגו'. פי' קבל דברינו שאנו אומרים לך לעשות והוא שאתה תבחר הקבר המובחר שבקברים וקבור מתך ואינך צריך לשאול רשות לו' מקום פלוני אני חפץ ולא לתת שויי והטעם הוא איש ממנו את קברו לא יכלה וגו' והרי נתינת רשות מעתה נתונה לך ולטעם כדי שלא יתעכב מתו לפניו המו שבא בטענותיו ואומר נשיא וגו'
יתבאר

EXAMPLE A Hebrew Text

From a book published in 1900.

Scanned in Window Mode as a Text/Lineart Image Type.

est évident que l'équation (4) ne pourra pas être satisfaite. Il s'ensuit que la circonférence de rayon ρ ne rencontre pas la courbe, et, par conséquent, le point M est un *point isolé*.

183. Lorsque l'inégalité (5) n'a pas lieu, les racines t de l'équation

$$(6)\qquad \left(\frac{\partial^2 f}{\partial x^2}\right)_0 + 2\left(\frac{\partial^2 f}{\partial x\,\partial y}\right)_0 t + \left(\frac{\partial^2 f}{\partial y^2}\right)_0 t^2 = 0$$

sont réelles, et elles peuvent être représentées par

$$\frac{\sin\alpha}{\sin(\theta-\alpha)},\quad \frac{\sin\beta}{\sin(\theta-\beta)},$$

θ étant toujours l'angle des axes, α et β des angles compris entre zéro et π; on peut alors mettre l'équation (4) sous la forme

$$\frac{1}{2}\left(\frac{\partial^2 f}{\partial y^2}\right)_0\left[k - h\,\frac{\sin\alpha}{\sin(\theta-\alpha)}\right]\left[k - h\,\frac{\sin\beta}{\sin(\theta-\beta)}\right] + R_3 = 0.$$

Nous remplacerons h et k par leurs valeurs $\frac{\rho\sin(\theta-\omega)}{\sin\theta}$, $\frac{\rho\sin\omega}{\sin\theta}$ déjà employées au numéro précédent; nous ferons en outre, pour abréger l'écriture,

$$\sqrt{\left[\left(\frac{\partial^2 f}{\partial x^2}\right)_0 - 2\left(\frac{\partial^2 f}{\partial x\,\partial y}\right)_0\cos\theta + \left(\frac{\partial^2 f}{\partial y^2}\right)_0\right]^2 + 4\left[\left(\frac{\partial^2 f}{\partial x\,\partial y}\right)_0^2 - \left(\frac{\partial^2 f}{\partial x^2}\right)_0\left(\frac{\partial^2 f}{\partial y^2}\right)_0\right]\sin^2\theta}$$
$$= M \times 2\sin^2\theta,$$

en convenant de prendre le radical avec le signe du produit $\sin(\theta-\alpha)\sin(\theta-\beta)$. L'équation (4), divisée par ρ^2, devient alors

$$(7)\qquad M\sin(\omega-\alpha)\sin(\omega-\beta) + \frac{R_3}{\rho^2} = 0,$$

$\frac{R_3}{\rho^2}$ s'annulant avec ρ.

EXAMPLE B Math Text

From a book published in 1900.

Scanned in Window Mode as a Text/Lineart Image Type.

That of the north was little more than a superior sort of Lombard, with less of the wild and monstrous

FIG. 126.—Cathedral at Worms.

imagery peculiar to the style The best examples are to be found at Pisa (Plate XXXVI), Florence (Fig. 132), and Montefiascone.

EXAMPLE C Line Drawing

From a book Published in 1896.

Scanned in Window Mode as a Text/Lineart Image Type.

That of the north was little more than a superior sort of Lombard with less of the wild and monstrous

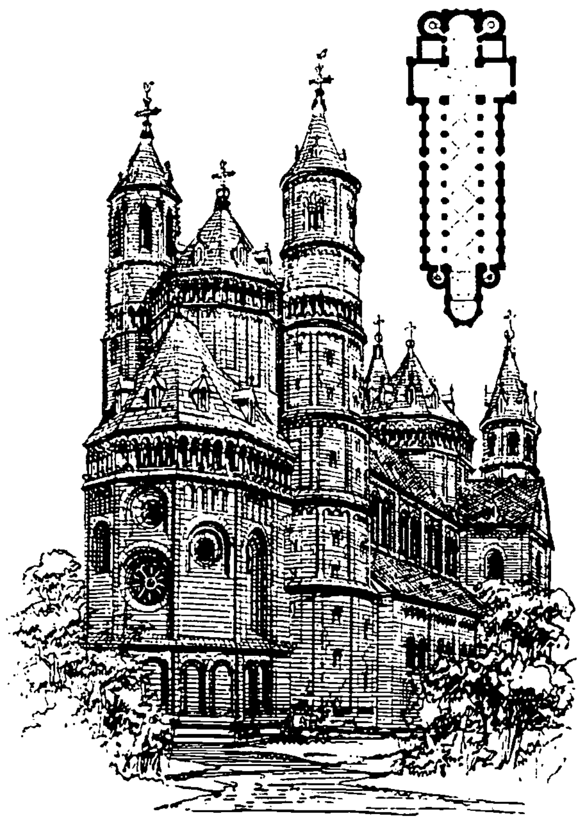


FIG. 126.—Cathedral at Worms.

imagery peculiar to the style. The best examples are to be found at Pisa (Plate XXXVI), Florence (Fig. 152), and Montefiascone.

EXAMPLE D Image Wizard

Modification of EXAMPLE C using Image Wizard.

Scanned in Window Mode.
Placed a window around the drawing to decrease the threshold from that used for the text.

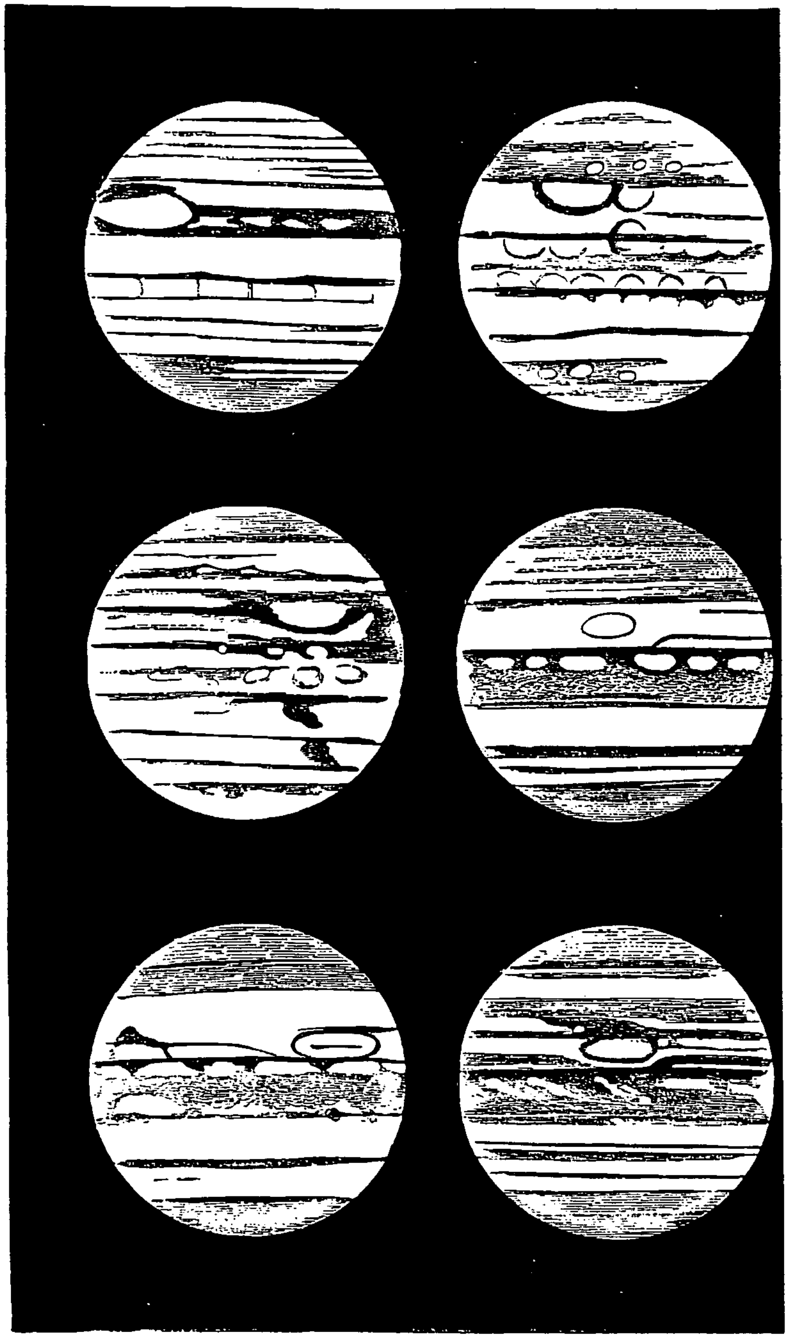
In Image Wizard bitmap editing package - Reconstucted words using existing text letters, and "erased" the black areas created by scotch tape used to repair the original page.

EXAMPLE E Manual Print - Relief - Wood Engraving

From a book published in 1873.

Scanned in Window Mode as a Text/Lineart Image Type.

Fig. 33.



I.	1857, Nov. 27.	(Dawes.)	II.	1859, Dec. 29.	(Huggins.)
III.	1858, Mar. 2.	(Huggins.)	IV.	1870, Jan. 23.	(Gledhill.)
V.	1872, Feb. 2.	(Gledhill.)	VI.	1886, Feb. 25.	(Denning.)

EXAMPLE F Manual Print - Relief - Line Block

From a book published in 1891.

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Scanned in Window Mode as a Text/Lineart Image Type.

another by spiral springs, thus bringing the inner heads of the screws against the ends of the box. These heads are often made square with the shaft of the screw; but they are much better made spherical, so as to fit into conical bearings at the ends of the box. A flat comb plate is placed over the moveable frames across the open centre, with a fine-toothed comb cut so as to form a chord to the circle of the field of view at right angles to the moveable webs. This comb plate carries two stout parallel wires (called *position wires*), about 12″ apart, across the centre of the field, and at right angles to the moveable webs and parallel to the comb. The eyepieces are attached

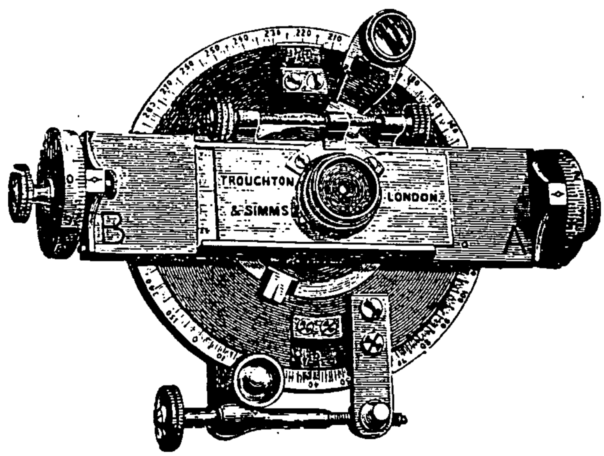


FIG. 3. (Parallel-wire Micrometer.) *

outside the box to a sliding-piece, moved by a screw for centering over the webs in the direction of their motion. The webs, position wires, and comb should be clearly defined with a high power at the same time. The eyepieces should as much as possible slide into the same adapter, to save screwing and unscrewing.

* One reading lens is removed to show the slow-motion clamp.

EXAMPLE G Manual Print - Intaglio - Steel Engraving

From a book published in 1879.

Scanned in Window Mode as a Text/Lineart Image Type.

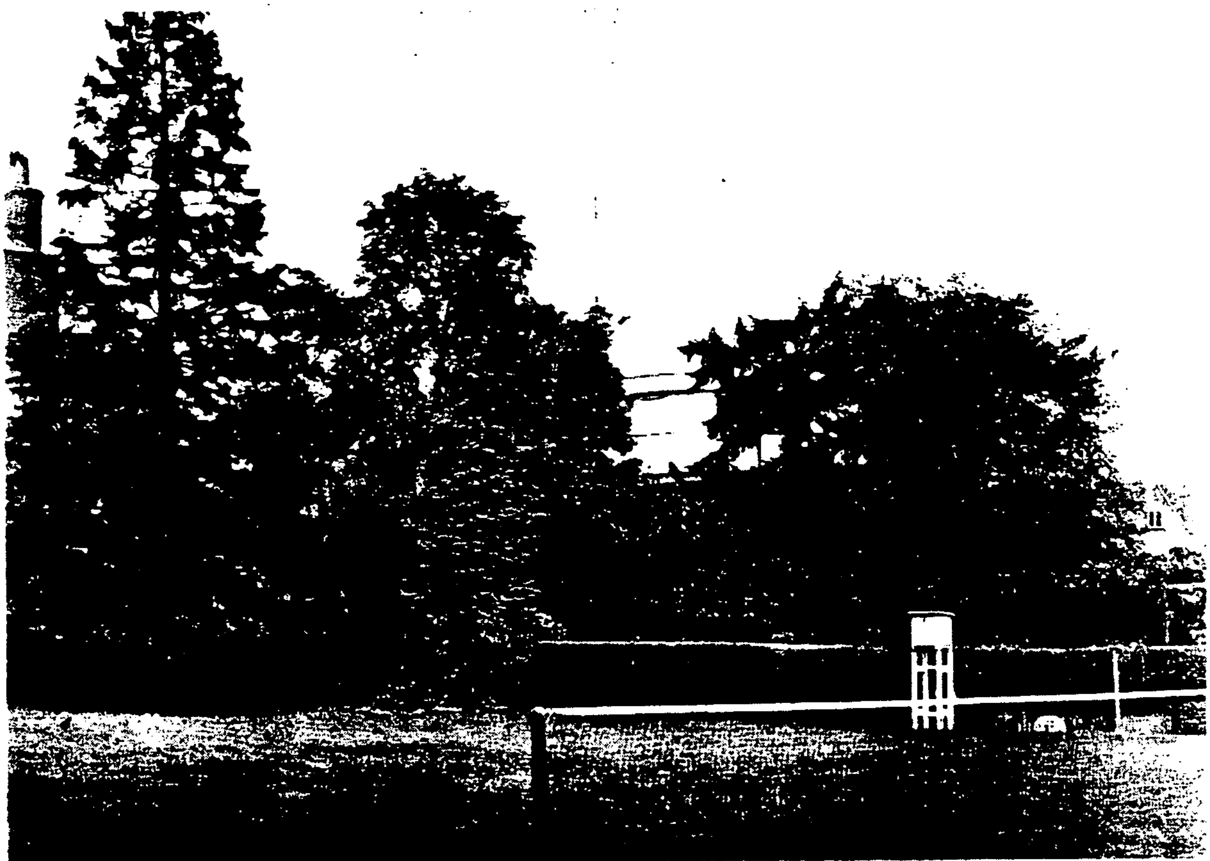
A FINE RUBBER TREE (HEVEA BRAZILIENSIS)

COTTON-WOOD TREES AT PORTO VELHO

EXAMPLE H Process Print - Relief - Halftone

From a book published in 1914.

Scanned in Window Mode as a Halftone Image Type with Text/Lineart Image Type used for the accompanying text.



LONDON STEREOSCOPIC CO PHOTOMEZZOTYPE

STANMORE OBSERVATORY.
OUTSIDE VIEW

EXAMPLE I Process Print - Intaglio - Mezzo type

From a book published in 1891.

Scanned in Window Mode as a Photo Image Type with Text/Lineart Image Type used for the accompanying text.

影 近 者 著

EXAMPLE J Process Print - Intaglio - Machine Printed Gravure

From a book published in Japan in 1937.

Scanned in Window Mode as a Photo Image Type with Text/Lineart Image Type used for the accompanying text.

EXAMPLE K Process Print - Planographic - Photolithograph

From a book published in 1875.

Scanned in Window Mode as a Low Frequency Image Type.

EXAMPLE L Process Print - Planographic - Photolithograph

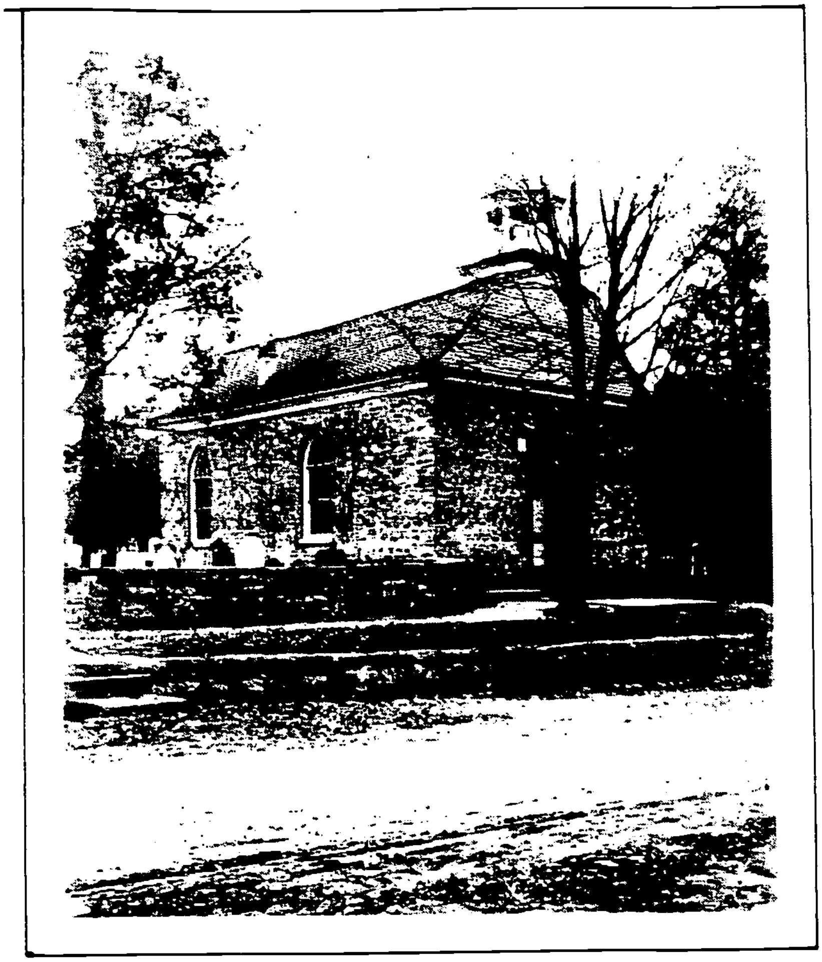
From a book published in 1875.

Scanned in Window Mode as a Photo Image Type with Text/Lineart Image Type used for the accompanying text.

EXAMPLE M Process Print - Planographic - Collotype

From a book published in 1868.

Scanned in Window Mode as a Low Frequency Image Type.



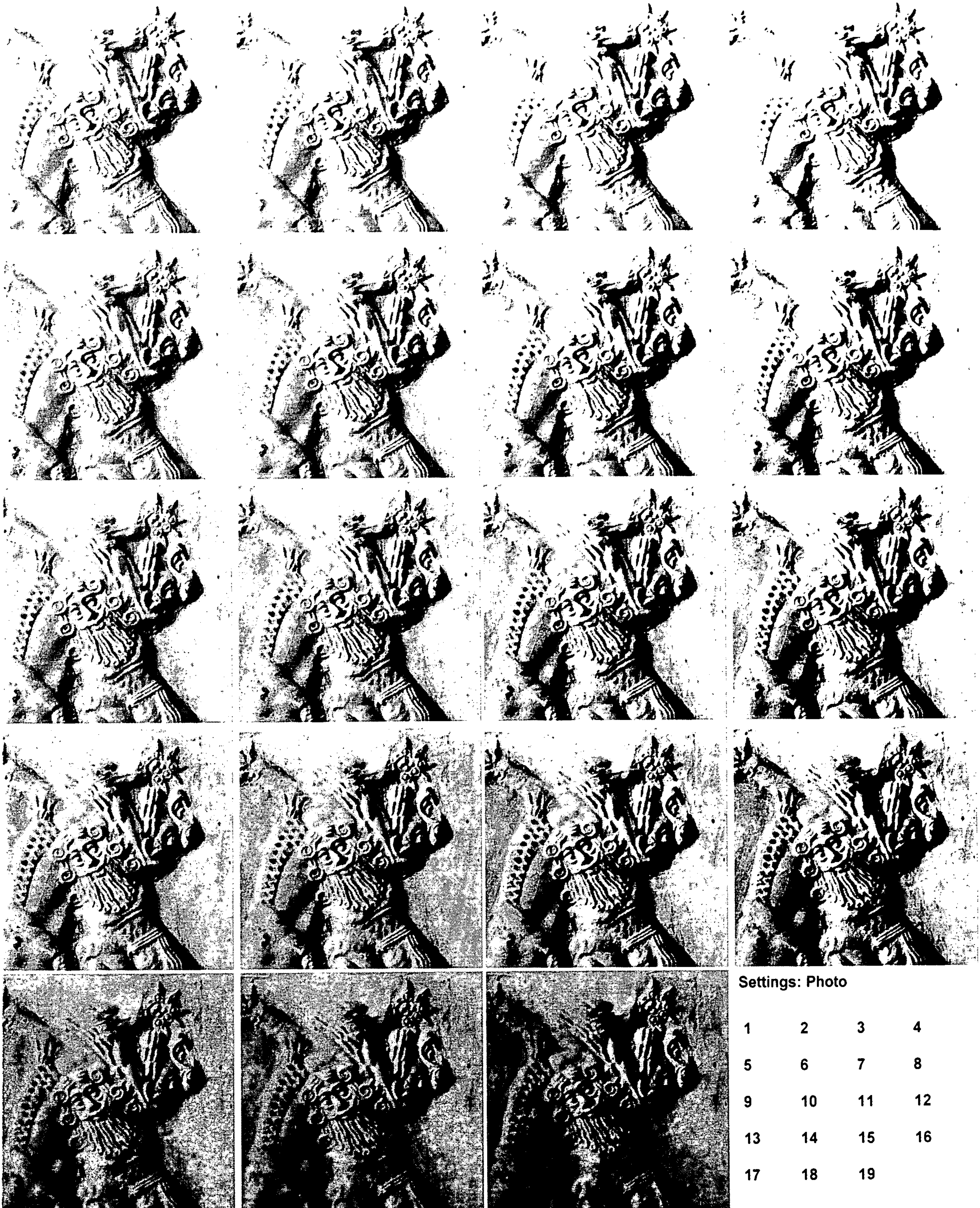
Old Dutch Church · Tarrytown · 1699.

EXAMPLE N Process Print - Photograph - Attached

From a book published in 1905.

Original Photograph quite faded.

Scanned in Window Mode as a Photo Image Type with Text/Lineart Image Type used for the accompanying text.



Settings: Photo

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16
17	18	19	

AMPLE O

CAMI Scan - Photo
From a book published in 1876.
Scanned in CAMI Mode - Image Number 10 was chosen to be reproduced.

S. Thompson.

IZDUBAR (NIMROD) IN CONFLICT WITH A LION.

FROM AN EARLY BABYLONIAN CYLINDER.

EXAMPLE P Process Print - Photograph - Attached

From a book published in 1876.

Scanned in Window Mode as a CAMI-Photo Image Type with Text/Lineart Image Type used for the accompanying text.

III. Expanding the Digital Library

Originally the digital library was intended only as a way to preserve library materials already owned by Cornell University Library. The testbed project has served as the impetus for the digital library to begin an expansion that will include current and recent scientific journals, dissertations, research papers, and current textbooks. Major collaborative projects have been proposed to add scholarly material that will be used nationwide. Cornell has worked to provide an infrastructure for the testbed that is sufficiently flexible and expandable to enable the digital library to meet the immediate needs for storage of library material, and to support the additional services that are anticipated over the next three years.

Several initiatives are underway that are testing the scaling of the digital library:

- The University LIcensing Project (TULIP), is a cooperative research project in which Elsevier Science Publishers and eleven universities, each with strength in the physical and engineering sciences, are testing systems for networked delivery and use of journals. Cornell University's objective in this project is to evaluate its capacity (a) to make scholarly articles in on-line form available and easily accessible over the campus network to Cornell faculty, students and staff, and (b) to exchange such publications over the national network with other institutions. Cornell is loading the electronic files for 30 materials science journals into its digital library, and making this information accessible to the Cornell community over the campus network. Over the course of three years, 100,000 pages/year will be scanned and added to the Cornell Digital Library.

- Further growth of the digital library will occur as more publishers begin supplying material in electronic form rather than on paper. Already, some journals of interest to the research community are being published primarily, or only, in electronic form. For material with time value (such as scientific journals) electronic publishing offers obvious advantages.

- The preservation scanning currently being done in-house will increasingly shift to service bureaus, following the model of preservation microfilming. This will increase vastly the rate of incremental growth of the digital library. It is estimated that Cornell owns over 1 million volumes in need of preservation through reformatting.

- The level and complexity of indexing will increase. Currently, searching of the digital library is provided through an SQL database running on the digital library server. This database provides limited searching capabilities by title, author, and document ID, and is intended primarily for known-item searching (that is, locating a document that is known to be in the digital library). The database processing needs will grow exponentially as the digital library grows. Projects such as TULIP are based on a many-to-one database so that journal articles can be accessed individually. This will mean an order of magnitude increase in database entries per document.

- As the digital library becomes a tool used for actual research, the number of users and their level of sophistication will increase. Not only will there be more concurrent users, but each user is likely to open more documents simultaneously.

- A variety of storage formats will be accommodated. Although the document architecture provides for different storage formats, at present the digital library software supports only TIFF bitmap images stored using the International Consultative Committee on Telegraph and Telephone (CCITT) Group 3 or Group 4 compression. Other formats are being used to capture documents that will be added to the digital library, including gray scale images compressed using JPEG (the Joint Photographic Experts Group) or other compression schemes, color images produced through the Kodak Photo CD Technology, ASCII text produced by OCR from scanned images, PostScript, and SGML documents. Each format will require an additional software library to be added to the digital library server, and may require additional processes to be running simultaneously.

- Database searching capabilities are being enhanced. At present, the Cornell University Library on-line catalog is the primary searching tool for all material, whether in paper or digital format. The digital library database is much more limited, and is intended to assist with locating and browsing documents that have been identified by searching the on-line catalog. The on-line catalog is being integrated with the digital library by adding Z39.50[7] database searching links to the digital library server and client software. Z39.50 is a protocol for information retrieval via networks. It defines the way in which a program on one computer can: 1) query the database of another computer, and 2) request the transfer of a particular record or group of records. In addition, there is a demand for full-text searching. The TULIP project includes searching of the abstracts of the articles, and some of the other planned projects will

7. Z39.50 is an OSI (Open Systems Interconnection) application-layer protocol from the National Information Standards Organization.

focus on database searching techniques. To provide this capability will require additional storage and processing resources, particularly to generate the full-text indexes.

IV. Conclusion

The work described in this report builds on the earlier work to study the feasibility of the use of digital technology to preserve deteriorating library material. In the course of three years Cornell has moved from prototyping and testing to implementing requirements for building a broad-based digital library accessible over world wide networks for printing and desktop computer use.

Cornell University Library and Cornell Information Technologies have embarked on a major project to scale these efforts both in terms of the volume of material to be included but also in moving from a single institution project to a collaborative enterprise. The Making of America project aims at revolutionizing scholarly access to source material on the development of America's infrastructure—transportation, communications, and the built environment—between the years 1860-1960.

In the course of this project to build a large digital library—numbering 100,000 volume equivalents—in cooperation with other research institutions, Cornell and its partners will address key remaining issues that must be resolved before digital libraries become an everyday reality. These include—but are not confined to—defining standards for the quality of images captured, ensuring the long-term accessibility of the digital files and developing the infrastructure that will enable broad access to sources in network-connected digital repositories.

In advancing the electronic preservation of and access to research library materials Cornell seeks to understand how on-line availability of thematically related materials will, over time, influence patterns of teaching, study, research, and scholarly publication. In the process, this project will assist research libraries redefine their missions in an electronic age and come to terms with the challenges they face. These include the spiraling cost of books and serial subscriptions; the rapid deterioration of collections caused by the rise of acid paper in publishing since the mid-nineteenth century; escalating costs and resistance to additional library buildings; and rising expectations by students and scholars for improved access to information. Digital image technology hold great promise to assist research libraries—and other purveyors of information—in addressing these challenges.

APPENDIX I — THE CLASS SCANNING SYSTEM

The CLASS scanning system utilizes a variety of software settings to optimize image capture. During the initial setup, technicians apply a combination of settings and preview the image on the screen. The following settings can affect image capture.

1. IMAGE TYPE

This setting refers to the method that is used to capture the page, not to the type of original. The system can be configured to treat a page as:

Lineart: used for text or line drawings (see examples A,B,C)

Photo: applied to continuous tone originals or to very fine steel engravings that can not be captured by lineart (see examples G & N)

High Frequency: applied to high frequency halftones (see example H). Halftone screening functions similarly to threshold (see below) in that it converts gray video to binary. However, in the case of halftone screening, a small two-dimensional array of thresholds is used to generate dots to represent continuous tones in the original. This allows the image to then be rescreened with a new halftone while avoiding moiré (an undesirable pattern often introduced by overlaying halftone screens).

Low Frequency: applied to stippled engravings in which light and shade are represented by employing dots or flicks instead of lines. (see example K)

Mixed: allows for automatic segmentation of each page and is intended for scanning illustrated books with minimal manipulation by the technician. This option is still under development and the version available to the technicians during the Testbed Project did not prove satisfactory for scanning books with a variety of illustrations.

Cami Patch: is used to create a test sheet with a variety of scanner setting options for illustrations and is most useful for technicians just learning the system. (see example O.)

In addition to Image Type, operators also chose a variety of other setting options designed to enhance image capture. These include:

2. THRESHOLD

The CLASS scanner starts by capturing 8 bit gray video. This means that each pixel can have one of 256 possible values, each value representing a different density level on the original. Thresholding is a function that allows the gray video to be converted to binary, which has only two values per pixel, either black or white. This bilevel image is often referred to as a bitmap.

The threshold setting is primarily used to establish contrast between text and background. Threshold is analogous to density in micrographics. By varying the threshold setting between 0 and 255, technicians can determine how light or dark the image will appear after it has been scanned. The threshold level has a direct effect on the shape and density of individual letters, and in order to determine the appropriate threshold, the technicians compare a 600 dpi version on the screen with the original page, using a 5X loupe to view the original.

3. FILTER

The digital filter is a powerful image processing function that has a variety of purposes. In the CLASS scanner, digital filters are used for both enhancement and halftone screening. Digital enhancement allows the edges and slope of a character to be emphasized, making it appear crisper. Line broadening or darkening often accompanies enhancement, requiring the threshold to be adjusted. Digital descreening is used to remove high frequency halftone dots from the original which are too small for the scanner to reliably reproduce.

The choice of filters can determine how accurately the scanned image reflects the original. The CLASS scanner provides a variety of filter choices which are set for capturing published material. The current system offers a choice of three settings: filter 1, filter 2, or none. For each filter there are 9 different settings that can be applied.

4. TONAL REPRODUCTION CURVE (TRC) MAPS

Every scanner has an inherent tone reproduction capability which governs the relationship between the density (darkness) of the original and the resulting gray level as perceived by the scanner. TRC mapping is a function which allows the original gray levels from the scanner to be remapped (via a look-up table) to some new set of gray levels. TRC mapping is used only in conjunction with capturing photographs and halftones, and is most commonly used to adjust the brightness and contrast of pictures when halftone screening is used. A "neutral" TRC is used to designate the unchanged tone reproduction; a "darker" TRC is used to increase the darkness of the original.

5. EDITING SOFTWARE

The CLASS software includes a bitmap editing program produced by Wang Laboratory, called Image Wizard. This software was used by the technicians to remove stains and foxing, to fill in incomplete characters, to reverse polarity, and to label scanned images. The program enabled the technicians to edit images at the "pixel" level, which proved very valuable in reconstructing damaged type. However, bit map editing is time-consuming and the program was used only sparingly. (compare examples C & D)

6. MOIRÉ AWAY

This image processing function masks the undesirable patterns introduced when moiré occurs. Moiré is an independent, usually shimmering pattern seen when two geometrically regular patterns (such as two sets of parallel lines or two halftone screens) are superimposed, especially at an acute angle. Although designed primarily for use with capturing halftones, the technicians found moiré away useful when using the low frequency mode to capture stippled line engravings. The CLASS includes five different settings for moiré away.

7. SCAN MODE

There are four scan mode options available with the CLASS System: Quality Control Mode, Production Mode, Window Mode, and Cami Scan Mode.

<u>Quality Control Mode</u> is used when setting up a book and allows the technicians to display the 600 dpi image on the screen in a view window so as to make adjustments to threshold and filter settings and to establish page trim. The technicians will scan a number of pages from a book in quality control mode to ensure that the settings they have chosen will capture most of the text in an acceptable manner. In this mode, the technicians may scan and view; rescan and view; save the image; and calibrate the scanner to determine whether the mechanical parts of the system are operating within tolerance levels. If the scanner is not calibrated, the image quality will deteriorate with subsequent scans.

Production Mode is used for scanning when the same settings can be maintained for multiple pages. In this mode, technicians can scan and save (but not view) an entire document. Because each image is not displayed on screen, scanning time is significantly reduced. Production mode works well for capturing text and line art where there is very little variation in printing quality throughout the document.

Window Scan Mode is used mainly for capturing illustrated text. This mode allows the operator to treat three different areas of a page in an independent manner. The image is displayed in a view window and the technician can overlay rectangular windows over one or two portions of the page and may choose separate options for capturing the material contained in those windows. The material may be captured as high frequency, low frequency, lineart, photo, or as a cami patch. The two windows may also overlap, enabling the technicians to capture text within a halftone or photo. The limitations of the window scan mode are that only two thresholds, two filters, and one tonal reproduction cure (TRC) may be selected at a given time. This can pose a problem when a page contains two halftones, one of which is high contrast and the other is low contrast. Because only one TRC map can be chosen, it may not be possible to create the best reproduction of both halftones. As noted earlier, Xerox is developing a system of auto-segmentation that may ultimately obviate the need for using window scan mode.

Cami Scan Mode is used to create a test sheet that provides 19 different versions of scanner settings for an image. The test sheet can then be used to determine scanner settings for capturing the illustration. During each of 19 scans, the system applies a different combination of scanner settings to the selected portion of the image. (see example 0.) The cami scan mode is of most use to technicians learning the system and to experienced technicians when they encounter a new type of illustration.

APPENDIX II — DOCUMENT ARCHITECTURE DESCRIPTION

A digital library consists of a Image Delivery Server, networked storage, and a referencing database. A single digital library will contain one or more collections. Each collection will contain one or more documents.

Conceptually, a single instance of a Digital Library is all the material and databases directly accessed by a single Image Delivery Server. If searches and retrieval of material must be mediated by another server (in order to verify authorization, for example), that material is considered to be in a separate Digital Library. Collections exist within a Digital Library for several reasons, including the traditional library reasons of grouping thematically-related material (such as a Witchcraft Collection or an Icelandic Collection) and information technology-related reasons (such as keeping licensed material with special authorization requirements grouped together).

The referencing database allows searching for documents by author, title, and document ID. Searching is qualified by collection. Hence a database search could mean a search of the entire database (all collections within the Digital Library instance) or a single collection.

In the current implementation, the referencing database is a relational SQL database, and each collection is represented by a table in the database. It is planned to migrate to Z39.50 database searching as the preferred method, as this protocol has been established as the standard for library applications.

Authorization will be primarily collection-based, although the design will permit authorization checking at any level down to the individual file. It is intended that when a patron select a library or a collection for searching, he will immediately be informed if he is not authorized to access documents within that library or collection. A patron might not be authorized to access a particular document or component of a document, but in that case the notification would come only when the patron attempted to open the document or access the particular component.

Each document consists of three components: the logical structure; the physical references; and the data files.

The logical structure is a logical description of the document. Conceptually, a document is a tree, with the leaves being the data files (pages). At a minimum, all documents have a logical structure which lists the pages in the document and the order in which they appear. Usually, documents will have a more elaborate structure. The logical structure relates the logical structure of a document to the physical references which make up the document.

The physical references maps the lowest levels of the document's logical structure (the leaves of the tree) to the files that contain the data. Where there are multiple representations of a page, such as images at various resolutions, these are linked together in the physical references file.

The data files contain the data making up a document. Any format can be accommodated: image files, ASCII text, PostScript, etc. However, one-to-one correspondence between data files for a given physical reference is assumed. That is, if there are multiple file types for a single page, these files should represent exactly the same information.

PHYSICAL REFERENCES FILE

The Physical References file is the component of the document which relates logical structures (logical components of documents) to physical files. Document references, by which a document can be composed of all or part of other documents possibly residing on different servers, are handled in the Physical References file.

A document may contain multiple document objects, each of which contains one or more data objects. When a document contains actual physical data (for example, it is created by scanning or importing images), a Master Document Object is created. When a document incorporates components of other documents, a Reference Document Object is created for each of the other documents. The Document Objects are numbered with internal reference numbers, which are included in the corresponding Data Object lines.

Data Object lines include the Document Object number, the file reference number, and the file type. The Document Object number refers to a Document Object line, from which the library name, collection name, and document ID can be retrieved. The tuple

<libraryID>+<collectionID>+<documentID>+<filetype>+<file reference>

is guaranteed to locate a file. Each Data Object line refers to a single file; where multiple file types of a single document page exist, there will be multiple Data Object lines for that page.

In the file, all Document Object lines will precede all Data Object lines for a given document. Document Object lines may be either grouped together at the beginning of the file, or may immediately precede the first Data Object line for the Document Object. Document Object lines will appear in order by Document Object number. Data Object lines will appear in order by sequence number, NOT by Document Object number.

The fields in the Physical References file are delimited by vertical bars.

Document Object lines

Field	Description	Comments
1	Document Object number	0 = Master Document Object Other = Reference Document Object
2	Library name	Server name
3	Collection name	
4	Document ID	8-digit number
5	Author name	
6	Volume	
7	Title	
8	Edition	

Data Object lines

Field	Description	Comments
1	Document Object number	Corresponds to above
2	Sequence number	
3	File reference	Reference number used to locate file in filing system
4	Physical reference number	Corresponds to Logical Structure file
5	File type	0 = Structure file 1 = TIFF 600dpi 2 = TIFF thumbnail 3 = ASCII version of page (i.e., OCR output) 4 = ASCII notes 5 = Other
6	Note	

Physical References file example

```
0|CORNELL|OLINLIB|00000001|Boole, Mary Everest||Philosophy & Fun Of Algebra||
0|0|00000001|0|0||    (File ref. #1 =Physical ref. #1 = Logical Structure file)
0|1|00000002|5|1|     (File ref. #2 = Phys. ref. #5 = 600dpi TIFF image)
0|2|00000003|5|2||    (File ref. #3 = Phys. ref. #5 = 100dpi TIFF image)
0|3|00000004|6|1||    (File ref. #4 = Phys. ref. #6 = 600dpi TIFF image)
0|4|00000005|6|2||    (File ref. #5 = Phys. ref. #6 = 100dpi TIFF image)
```

Note that in the above, it is guaranteed that file references 2 and 3 are two different versions of the same page, as are file references 4 and 5.

LOGICAL STRUCTURE FILE

The Logical Structure file is the component of the document structure which offers "views" of a document and links images together logically to define documents. The file is actually an unloaded tree; when a document is "opened", the file is read and the tree reconstructed. By convention, all Logical Structure files contain one logical structure "PAGES" which defines the document by listing the pages in the order in which they appeared in the original document.

Document Structure lines

Field	Description	Comments
1	Parent structure number	Structure is a child of...
2	Sequence number	
3	Logical Structure name	Label for this structure
4	Structure number	Corresponds to Physical Reference file
5	Logical Children	# of logical children of this structure
6	Physical Children	# of physical children of this structure
7	References	# of references to this structure within this document (for how many structures is this a substructure)

Logical Structure file example

```
|0|0|ROOT|0|4|0|0|                          Structure 0, ROOT, has 4 logical children
|0|1|PAGES|1|100|0|1|                         Str. 1, PAGES, has 100 logical children
|0|2|CONTENTS|2|22|0|1|                    Str. 2, CONTENTS, has 22 logical children
                                                         ...has no physical children
...
|1|1|Production note|5|0|2|2|                         Str. 5 is child of structure 1
                                                    ...has a label "Production note"
                                                         ...has no logical children
                                                       ...has 2 physical references
                                            ...is referenced twice in this document
|1|2||6|0|2|1|                                                   Str. 6 has no label
|1|3||7|0|2|1|                                      Str. 7 has 2 physical references
|1|4||8|0|2|1|                                        Str. 8 is referenced only here
|1|5||9|0|2|1|                            Str. 9 is the 5th sequential child of PAGES
...
|1|99||103|0|2|2|
|1|100||104|0|2|2|
|2|1|Production note|105|1|0|1|                        Str. 105 is a child of str. 2
|2|2|Title page|106|1|0|1|                              Str. 106 has 1 logical child
|2|3|Table of contents|107|2|0|1|
|2|4|Chapter 1. From Arithmetic to Algebra|108|6|0|1|
|2|5|Chapter 2. The Making of Algebras|109|4|0|1|
|2|6|Chapter 3. Simultaneous Problems|110|4|0|1|
|2|7|Chapter 4. Partial Solutions...|111|3|0|1|
|2|8|Chapter 5. Mathematical Certainty...|112|3|0|1|
|2|9|Chapter 6. The First Hebrew Algebra|113|8|0|1|
|2|10|Chapter 7. How to Choose our Hypotheses|114|9|0|1|
|2|11|Chapter 8. The Limits of the Teachers Function|115|5|0|1|
|2|12|Chapter 9. The Use of Sewing Cards|116|4|0|1|
|2|13|Chapter 10. The Story of a Working Hypothesis|117|6|0|1|
|2|14|Chapter 11. Macbeths Mistake|118|6|0|1|
|2|15|Chapter 12. Jacobs Ladder|119|2|0|1|
|2|16|Chapter 13. The Great X of the World|120|4|0|1|
|2|17|Chapter 14. Go Out of My Class-room|121|4|0|1|
|2|18|Chapter 15. ...|122|3|0|1|
|2|19|Chapter 16. Infinity|123|6|0|1|
|2|20|Chapter 17. From Bondage to Freedom|124|5|0|1|
|2|21|Appendix|125|2|1|1|
|2|22|advertisements|126|4|1|2|
|105|1|Production note|5|0|2|2|                     Str. 5 is a child of str. 105
|106|1|Title page|11|0|2|2|                             2nd reference to str. 11
|107|1|7|15|0|2|2|
|107|2|8|16|0|2|2|
...
|126|4||104|0|2|2|
```

IMPLEMENTATION DETAILS

The tuple:

<library ID>+<collection ID>+<document ID>+<filetype>+<file reference>

is guaranteed to locate a file. A file locator program will translate between this tuple and the fully-qualified path and file name in the underlying file system.

While a library will always have a hierarchical nature corresponding to UNIX file systems, the order of the hierarchy will be flexible to accommodate optimization efforts. Each level of the hierarchy will have an INFO file that describes the order of the lower levels of the hierarchy. The file locator program will read these files as it navigates the directory structure of the file system when a library, collection, or document is opened. Two examples follow:

Example 1.

```
Hierarchy is LIBRARY, COLLECTION, DOCUMENT, FILETYPE.

/<library name>
        LIBINFO.TXT             Description of library
        /<collection name>
                COLINFO.TXT     Description of collection
                /<document ID>
                        DOCINFO.TXT                         Description of document
                        LOGSTR.000                           Logical structure file
                        PHYSREF.000                         Physical reference file
                        /<filetype1>
                                00001.TIF
                                00002.TIF
                                ...
                        /<filetype2>
                                00001.TIF
                                00002.TIF
                                ...
```

Example 2.

```
Hierarchy is LIBRARY, FILETYPE, COLLECTION, DOCUMENT.

/<library name>
        LIBINFO.TXT          Description of library
        /<filetype1>
                /<collection name>
                        COLINFO.TXT                    Description of collection
                        /<document ID>
                                DOCINFO.TXT              Description of document
                                LOGSTR.000               Logical structure file
                                PHYSREF.000              Physical reference file
                                00001.TIF
                                00002.TIF
                                ...
                /<filetype2>
                /<collection name>
                        COLINFO.TXT                    Description of collection
                        /<document ID>
                                DOCINFO.TXT              Description of document
                                LOGSTR.000               Logical structure file
                                PHYSREF.000              Physical reference file
                                00001.TIF
                                00002.TIF
                                ...
```

This implementation involves some redundancy, but it permits complete copies of a collection to be mounted on different file systems for performance considerations. In particular, the second scheme would facilitate storing all low-resolution images on high-speed magnetic disk for fast access, and all high-resolution images on slower, less expensive storage. This will also facilitate authorizing access to low-resolution images by other software systems (FTP, Gopher) while restricting access to high-resolution images.

APPENDIX III — TESTBED DESCRIPTION

Creation of the Testbed involved assembling the core support for test activities. Core support requirements included staff, equipment, facilities, and the implementation of a methodology for testing and evaluating technologies.

1. Staff

Cornell recruited the necessary staff to begin work on the Testbed in September 1991. The staff to support the testbed includes scanning technicians and software programmers. Fortunately, scanning technicians who had been with Phase I continued to work on the Testbed project. In addition to their experience with preservation scanning acquired as a result of their work on this project, each of them brought relevant experience in printing and photography that has proven useful for digital imaging. Technical staff had to be found with the knowledge and experience to develop an image delivery server and client software for three computer platforms. Again Cornell was fortunate that the technical leader for Phase I of the Joint Study continued in that role for this phase. A search for qualified individuals to develop software for UNIX and Apple Macintosh environments resulted in two excellent candidates joining the project team.

2. Equipment

Cornell brought all of the equipment from the Phase I project, including Xerox scanning workstations and the DocuTech printer, to the Testbed. In addition, equipment to support the software developers and provide a production level of service to library patrons was secured. New hardware was provided by Sun Microsystems, Inc. and by Cornell Information Technologies. Sun Microsystems provided the image delivery server, consisting of a Sun SPARCstation and peripheral equipment, to enable researchers at other institutions to access digital files stored at Cornell; two publicly located workstations to offer library patrons the opportunity to browse and select books from the digital library within library buildings; and one workstation for software development. Cornell Information Technologies provided an Apple Macintosh IIci computer and peripherals for use in the development of client software, an IBM PS/2 Model 95 XP for client development, and a Sun SPARCStation 1+. All hardware and associated software were in place by March 1992.

3. Facilities

Cornell University Library provided dedicated work space for the scanning technicians and for the software development team. Room 701 Olin Library was established as the scanning area for the Testbed. It was equipped with 2 telephone lines and enough telecommunications capability to support 3 Ethernet connected workstations and one Appletalk workstation. The software development team was located in Room 503 Olin library. This room was equipped with three telephones and extensive telecommunications capability. Eight Ethernet lines and one Appletalk line provide the connectivity for the workstations and development servers being used by this group. Sufficient communications are included to support some level of experimentation with new equipment as deemed necessary as part of Testbed activities.

4. Set of Test Source Materials

In order to meet the objectives of the Cornell Testbed, it was necessary to identify and prepare a consistent set of test source materials that could be used repeatedly to compare different scanning technologies. This group of materials, along with a set of procedures and protocols, was used to evaluate technologies in a consistent manner.

A set of test documents has been chosen across the range of materials typically found in modern research libraries, including:

a. Books, representing a variety of printing processes and languages, as well as those containing illustrations (photographs, halftones, photogravures, woodcuts, line art, original etchings, engravings, and color plates) that were selected from the first 1,000 volumes scanned during the Phase I. These books are used to test and retest a variety of image capture processes. For example, among the books included is The Steam Turbine: The Rede Lecture 1911, by Sir Charles A. Parsons, which contains halftones and line drawings embedded in text. This volume was scanned in September 1991 on the P2.8 scanning system using a mixed scanning mode; rescanned in March 1992 with software upgrades that resulted in improved image capture; and scanned a third time in April 1993 on the final prototype version of the CLASS scanning system. A digital computer output microfilm copy was created from the earlier scanned version in late 1991, and a conventional film copy was created from the original volume at the same time.

b. Serials, chosen from the fields of materials science and engineering that are being used in TULIP, The University LIcensing Program, a cooperative research project testing systems for networked delivery and use of journals, involving Elsevier Scientific Publishers and ten U.S. universities, including Cornell.

c. Dissertations, from the School of Engineering that are being used in the Cornell/Michigan/Penn State Dissertations Online Project. The Cornell portion of this project is referred to as DAISY, Dissertation Access over Internet SYstems. During the first year of DAISY (1993), the project will be a modest one, involving only a subset of dissertations, produced in paper format. Ultimately, the project could be expanded to cover all dissertations including those produced in multi-media formats.

d. Archival and Manuscript Material, including holographs, architectural drawings, photographs, typescript and machine-printed documents, and maps. Items have been drawn from the holdings of Cornell's Division of Rare and Manuscript Collection and those kindly donated by the University of Rochester that were scanned during the Preserving Archival Material through Digital Technology Cooperative Project (1992/93), sponsored by Cornell on behalf of the Eleven Comprehensive Research Libraries in New York State. Some of this material has also been scanned using a LaCie Color Scanner to capture 8-bit gray scale at a variety of resolutions.

e. Other material includes art work (water colors, pencil sketches) and field books from the Louis Agassiz Fuertes Papers; photographs and architectural drawings from the planning collection of John Nolen; and photographs from the University Archives that were selected for use in the Kodak Library Image Consortium (KLIC) Project, involving Cornell, University of Southern California, Eastman Kodak, and the Commission on Preservation and Access. KLIC is a cooperative investigation into the use of the Kodak Photo CD technology to preserve and make available on-screen historical photographs, paintings, and other images. A number of items scanned using the Xerox CLASS binary scanner have also been converted via the Kodak Photo CD technology.

f. Technical Test Targets, including the AIIM Scanner Test Charts, as cited in ANSI/AIIM MS44-1988, "Recommended Practice for Quality Control of Image Scanners, are used to test a variety of scanning technologies and settings. Test charts include IEEE Std 167A-1987 Facsimile Test Chart and AIIM Scanner Test Chart #2. Kodak gray wedges and color charts will be used where appropriate.

5. Criteria for Evaluation

In addition to developing a control group of source material, a procedure for comparing digital scanning and storage systems was developed which occurs in two phases. The first phase involves screening to test new equipment against established benchmarks identified for the Xerox CLASS system. A decision is then made whether to proceed with a full evaluation. During this phase, a portion of the control set of material is processed that is most appropriate to the equipment under evaluation.

The second phase of evaluation will be initiated for the most promising of systems and consists of a full test of the new technology. A large number of items will be digitized—the amount and type may vary—but the intent is to work with new documents in this phase and to test the particular capabilities of the system. Material will be scanned, stored, transmitted, retrieved and reformatted from the digital file. In this manner, the size of the digital library will continue to increase, more material will be preserved, and tests of new material can be conducted.

Each new system will be tested and evaluated in terms of usability, quality, and production capabilities. In evaluating each system, the following will be considered:

—Adherence to standards and open system connectivity

—Efficiency or speed of capture

—Costs of the process and the products

—System usability, including user friendliness and availability of documentation

—Equipment reliability and vendor support.

Scanning technicians use standardized worksheets to record information on the items being scanned; time spent in set up, image capture, transmission, storage, and quality control; and system settings used.

The digital files are reviewed for the quality of image capture, resolution, compression, file size, and adherence to standards and protocols. Where appropriate, the quality of output choices (paper, on-screen images, digital COM) will also be compared.

QUALITY

Criteria for evaluating the quality of scanned images, in particular printed facsimiles, were developed as part of the Testbed Project. Image capture is affected by a number of factors, including the scanning process (binary, gray scale, color), the compression method, the equipment (including the scanner, the view station, and the printer), the condition of the equipment, the type of original (including media and support), and the physical condition or quality of the original.[8]

Material scanned to date in the Testbed falls into four main categories:

a. line art (printed matter, holographs, typewritten material, blueprints, maps, etchings, various copying processes, including letterpress, thermofax, carbons, and photocopies).

b. continuous tone (photographs, crayon and chalk drawings, acrylic, watercolor, and photographically reproduced facsimiles of artwork).

c. halftones (reproductions, usually created from photographs, in which dots are used to represent continuous tones.) Color halftones use varying hues and combinations of the subtractive, or "process" colors to represent full continuous tone images.

d. mixed (containing both text and continuous tone or halftone images).

The following factors are considered in determining overall quality. These are divided into those affecting the quality of line art and text and those to consider in evaluating continuous tone and halftone images. If the item falls into the category of "mixed," all of the factors listed below should be considered.

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8 For a description of their effects on scanning, see Kenney, A. with M. Friedman and S. Poucher, Preserving archival material through digital technology. Final report. 1993. Available for $10 from Cornell University Library, Department of Preservation, 215 Olin Library, Ithaca, NY 14853.

Text/Line Art Characteristics for Evaluation

1. Legibility and completeness. Is the text readable? Is it completely rendered?

2. Darkness. How dark do the characters appear? Are the characters consistently dark across the page (bearing in mind the original)? In general, the darker the better.

3. Contrast. Is there good contrast or differentiation between the text and the background? Is there even illumination across the image (again bearing in mind the original)? Is there a gray cast or streaking in the background? Is the image washed out? too dark?

4. Edge Raggedness. This relates to the "smoothness" or "straightness" of edges along lines at very close inspection. Special attention should be paid to curved and diagonal lines on characters and line graphics, as compared to the original. Review should be made with a magnifying lens or eye loupe (5 to 10X magnification will suffice) and also by unaided visual inspection. The human eye is often forgiving of minor imperfections and will fill in a character to make it complete.

5. Sharpness. This is a measure of the quality of the transition from black to white across an edge. A perfect line is black on one side and white on the other. A true straight line is difficult to duplicate, and the perceived quality of line reproductions can be affected. Using a magnifying glass, follow a line across the page and repeat this with the unaided eye. Does the line appear sharp or is it jagged in places?

6. Line width fidelity. This relates to the system's ability to reproduce reliably the width of lines as defined by the original. Line widths for the original and the scanned copies should be compared, including samples ranging from very thin to very thick lines. Check to see if the smallest lower case "e" or "a" is closed in. Are serifs and fine detail fully rendered? An eye loupe with millimeter line markings will be useful in this evaluation.

7. Character size fidelity. This relates to the system's ability to reproduce reliably the height and width of individual characters as defined by the original. This can best be determined by measuring the height of the lower case "x" or "e." Again, an eye loupe with millimeter line markings would be useful in this evaluation.

Pictoral/Graphic Characteristics for Evaluation of Continuous Tone and Halftone Images:

1. Tone reproduction. This relates to the ability of a system to reproduce the range of tones in the original. The quality of the highlight and shadow regions often suffer from a reduced dynamic range in reproductions. This can be evident when detail present in the original is lost in the dark or light portions of the copy. It can also be seen in the rendering of distinctions presented by colored items.

2. Uniformity. The system should produce uniformity of grays in the reproduction. Look for even gradations and the full medium values of halftones. Banding, streaking, and graininess are typical problems encountered in reproducing graphic materials. The digital versions of halftones in particular can exhibit a moiré effect which will appear as a watered or wavy pattern.

3. Detail. This relates to the system's capability to preserve any fine detail in an original. System evaluation will require a careful comparison of the copies to the original, and a magnifying glass will come in handy.

Color Items

In addition to the above categories, consideration must be given to whether the item is monochrome or color. For those systems that only reproduce black and white, color information is conveyed by shades of gray. The question then becomes how well the distinctions in shading represented by the color have been rendered.

For color scanning, the evaluation should also take into consideration the fidelity of the hue, value, and intensity of different colors represented in the original. Fuller criteria for evaluating color scanning will be developed as the Kodak Photo CD project progresses. Modification of this evaluation process will result from practical experience and technological developments.

APPENDIX IV — "DOCUTECH-PRINTED" EXAMPLES

CHAPTER VII

THE USES OF THE STARS

SOME persons habitually regard everything and everybody by the use that may be made of it or them, their idea of the word being very closely related to hard cash. If we were all to indulge in this eminently practical view, many of the things proudly considered by civilised humanity as among its highest and most lasting possessions would indeed be of little "use" to us, as their value cannot be appraised by this rule of the market-place. Milton would rank far behind a smart man of business, if the activities of the two men were measured by the prosaic everyday scale some folk are so ready to apply. It is a difficult task to estimate brain-work according to its material value. Schiller received the absurd sum of £15 for his "William Tell," but he might just as well have been presented with a castle on the Rhine, for it is enthusiasm and not cold calculation that plays the part of valuer in these cases. Nor must we forget that things of but little practical value may possess a very high ideal one. The delight in all that is lofty and sublime will act as a perfect tonic and recreation on the mind of man weary with his daily round of toil; it will strengthen him to battle with the strain of this life, and assist him to emerge successfully from the struggle.

The Lesson of the Stars.—The majority of those to whom I have shown the wonders of the heavens in the silent observatory halls have usually been impressed and subdued by the majesty of the universe; but, naturally, there were some who could not leave the world's dross behind, and who were anxious to ascertain the actual use of the stars to us. As a matter of fact, the stars are of great use to us, or, rather, astronomy has a very definite value, although in my own humble opinion their ideal influence ranks infinitely higher. Man, the insignificant parasite on the grain of sand called earth, floating in the infinite, is by nature a searcher in the quest of truth and eternity; he would not be satisfied if he could not gain a definite idea, based on scientific research, of those sparkling lights overhead. And even if he were still more advanced in the grim realities of life, he would be unworthy of the civilisation he revels in were he entirely ignorant of the problems nightly set to him by the starry heavens. The knowledge that the vast army of stars moves according to eternal, inexorable laws, that this very regularity guarantees its everlastingness, unwittingly influences human actions and creations. The grandeur of the universe should be a powerful agent in eradicating that empty pride and class distinction from which the private and social contrasts that burden mankind generally arise. A careful study of our all-mother Nature will assist us to do away with self-righteousness and overbearing demeanour, and teach us dignity and modesty in every walk of life.

Practical Value of Astronomy.—But it is of the usefulness of celestial science I wish to speak. It has been stated several times in this volume that astronomy originally was a definition of time, a calendar science. Civilisation is more closely allied to time determination and definition than may be at first believed possible. Primitive man, whose daily work consisted in the protection and nourishment of his body, and who rested in his cave at night, was content with the setting and the rising of the sun to mark his day. It is quite probable that he, too, noticed an alteration in the position of the sun at different seasons, the appearance of the constellations at various times of the year; and, guided by them, began the preparations necessary to guard him from the cold and the rains. The more the brain of man developed, the more complicated his needs became; the higher civilisation rose the more his conception of time increased, and the greater his interest in the course of days and years grew. Stonehenge, near Salisbury, that ancient circle of gigantic hewn boulders erected about three thousand years ago, is naught but a time and calendar definition of our forefathers. The huge stone blocks, 150 in all, are set up in two circles; an altar stands in the centre, on which animals were probably sacrificed on certain days. On look-

Fig. 83.—Monument at Nuremberg to Peter Henlein (Hele), erected by the German Clockmakers' Union.

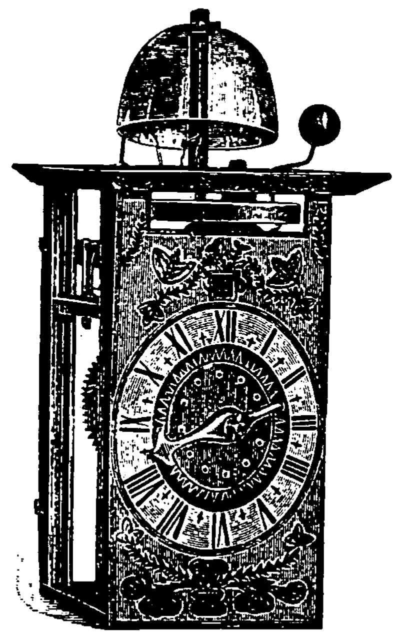

Fig. 85.—Old Household Clock.

Fig. 84.—Drum-shaped Watch from the Marfels Collection.

Fig. 86.—Sun Clock on Chartres Cathedral.

ing straight over the altar, the eye meets a stone column in the distance (Fig. 82), and on June 21 (summer's beginning) the sun will be seen to rise exactly over its top. Other boulders very likely served a similar purpose and were used as sun-dials.

Time's Changes.—They have gone past recall, those good old times when the post-chaise jolted one's bones over the country lanes and the postilion blew merry blasts on his horn. Past are the days when it took five minutes or so to strike a light or set the lamp burning, when telephone, telegraph, railway, motor-cars and all else that counts time by seconds were yet unknown. "Once upon a time!" We of the twentieth century, who grumble even at modern locomotion, pursue the very seconds. All this counting of minutes and fractions of minutes, rendered necessary by train and tram services, telephone and telegraph, which forces a more rapid mode of existence on us and permits us to accomplish more in an hour than was formerly possible in half a day, all this, I say, would be entirely impossible without the clock.

The Invention of the Watch.—Since when did we carry this ticking register of the fleeting hours about with us? It was a German who presented the world with the first watch, an honest locksmith of Nuremberg named Peter Henlein (or Hele, as it is popularly abbreviated), who constructed the first clumsy iron pocket chronometer (Fig. 83). The following account of it appeared in the *Cosmographia Pomponii Melae,* published in Nuremberg in 1511: "Every day finer things are being invented. Peter Hele, still a young man, has constructed a piece of work which excites the admiration of the most learned mathematicians. He shapes many-wheeled watches out of small bits of iron, which run without weights for forty hours, however they may be carried, in pocket or chemisette."

One of these earliest of pocket watches is contained in the celebrated Marfels collection (Fig. 84); it is made completely of iron, and the weird works show that the watchmaker's art was still in its earliest infancy. A very quaint feature is the pig's bristle in the centre of the works to regulate the movement—replaced now by the tiny throbbing

F

spiral spring. This watch only has one hand, and a small knob is fixed above every figure on the handsome dial of punched bronze to enable the position of the hand to be told in the dark. The watch is not oval in shape, as is generally believed, but rather resembles a drum. The "Nuremberg egglets" are a decided improvement on these clumsy things, which were more suited to saddlebags than to a waistcoat pocket. Watches in those early days were expensive articles, purchasable only by gentlemen of rank, and circumstantial details are given in old letters and chronicles of the purchase or presentation of such an "egglet." Dandies for many years carried pretty little hour-glasses in their pockets. Mechanism in those days was hardly at its height; clocks and watches went very much as they pleased, and the lucky individuals of that period did not need to bother about fractions of a minute. Until the year 1700 watches only had an hour-hand, the minute hand was totally lacking, and it was impossible to tell time correctly within ten minutes or so; but in those days a quarter of an hour was of little importance. There was no boat-train to leave for Dover at 8.30 A.M., no electric car to be caught at a certain time, and the speed craze in all its shapes was yet unknown.

Early Public Clocks.—The people who dragged these timekeepers about in their pockets had no little weight to carry, and yet what a vast step in the right direction they marked! Until they were invented, in 1511, all smaller towns and villages had to depend entirely on sun-dials. True, in 996 the French priest Gerbert, who later reigned as Pope Sylvester II., constructed the first clock with weights and wheels, and some very rich communities had one such erected on the church tower or the town hall; but that was an extravagance only a few of the very largest towns could afford.* The oldest public clocks were those set up in 1314 on Caen Bridge, in 1340 at the Cluny Monastery, and the celebrated clock of Jacques de Dondi at Padua four years later. Instead of a pendulum these old clocks had a beam which swung horizontally and turned a spindle that

* Later researches by F. M. Feldhaus have questioned the correctness of the attribution to Gerbert of the invention of the wheelwork clock.

gripped the wheels. A precise movement such as the clocks have to-day was utterly unknown. Fig. 85 gives a picture of an old household clock.

Pendulum Clocks.—The connection of the wheels with the pendulum was another step onward. In 1639 Galileo proposed to use the regular beats of the pendulum for time determination and to keep it in motion by a wheel-work. The Dutch physicist Huygens constructed the first pendulum clock in 1657. These were naturally not intended for ordinary folk, and they did not need them either, as time was no object. Scholars and noblemen looked to hour-glasses and clepsydras (Fig. 87) for their time before pendulum clocks became popular. In both cases large glass bowls were used, filled either with fine dry sand or with water, which dripped away through a small opening into a smaller, notched vessel. As an equal amount of sand or water flowed away within a certain period, there was not much difficulty in ascertaining the time up to a quarter of an hour or so. Smaller instruments, such as are to-day used for egg-boilers, measured off still shorter periods.

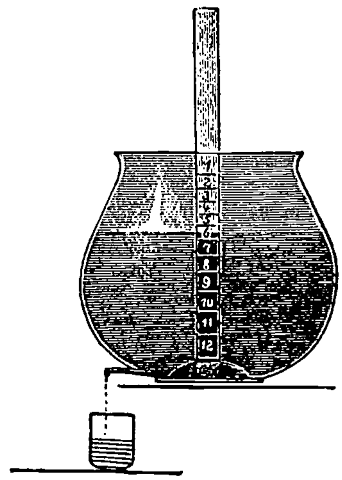

Fig. 87.—Clepsydra, or Water-Clock.

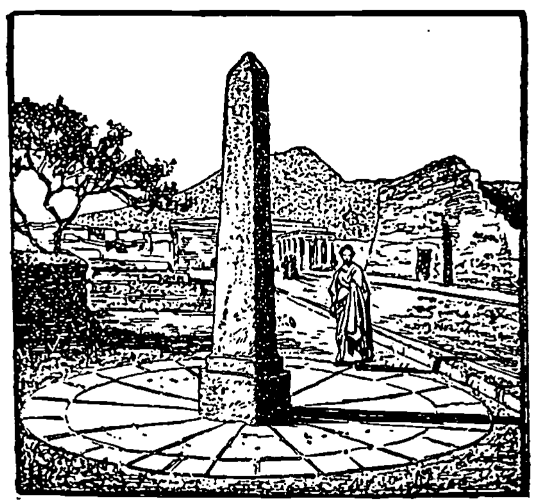

Fig. 88.—Shadow Column in Ancient Rome.

Sun-Dials.—Good water- and sand-glasses were, however, extremely expensive, and the lower classes pinned their faith to the sun clock (Fig. 86), which every paterfamilias of moderate skill could fashion for himself. The ancient civilised races knew of no other chronometer but this; in early Roman days there were special officials whose duty it was hourly to cry out the time as shown by the shadow columns (Fig. 88). Still farther back, people were content to tell the time by the direction of the sun or the length of the shadows thrown by trees and houses; ay, even their own shadows were used as clocks, for Pliny says: "I beg thee to honour my house when thy shadow will be six feet long." That most decidedly was the cheapest and least complicated movable clock in the world, always in action when its owner was in motion and the sun shone. I wonder what we should do with such chronometers to-day!

Astronomy and Time.—Few people ever give the fact a thought that time is "made" by the astronomer, who even sends it out into the world. We all of us regulate our watches by the chief clock in the observatory, for all public clocks, those of churches, stations, post-offices, etc., are either directly or indirectly regulated according to the observatory clocks.

Fearful confusion and endless railway accidents would result if station clocks, for instance, were not electro-magnetically regulated every day from the observatory headquarters (Fig. 89).

Mariners and Time.—The astronomer sends his precise time determinations out into the sheer endless vasts of the oceans, for without this the ships would run risks too dreadful to think of. Each vessel possesses several clocks of great precision and particular shape and mounting, which render them independent of the tossing and rolling. These marine chronometers are veritable masterpieces of the watchmaker's art (Fig. 91). Many of them only deviate five seconds within a fortnight, during which period they have twice crossed the ocean. Sailors find occasion to regulate their watches in the ports of all countries, as the harbour officials generally send up a time signal at midday, and time is checked accordingly by the officers entrusted with the regu-

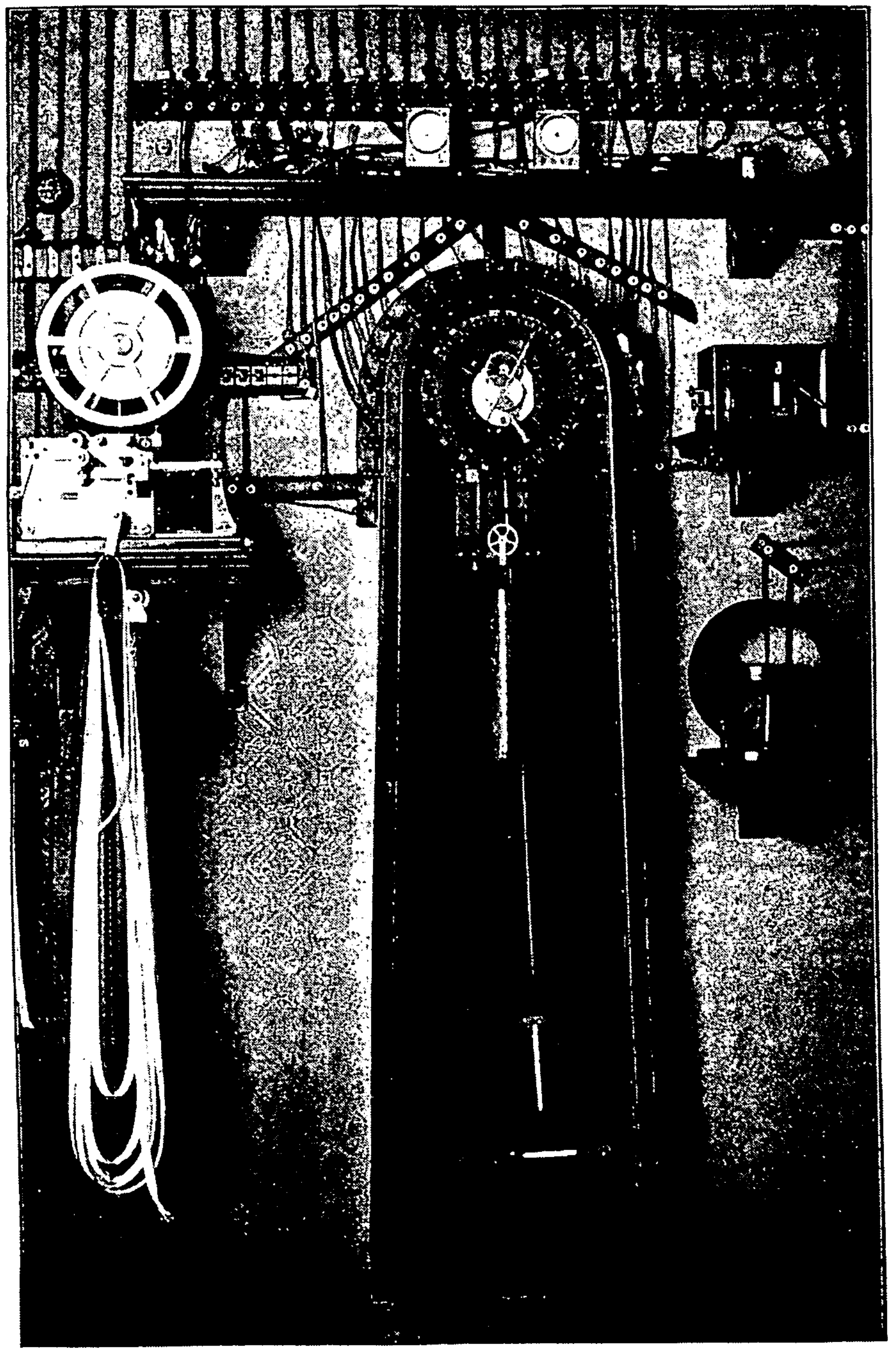

Fig. 89.--Electric Time Transmission Plant at the Observatory, Berlin.

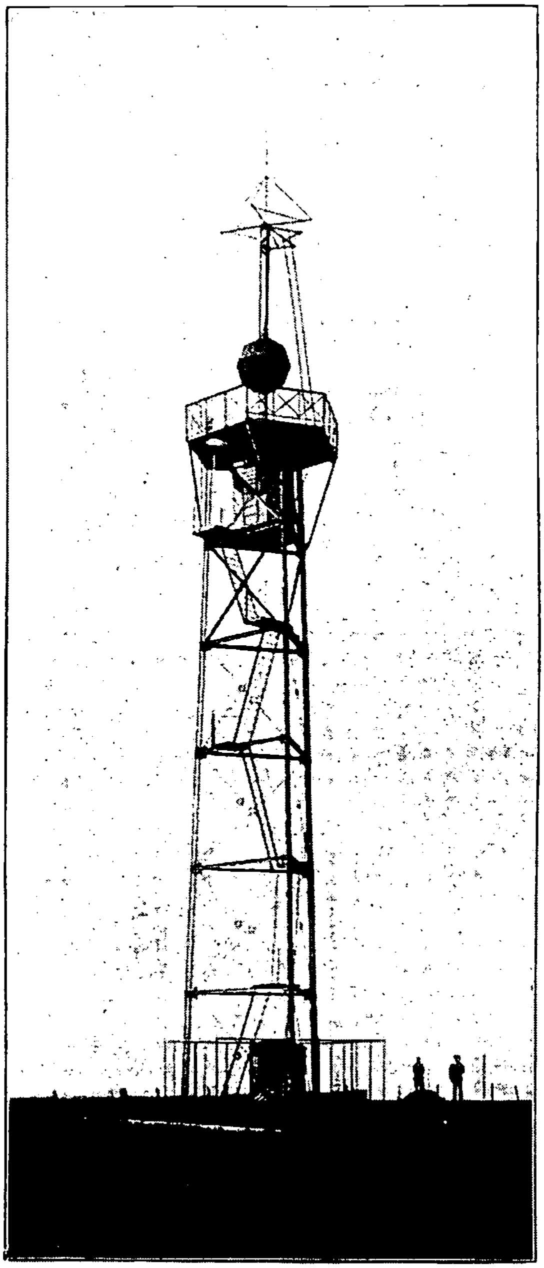

Fig. 90.—Time-ball at Wilhelmshaven.

lation of the chronometers; this signal is usually given by a cannon, or the time-ball, a large ball attached by ropes to a signal tower, is dropped at a certain moment, say, 12 o minutes o seconds. This time-ball (Fig. 90) is worked by electro-magnetism from an observatory. As soon as the hands of the observatory clock indicate midday an electric current is transmitted to the cables that keep the ball in place

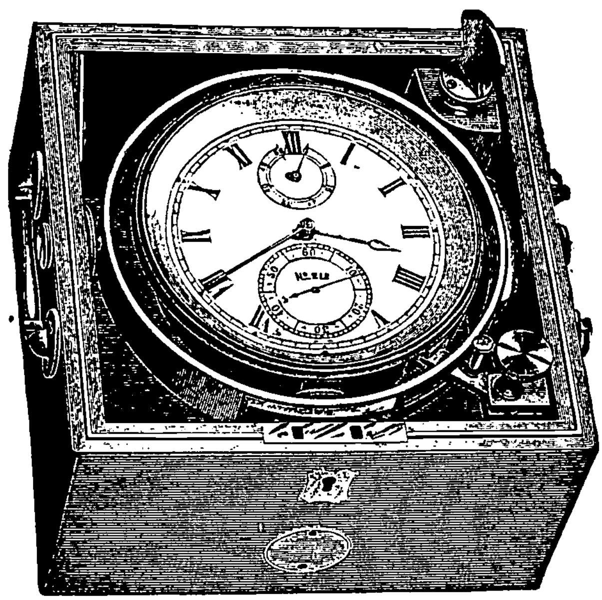

Fig. 91.—Marine Chronometer.

and releases it. Any slight remissness in the motion of watch or clock can thus easily be rectified.

The Astronomer the World's Timekeeper.—We shall recognise the great importance of this later; at any rate, we have learnt that the astronomer keeps time for the world. This duty alone should suffice to establish a high practical value for his work. He in turn takes his time from the most marvellous clock of all, which through all history has gone with unfailing accuracy, never fluctuating for a second, with the rotating earth for its works and the star-set heavens for its dial. The transit circle, the pendulum clock and chronograph aid him in reading the time from the stars.

The astronomer also attends to naval and explorers' chronometers, testing them in different temperatures, and working out tables in advance for their regulation in localities remote from civilisation.

The Nautical Almanac.—The ship driven from its course by tremendous gales, the expedition forcing its way onward through virgin forests or in the ice and snow regions of the Poles, are one and all guided back to safety by the astronomer's skill. A person familiar with observation and calculation will, if stranded at any desolate place in the world, soon be able to ascertain his bearings according to longitude and latitude to a very mile if an astronomical or nautical almanac, a chronometer and a sextant have been left him. All vessels carry such an almanac, in which the exact positions of sun, moon and planets have been determined for every day and hour, years in advance. The exact position of the moon is given for every hour, of the sun and planets for every day, of the stars for every ten days. The stars act as milestones and road-signs to the sailor who for weeks at a stretch sees naught but sky and water, and the Nautical Almanac may well be termed his sky Baedeker.

The Sextant and its Uses.—A small instrument called a sextant (Fig. 92) is used for the determination of the distance two stars are apart, or the distance between the moon and a star, or the altitude of the sun above the horizon. A small telescope is attached to this instrument; an adjustable mirror fixed to it is moved until the image of the star, whose distance is to be ascertained, covers that of the moon in the telescope. If the observation is correctly made, an indicator attached to the adjustable mirror will denote the exact angular distance between moon and star on the graduated limb of the sextant.

Astronomical Determination of Position.—We will now imagine a vessel to have been carried right out of its course; the captain can no longer tell his bearings or the direction in which he should continue. How can astronomy assist him in the circumstances? We will endeavour to elucidate this as simply as possible.

The division of the earth into a net of latitudinal and longitudinal degrees renders it possible immediately to recognise the position of any spot on the globe, when we know its geographical longitude and latitude. If a boat were wrecked 36 degrees 20 minutes (36° 20′) north latitude and 133 degrees 20 minutes east longitude a good map would at once inform us that this occurred near the Japanese coast, at the island of Oki-shima. As soon as a vessel has determined its whereabouts according to geographical longitude and latitude and can once more take up its proper course, it is saved from all the dangers connected with unknown sur-

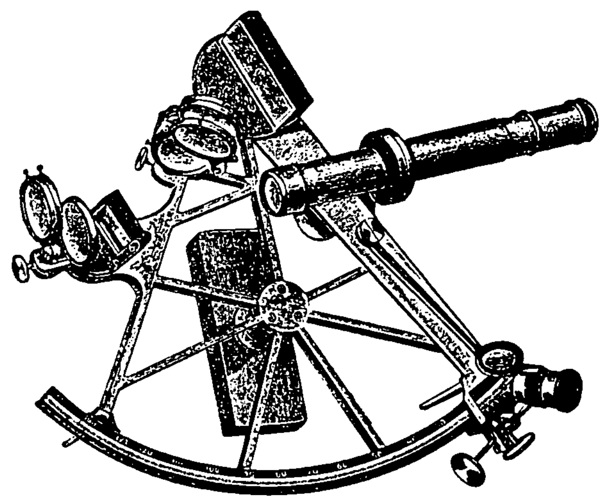

Fig. 92.—Mirror Sextant.

roundings, for a vessel can only be steered with impunity if the logs and charts distinctly set out the difficulties and peculiarities of the route. The captain will therefore, weather being propitious, have to turn to the skies for guidance. He first of all determines the geographical latitude. It is a clear starry night. The Pole Star, as we know, is stationed at the celestial North Pole. Now, the farther away a place is from the equator the higher the celestial North Pole rises above the horizon. At the terrestrial North Pole the Pole Star would stand right over the head of the spectator, in the zenith, at the equator it would just graze the horizon. The celestial pole is always elevated as many degrees above the horizon as the terrestrial place is removed degrees away from the earth's equator. For instance, at Berlin the celestial North Pole, near which the Pole Star is situated, is at an altitude of 52½°; Berlin is 52½° removed from the earth's equator, so its geographical latitude is 52½°. The altitude of the Pole Star above the horizon is therefore measured and the latitude* of the ship's position found. The sun serves a similar purpose in the day-time. At the instant the sun has reached its highest point above the horizon, when it is in the south at 12 o'clock midday, its distance from the water-line has to be determined with the aid of the sextant

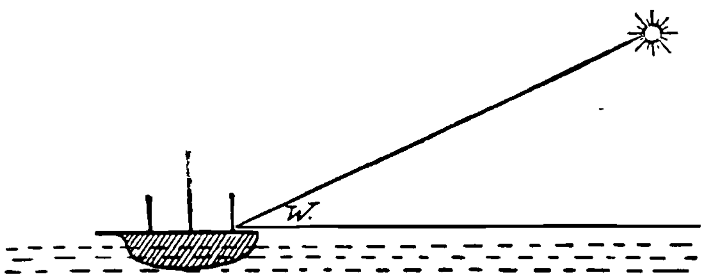

Fig. 93.—Measuring the Altitude of the Sun on Board Ship.
The angle w marks the sun's height above the horizon.

(see the angle w shown in Fig. 93). The distance of the sun from the celestial equator as stated in the Nautical Almanac is then looked up, and these two values soon determine the geographical latitude of the vessel's position. Let us imagine it to be 51° 10′ north latitude. One part of our task is now completed, but the longitude has next to be determined (this is the difference between the meridian of one's standpoint and that of Greenwich, 0, from which all calculations of longitude start). This should not be difficult in fine weather if the ship's chronometers are acting properly. The elevation of the sun above the horizon has to be measured at a distance from the meridian, when it is rising or falling rapidly. The chronometers set according to Greenwich time have immediately to be read off. The solution of a spherical triangle gives the local time, which has

* The Pole Star is in reality not quite at the celestial pole, but about 2½ full-moon breadths away.

to be compared with the Greenwich time. Suppose there is a time difference of three hours eleven minutes between the ship's position and Greenwich, where the day is more advanced. The vessel must therefore be west of Greenwich where the sun rises at a later hour. This time difference helps to determine the longitude. The earth rotates on its axis once every twenty-four hours, the sun therefore sweeps across all the 360 meridians of the earth during this period; every spot on the globe has its midday within these twenty-four hours, so it takes the sun the 360th part of twenty-four hours to pass from one meridian to another, and that works out at four minutes. Places with a time difference of four minutes are one degree apart. As a time difference of three hours and eleven minutes has been ascertained between the ship's position and Greenwich, or $47\frac{3}{4} \times 4$ minutes, the vessel must be $47\frac{3}{4}$ meridians to the west of Greenwich, or $47^\circ 45'$ west longitude.

We now know where the boat is:

$51^\circ 10'$ north latitude.

$47^\circ 45'$ west longitude.

The map shows this to be in the northern part of the Atlantic Ocean, half a day's journey east of Newfoundland, and if the vessel be bound for Halifax it will have to keep south south-west.

Should by mischance the chronometer have been rendered useless, the exact time can be ascertained by observing the stars with the help of the Nautical Almanac, for every kind of astronomical occurrence which a mariner can see with a small telescope has been calculated in advance and noted as a guide to sailors (the moon passing stars, its place among the stars at various times, etc.). At the instant any one of these events occurs the sailor knows Greenwich time to be such and such. The stars, however, assist him at other times than those of danger only; the vessel's time and place are determined daily by astronomical means, as all others would not be accurate enough and could not be fully depended on in these days of rapid locomotion. Travellers entrusting their lives to our modern floating palaces owe a very considerable part of their well-being to the observer measuring the transit of the stars in the meridian-chamber, to the mathematician who compiles the tables in the Nautical Almanac.

Astronomy and Aeronautics.—Latterly aeronauts and aviators have turned to the observatories for assistance. They frequently encounter grave difficulties when the mists and clouds beneath them make it impossible to study the chart, or when the balloon is carried away to districts of which they possess no maps. There are a few cases on record of aeronauts who had lost their bearings being driven out to sea, where a watery grave awaited them. A special kind of sextant has been designed by Marcuse, of Berlin, which serves for the astronomical determination of position for balloon and airship.

Astronomy and History.—The statement that astronomy has proved invaluable to historians may sound odd at first, and yet its truth is undeniable. All noteworthy astronomical occurrences have been chronicled since the earliest days, generally in connection with some one or other important political or religious event. It is often of the utmost importance to historians to be able to state the exact date of any one event, and as an astronomer is able to trace celestial phenomena in the past, often to the very hour of their occurrence thousands of years ago, historians have been helped out of a difficulty on innumerable occasions. We know that a battle was fought between the Lydians and the Medes on the Halys in the sixth century B.C., and that a solar eclipse occurred during the fight. It was determined astronomically that this was most likely the total eclipse of the sun on May 28th, 585 B.C., and that the great battle must therefore have been fought on that day. The ancient Chinese chronicle "Tshu-king" is fraught with the deepest interest for historians and astronomers. All the dates in the volume refer, however, to the reign of the sovereign in whose time they were entered, as, for instance, "in the eighth year of the Emperor Fu-hi" such and such an event occurred. This had to be converted into our time-reckoning to be of use to European historians. The "Tshu-king" tells of a great solar eclipse in the fifth year of the Emperor Tshun-khang's reign, which had not been announced by the Court astronomers, and, as the people could not be notified, a terrible panic ensued throughout the country. The two forgetful astronomers, Hi and Ho, were put to death by the Emperor's orders.

There is a very celebrated work entitled the "Canon of Eclipses," which was compiled by the great Austrian astronomer, Th. von Oppolzer, assisted by six other mathematicians, and in which all the sun and moon eclipses for centuries past and for the future up to A.D. 2163 have been calculated. This book, which is primarily intended for historical purposes, sets down the date of the eclipse which ended so sadly for Hi and Ho as the morning of October 22nd, 2137 B.C. The fifth year of the Emperor Tshun-khang's reign would therefore be the year 2137 of our reckoning, and the monarch ascended the throne in 2142 B.C. (Fig. 94 is a view of the old observatory at Peking, and in Fig. 95 is represented an armillary sphere, an ancient astronomical measuring instrument once used in the Chinese capital.)

So astronomy helps us to grope our way about in the grey labyrinth of ages long past, and the flaring torch of science lights up events which appeared as distant and as inaccessible as the stars above.

 

CHAPTER VIII

ASTROLOGY AND SUPERSTITION

SUPERSTITION, that extraordinarily rank weed, has struck strong roots in the very depths of human nature. Man, so little able after all to control the course of events and his own destiny, is again and again forced to recognise that he is but a toy in the hand of something so vast, so incomprehensible and so unknowable that it cannot be conceived or included as a unit in life's formula. Why, in a second the most carefully planned and constructed human creation—nay, even life itself—can be destroyed by a trifle of such insignificance that it almost seems ridiculous to contemplate, and yet we cannot fight against it even in thought. It is the story of a thunderclap in a bright sky all over again. And yet everything in this world has a firm, logical basis and occurs according to Nature's unvarying and consequential laws, and, strictly speaking, there is no such thing as *Chance*. Yet, if it is difficult for men acquainted with the laws of logic and theory, nature and philosophy, to recognise even the main principles only of those forces and happenings that influence a thousandfold human life and work, how much more difficult it must be to the untaught man, to the less intelligent races that lived in past centuries, to attempt to grasp the rudiments of these relations!

Basis of Superstition.—This inability forms the basis of all superstition. Secret forces and powers, good and evil

Appendix V — Screen Descriptions from Digital Library Unix Client

College Library Access Storage Server UNIX X Windows Digital Library Client Screen Descriptions

Technical Report #11 - April 2, 1993
Updated July 27, 1993

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Cornell University

I. Introduction — The UNIX X Windows Digital Library Client

The X windows digital library client provides access over the Internet to digital libraries that support the digital library image delivery server protocol. This document walks the reader through the actual screens of the X window digital library client and describes the functionality of each.

II. Login

Upon invoking the X window digital library client the user must enter a login and enter 'return' or select the 'LOGIN' button in order to access the digital library. Once the user has logged in searching is now available. (Figures 1 & 2)

III. Searching

After completing the login sequence, the search screen is displayed (Figure 2) and the user may now issue search queries.

To search, the user fills in any of the available search fields— 'Author', 'Title', and 'Catalog Identifier'—and the client will return the best matches from the SQL database that contains the bibliographic information. The user simply selects the 'SEARCH' button or hits 'return' to activate a search. The example search returned 38 documents (Figure 3). A search without user specified information will return up to the maximum search replies allowed by the server.

IV. Document Browsing

Once a search has returned a list of documents, the user can open the document by selecting the 'OPEN DOCUMENT' button. In the example, the document "The Popular History of the Civil War" was selected (Figure 4). When a document is opened a document structure window is displayed to assist the user in navigating through the document (Figure 5). Multiple views of a document may be represented by the document structure, such as a listing the chapters of a book, or listing articles by author name, or by title. In the example the top level of the document structure contains "Pages" and "Contents". The Pages structure contains a linear list of all the pages that were scanned for this document. The Contents contains a more detailed description of the structure of the document.

In our example we select the "Contents" structure and then expand this level by clicking 'Open/Enter Level' (Figure 6). The book is broken up into parts. Selecting the "Text" we now use 'Open & Display' to expand the next level (Figure 7). The "Text" level is divided into chapters (Figure 7). Finally, we select "Chapter I" and select 'Open/Enter Level' to reach the pages of "Chapter I" (Figure 8). A dot to the left of a label in the structure window indicates there is an image associated with the label, a plus '+' sign indicates additional levels below. The 'Open & Display' button causes page 21 to be retreived and displayed (Figure 9). Using the 'Next Page' and 'Previous Page' buttons the user can view the pages of "Chapter I" (Figure 10). The document viewer also allows the user to display two pages side by side (Figure 11).

V. Printing

Printing is supported at the document level and the page level. The X client current supports printing to the DocuTech printer. The primary rational for allowing only DocuTech printing is to enforce copyright and billing procedures. At the search or structure windows (Figures 2 & 5) the user may print the entire document by selecting the 'Print Document' button. The example shows how to select pages from Chapter I using the 'Select' button in the structure window (Figure 12).

Selection of individual pages is accomplished with the select/deselect buttons on the structure window (Figure 12). The 'Print Selection' button initiates the print dialog box (Figure 13). The print window indicated the number of pages to be printed, the costs associated with printing and obtaining copyright permission, and the address to deliver the printed document. In order to print the entire document or selected pages, the user must acknowledge the billing information by selecting the 'Print' button at the bottom of the print window.

VI. Seeking to Desired Page

Next we return to the "Contents" level and enter the structure entitled "List of Illustrations" (Figure 14 & 15). Selecting 'Open & Display' we display the list of illustrations page (Figure 16). In the list of illustrations page let's say we are interested in a picture of John Calhoun on page 24. Now type 24 into the 'Label:' field at the top of the page viewer and select the 'GO TO' button (Figure 17). The viewer now searches for the image and displays page 24. We see the picture of John Calhoun (Figure 18). Notice that the structure of the window is updated to reflect the new location within the document structure tree. The 'GO TO' command's usefulness depends on the document structure labels entered by the scanning technicians. A detailed document structure is very easy to navigate, using either the 'Next Page', 'Previous Page', 'Return/Exit Level' or 'Open/Enter Level' commands or the Go To Label command.

VII. Miscellaneous Features

The digital library X windows client allows the user to select the databases to search (Figure 19 & 20), and allows the user to open multiple documents (Figure 21).

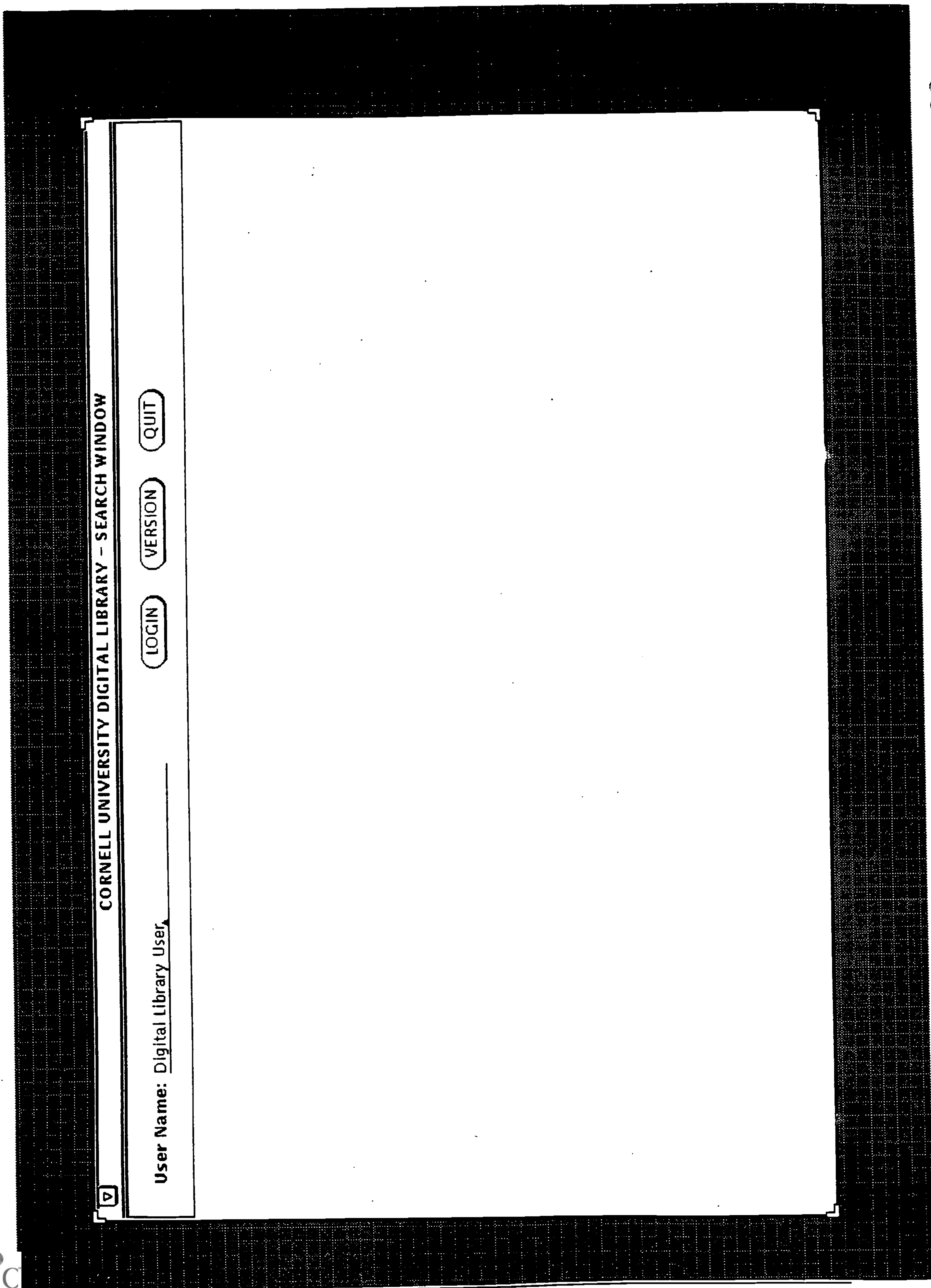
CORNELL UNIVERSITY DIGITAL LIBRARY – SEARCH WINDOW
User Name: Digital Library User
LOGIN
VERSION
QUIT

FIGURE 1

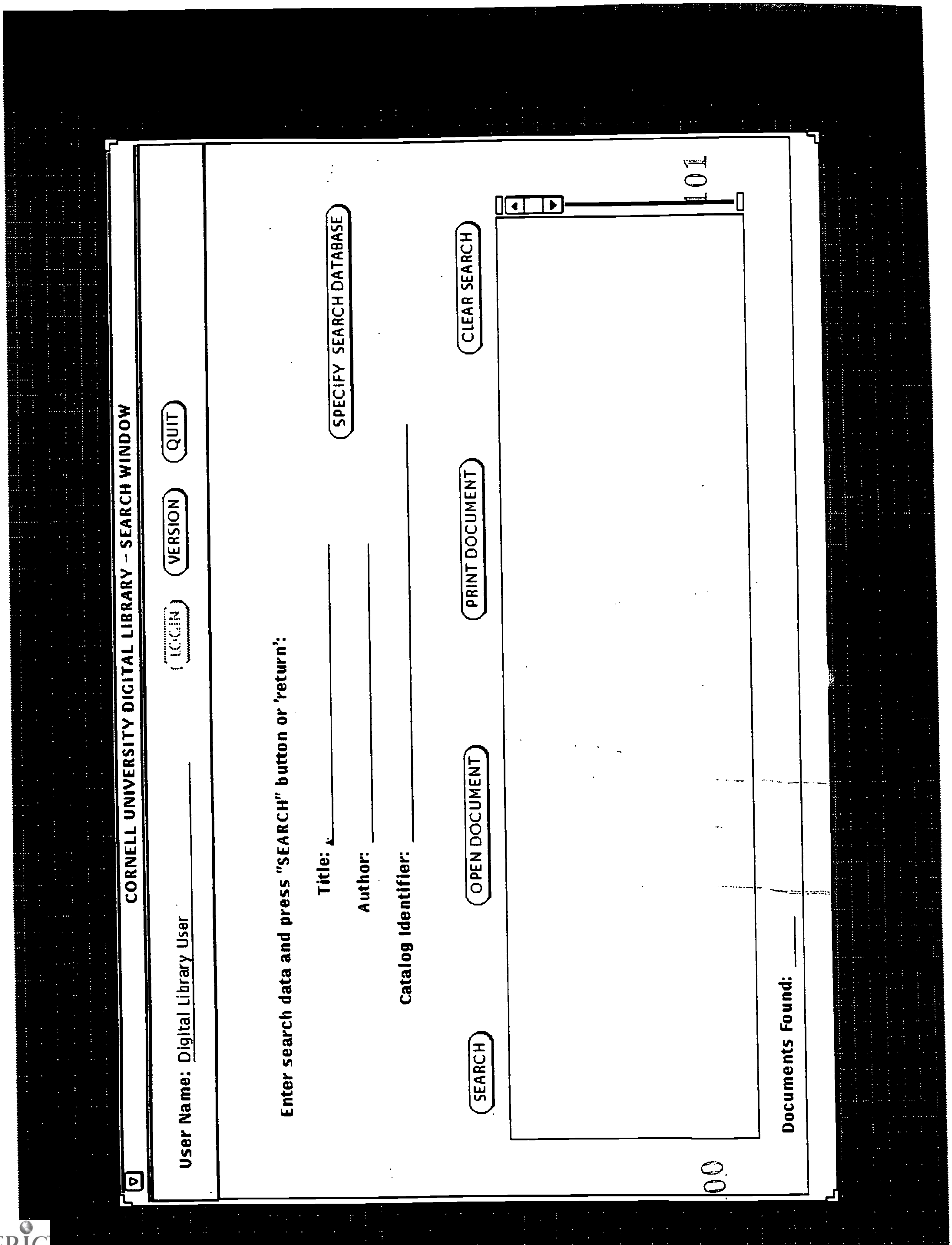
CORNELL UNIVERSITY DIGITAL LIBRARY – SEARCH WINDOW
User Name: Digital Library User
LOGIN
VERSION
QUIT
Enter search data and press "SEARCH" button or 'return':
Title:
Author:
Catalog Identifier:
SPECIFY SEARCH DATABASE
SEARCH
OPEN DOCUMENT
PRINT DOCUMENT
CLEAR SEARCH
Documents Found:

FIGURE 2

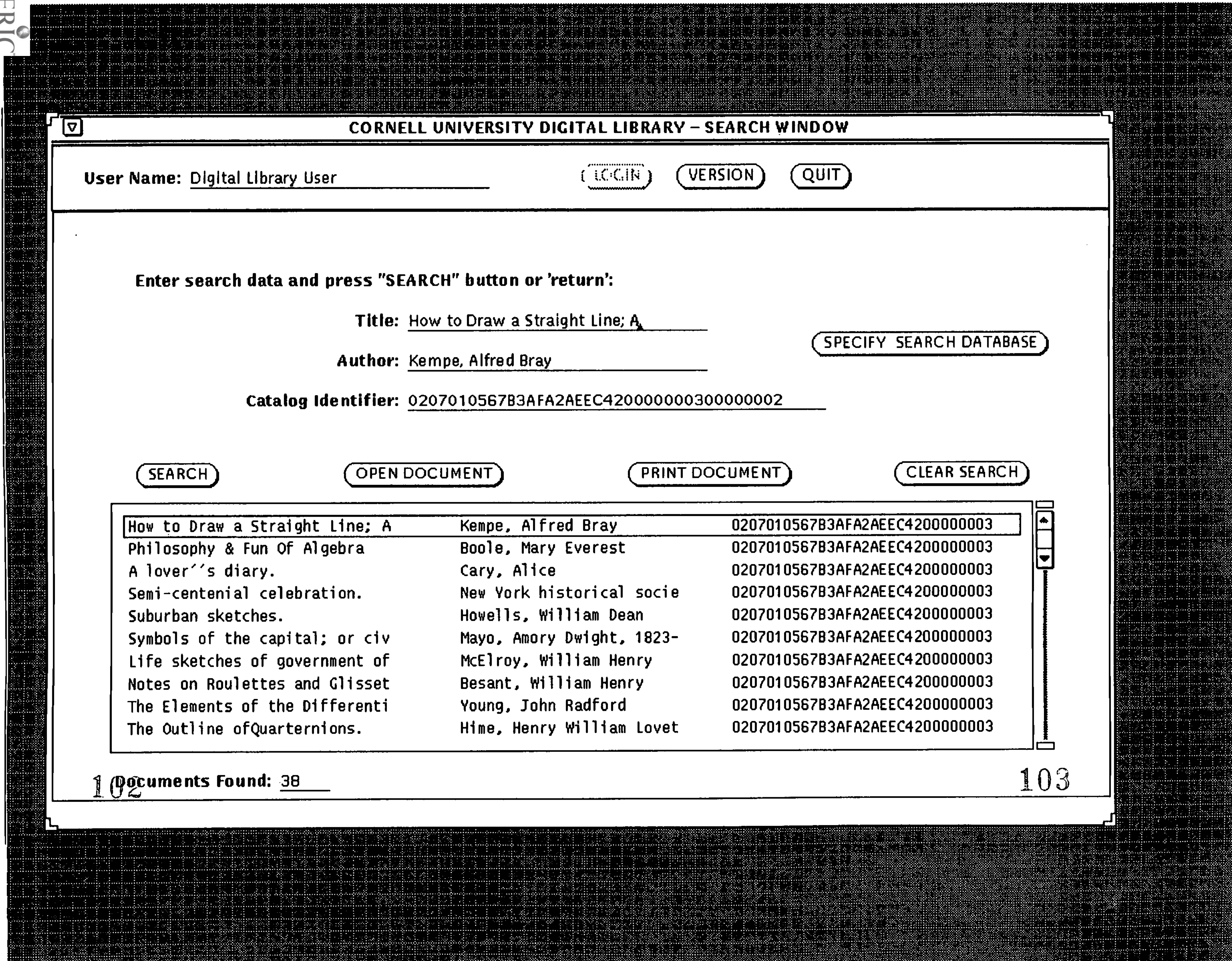
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FIGURE 3

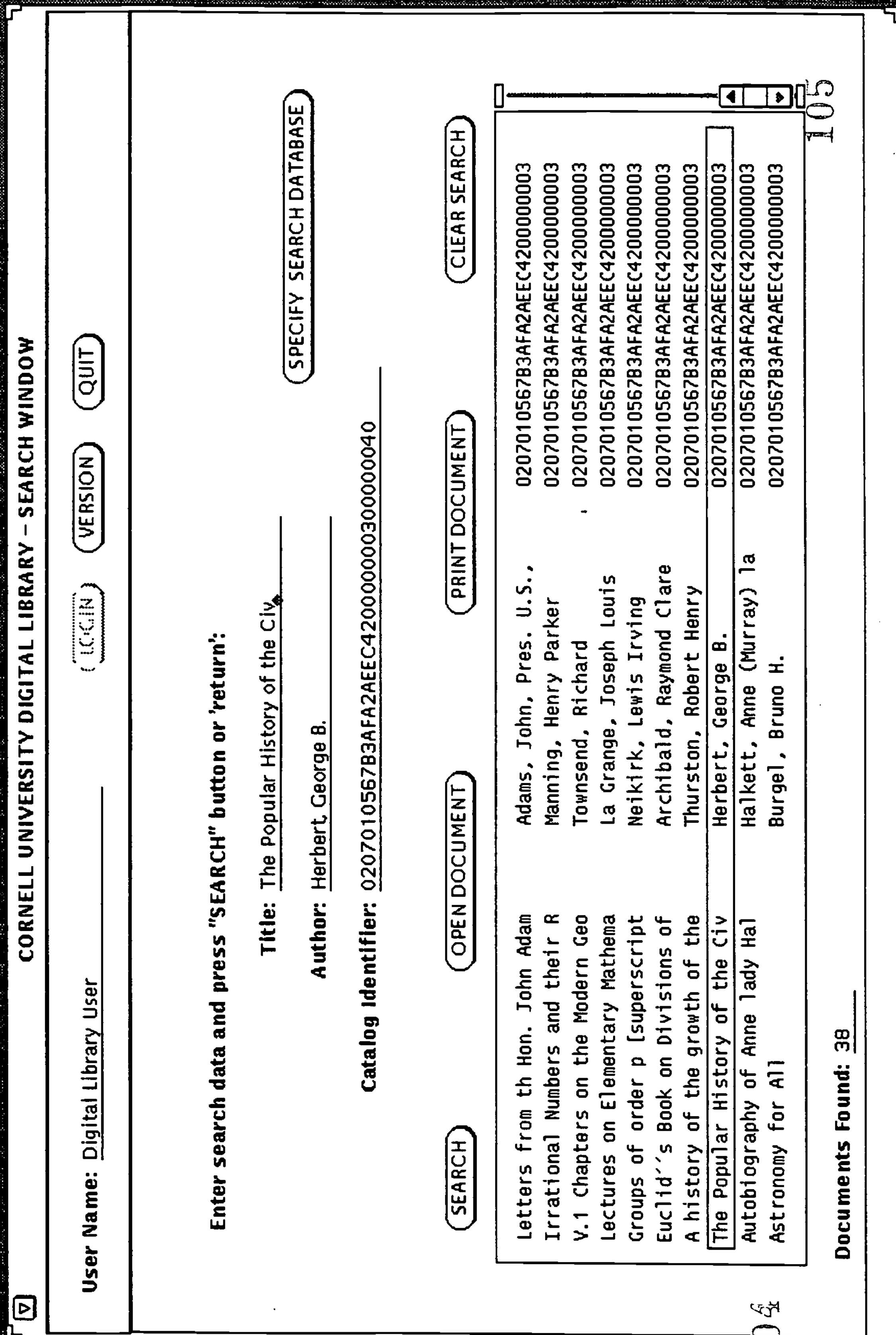
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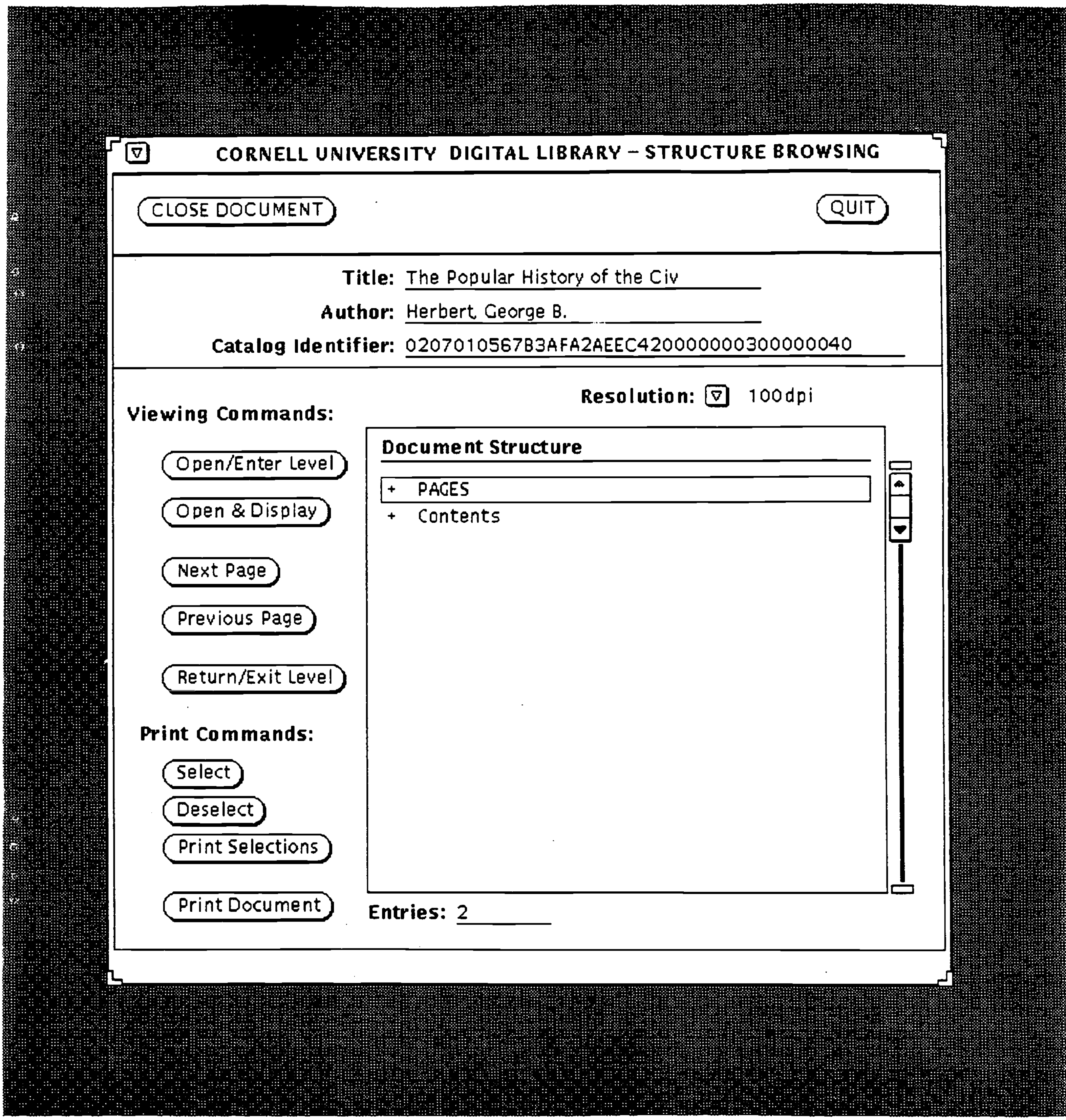
FIGURE 4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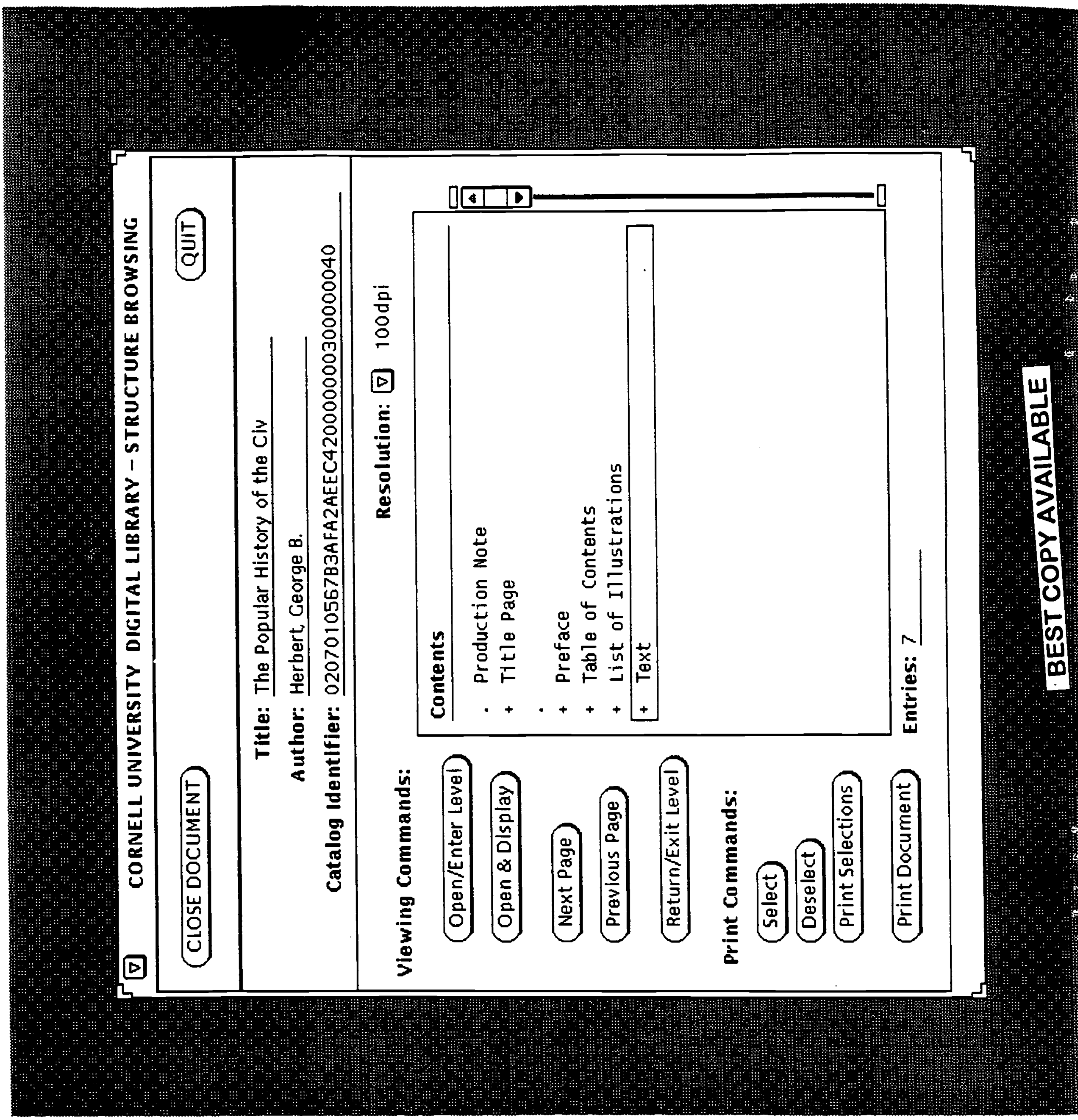
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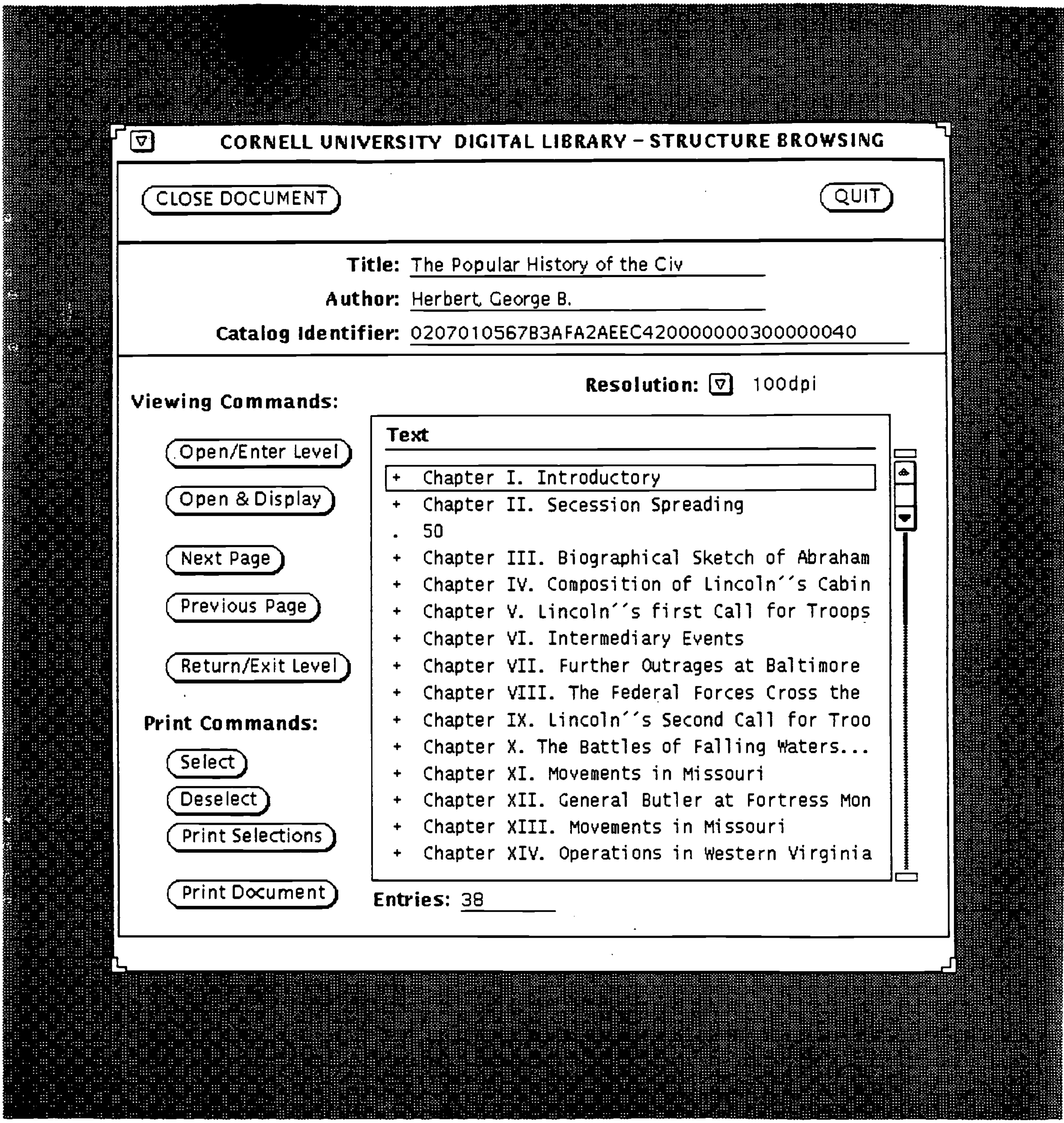
FIGURE 6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+ Chapter III. Biographical Sketch of Abraham
+ Chapter IV. Composition of Lincoln''s Cabin
+ Chapter V. Lincoln''s first Call for Troops
+ Chapter VI. Intermediary Events
+ Chapter VII. Further Outrages at Baltimore
+ Chapter VIII. The Federal Forces Cross the
+ Chapter IX. Lincoln''s Second Call for Troo
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FIGURE 7

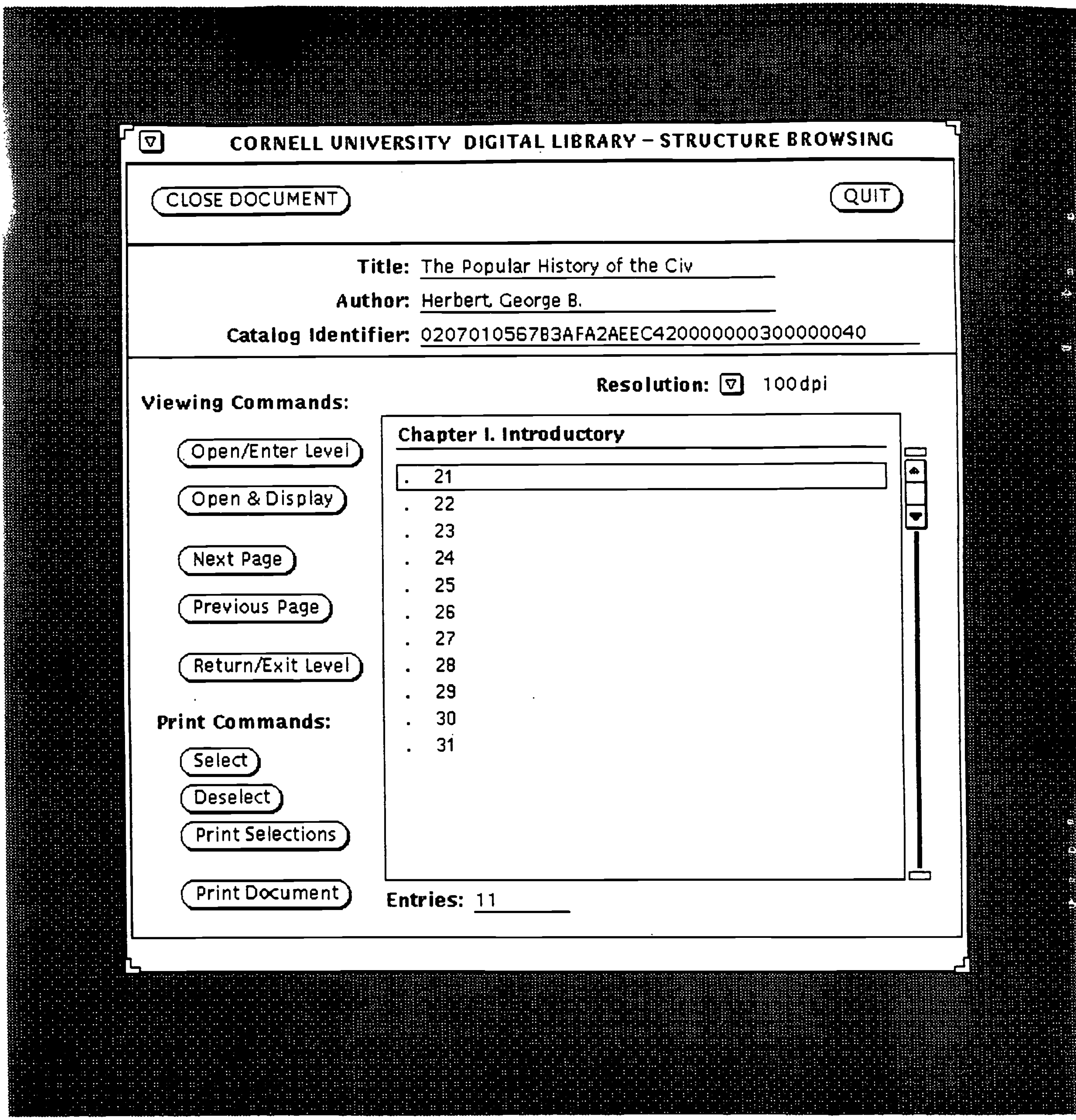
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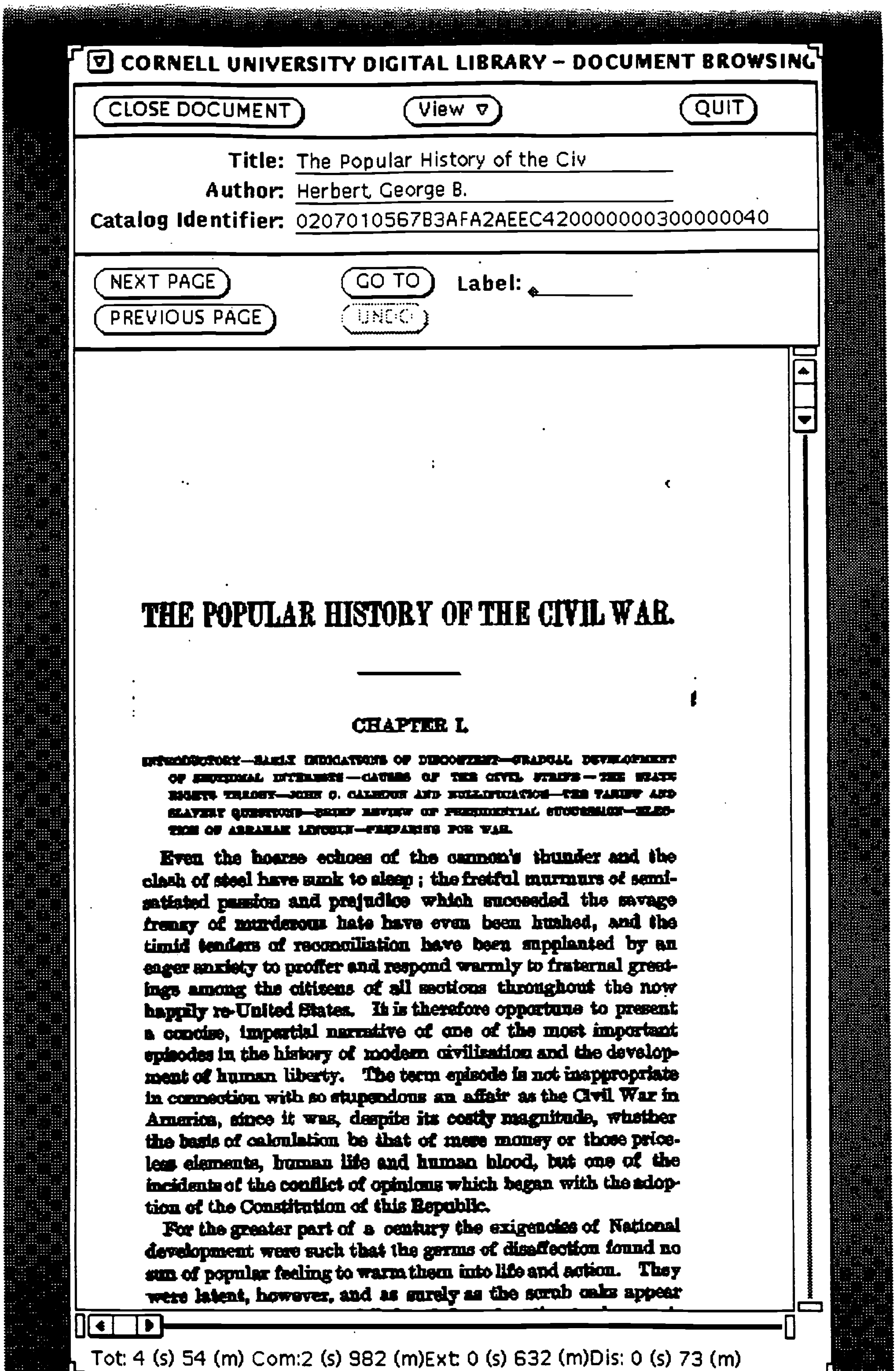
FIGURE 8



THE POPULAR HISTORY OF THE CIVIL WAR.

CHAPTER I.

INTRODUCTORY—EARLY INDICATIONS OF DISCONTENT—GRADUAL DEVELOPMENT OF SECTIONAL INTERESTS—CAUSES OF THE CIVIL STRIFE—THE STATE RIGHTS THEORY—JOHN C. CALHOUN AND NULLIFICATION—THE TARIFF AND SLAVERY QUESTIONS—BRIEF REVIEW OF PRESIDENTIAL SUCCESSION—ELECTION OF ABRAHAM LINCOLN—PREPARING FOR WAR.

Even the hoarse echoes of the cannon's thunder and the clash of steel have sunk to sleep; the fretful murmurs of semi-satiated passion and prejudice which succeeded the savage frenzy of murderous hate have even been hushed, and the timid tenders of reconciliation have been supplanted by an eager anxiety to proffer and respond warmly to fraternal greetings among the citizens of all sections throughout the now happily re-United States. It is therefore opportune to present a concise, impartial narrative of one of the most important episodes in the history of modern civilization and the development of human liberty. The term episode is not inappropriate in connection with so stupendous an affair as the Civil War in America, since it was, despite its costly magnitude, whether the basis of calculation be that of mere money or those priceless elements, human life and human blood, but one of the incidents of the conflict of opinions which began with the adoption of the Constitution of this Republic.

For the greater part of a century the exigencies of National development were such that the germs of disaffection found no sun of popular feeling to warm them into life and action. They were latent, however, and as surely as the scrub oaks appear

FIGURE 9

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mercial success had crowned the untiring efforts of a generation of unselfish, patriotic impulses.

But enough of generalization. The causes of the Civil War—call it *Rebellion* if you will, deem it *Secession* if you please—had their origin in but one Hydra-headed element, commonly known as State Rights. From the sovereign citizen to the sovereign State, was an easy transition in popular or personal opinion; from property in slaves to property interests in relation to tariff legislation, it was even yet more easy to turn, and therefore, *Nullification*, the earliest exemplar of the latent controversy, is entitled to but subjunctive rank among the cohorts of dissatisfaction. It was, however, the touchstone of the entire matter, and consequently we must begin our history by rapidly recounting the legislation which led up to the bold attempt of John C. Calhoun, of South Carolina, in 1833, to sap the integrity of the Union.

As early as 1812, Calhoun, when taunted by Rear Admiral Stewart with the sham under which the aristocracy of the South, supported absolutely by slave labor, assumed to affiliate with democracy, haughtily retorted, in effect, that such assumption, or pretense, was mere policy designed to aid the South in controlling the Republic; that the compromises of the past would not be repeated, and that any attempt to crush that policy or to abrogate its consequent power of control, would be met by a dissolution of the compact of the States.

Following closely upon the tariff agitation of 1816, a mere preliminary skirmish, came the heated discussions in 1820 on the slavery question, resulting in the Missouri Compromise, by which Missouri was admitted as a slave-holding State in 1821. Subsequent events proved that Calhoun's declaration of hostility towards compromise measures was not a personal feeling merely, nor an unmeaning threat. The issue was merely postponed and the agitation allayed until 1849.

The passage of the tariff act of 1824, which afforded protection to the iron trade of Pennsylvania, the manufacturers of the Eastern States and the Northern and Western wool and hemp interests, revived Southern hostility, and when, in 1828, after a bitter controversy lasting nearly a year, the tariff bill,

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imposing duties upon an average basis of fifty per cent., was passed, the outspoken indignation of the advocates of the cotton interests was so violent and aggressive that the long-threatened hour of dissolution seemed at hand.

In the fall of 1828, after an exciting Presidential campaign, John Quincy Adams was defeated, and Andrew Jackson, a native of North Carolina, but a resident of Tennessee, was elected, receiving 178 electoral votes against 83 for Adams' re-election. As usual, the mere partisan rancours of a campaign disappeared as easily and as silently as the morning mists. But gathering clouds took their place, the Bank Charter Act and the reopening of the tariff question precipitating another storm. The first annual message of President Jackson opposed the re-chartering of the Bank of the United States, and suggested that the old charter should be allowed to expire by the effluxion of time in 1836. The corporation power was, however, strong enough to set these views aside, and Congress in 1832 passed the bill to re-charter. This was promptly met by a veto, and failing to command a two-thirds majority, the friends of the bill were compelled to yield.

Meanwhile the agitation on the tariff question had been rapidly spreading, and when, as the result of the session of 1831-32, additional duties were levied upon manufactured goods imported from abroad, the smoldering discontent of the South leaped into flame. It was claimed that again the manufacturing districts were favored at the expense of the agricultural States, and South Carolina, under the lead of John C. Calhoun, with his nullification theory, determined to resist the power of Congress in the premises.

Inflammatory literature was widely disseminated, and other Southern States were invited to join the movement for mutual self-protection. On the 24th of November, 1832, a grand convention was held at Columbia, and the Nullification Ordinance was adopted. This instrument declared that no duties should be paid in South Carolina after a certain date; that no appeal should be permitted to the Supreme Court of the United States in reference to the validity of the ordinance, and that attempts by the United States Government to collect revenue would justify

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secession and the establishment of an independent government. This ordinance was approved by the Legislature of the State then in session. To emphasize the matter the Legislature ordered the raising, arming and equipping of State forces to resist to the uttermost the exercise of Federal authority.

Mr. Calhoun, then Vice-President of the United States, was named as the head of the proposed State organization, and medals bearing the words, "John C. Calhoun, First President of the Southern Confederacy," were struck off and distributed. In the streets blue cockades, with a center button ornamented with a palmetto, the symbol of the new nation, were freely displayed. Nor did the matter rest here. Colonel Hayne, Senator from South Carolina, boldly advocated, on the floor of the United States Senate, the right of a State, under certain circumstances, to nullify an act of Congress. To his fiery eloquence was opposed the masterly argumentative speech of that master of American oratory, Daniel Webster.

JOHN CALDWELL CALHOUN.

Debate, however, on such a subject, was not President Jackson's mode of meeting and dealing with a crisis. He promptly issued a proclamation, in which he asserted that "to say that any State may at pleasure secede from the Union, is to say that the United States are not a Nation." He declared his intention to collect the revenue under all and any circumstances. This was met by a counter proclamation, in which Governor Hayne, of South Carolina, sustained the Nullification theory, and called for twelve thousand armed volunteers to defend the State against Federal interference. On the 26th of February, 1833, Congress passed the Force bill, which gave jurisdiction to the United

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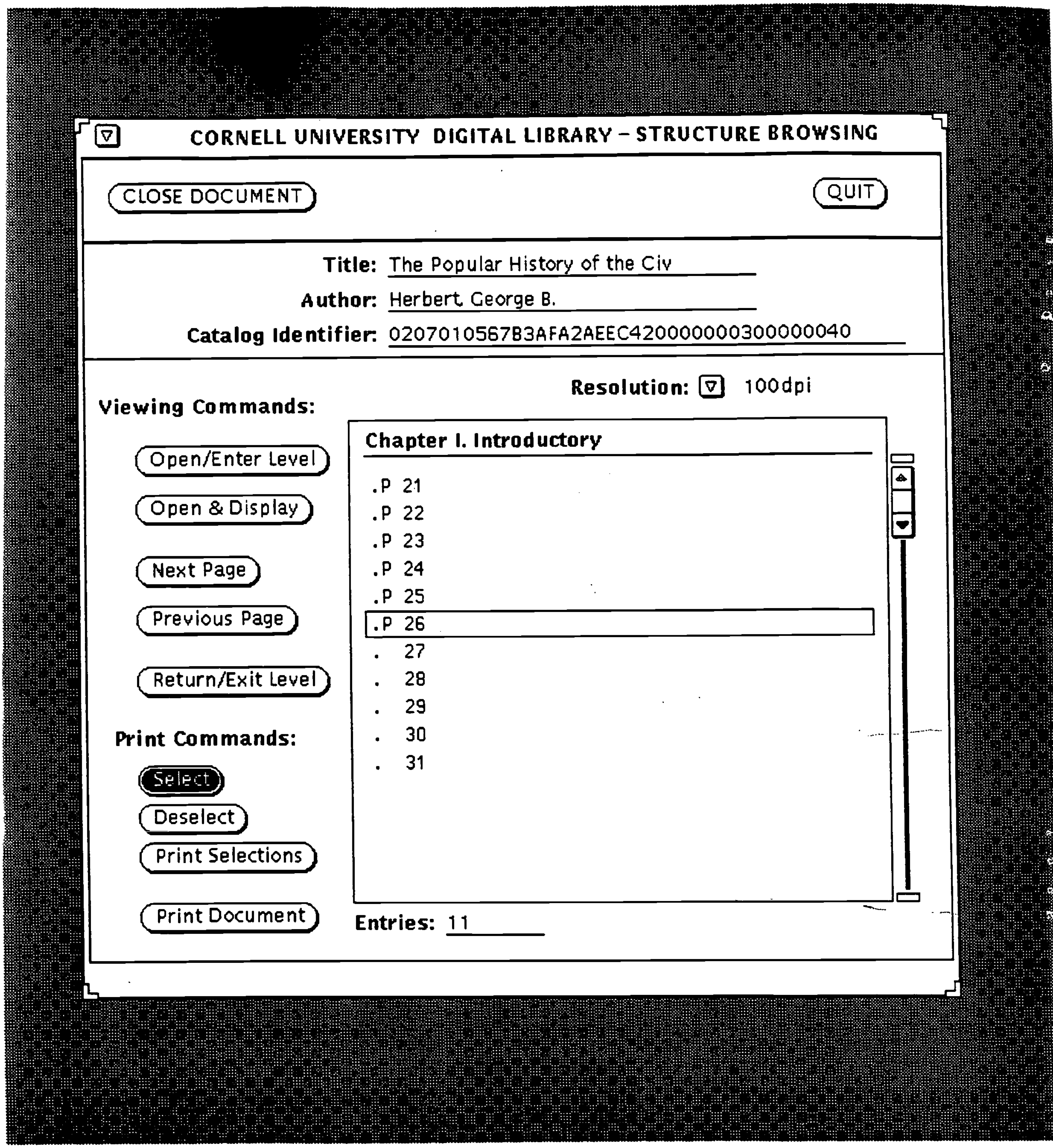
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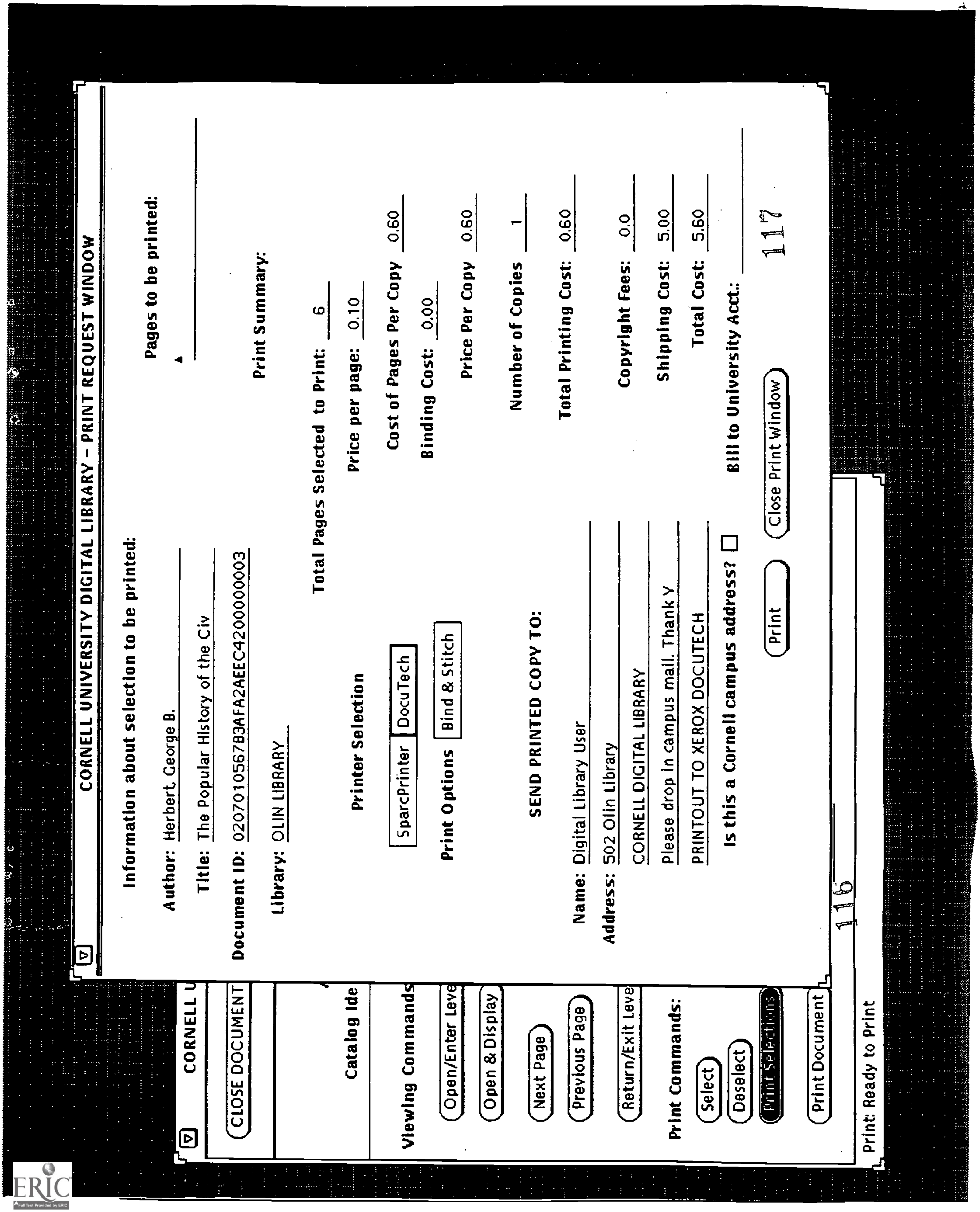
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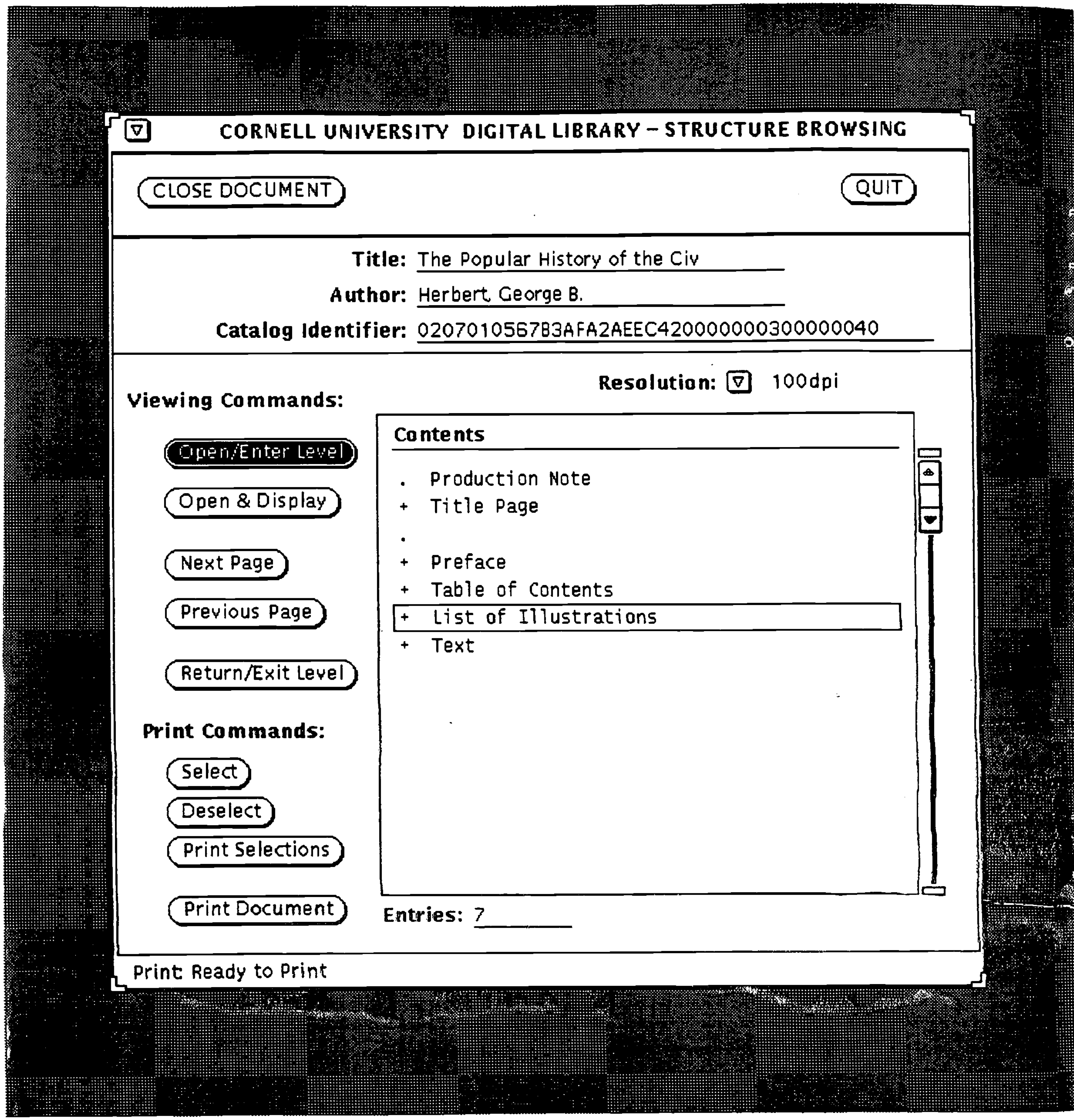
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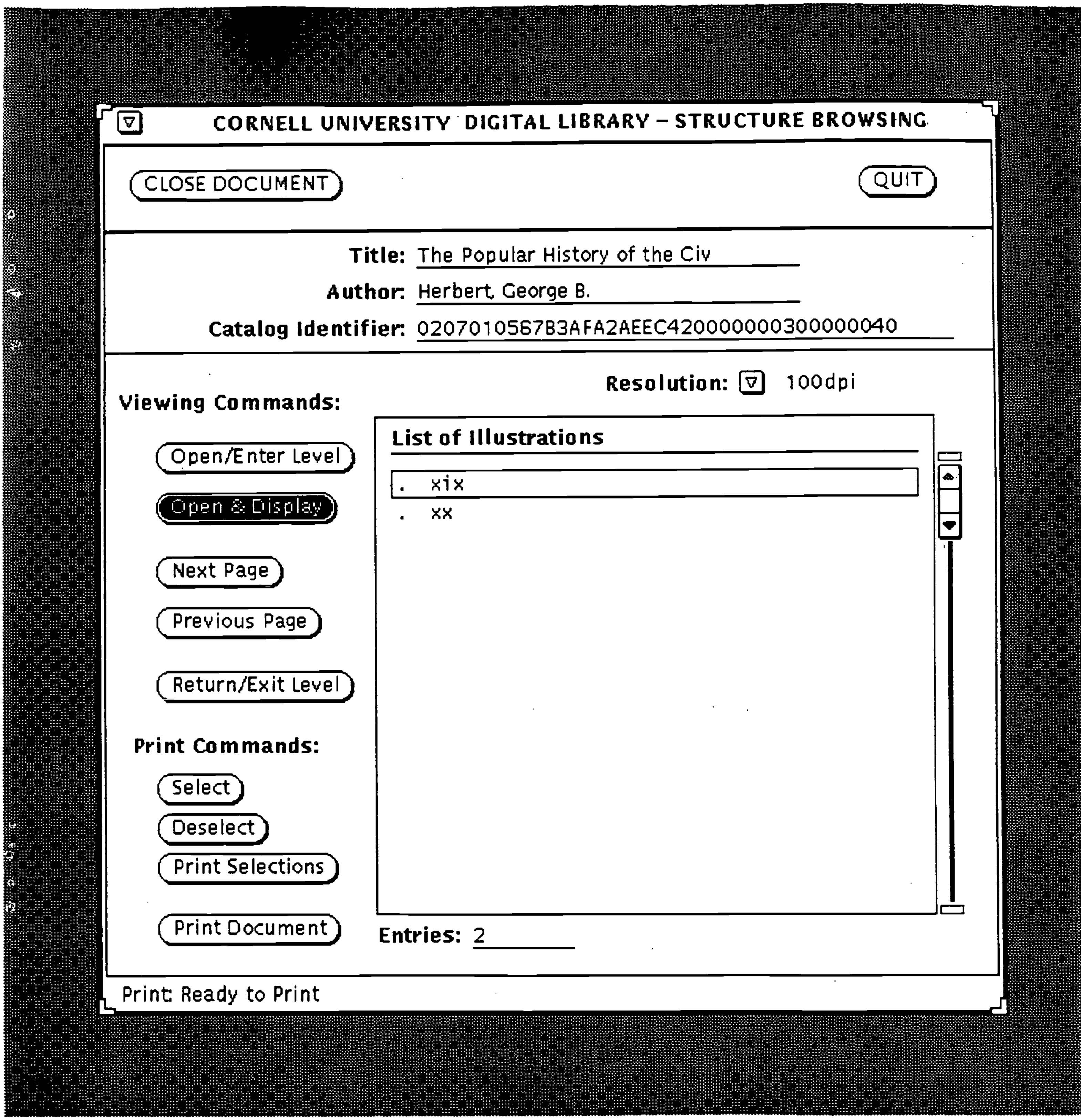
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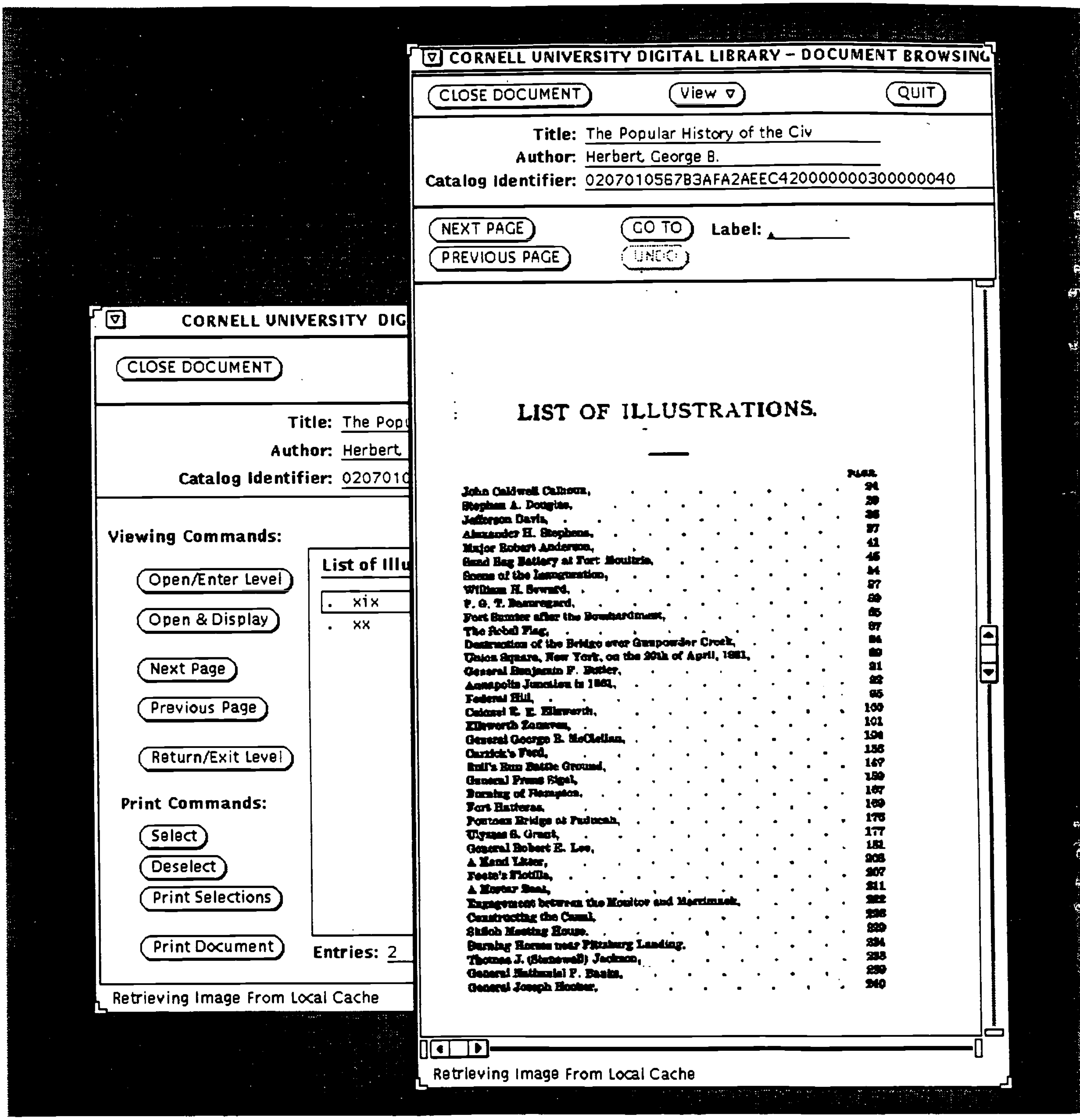
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Annapolis Junction in 1861,
Federal Hill,
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Bull's Run Battle Ground,
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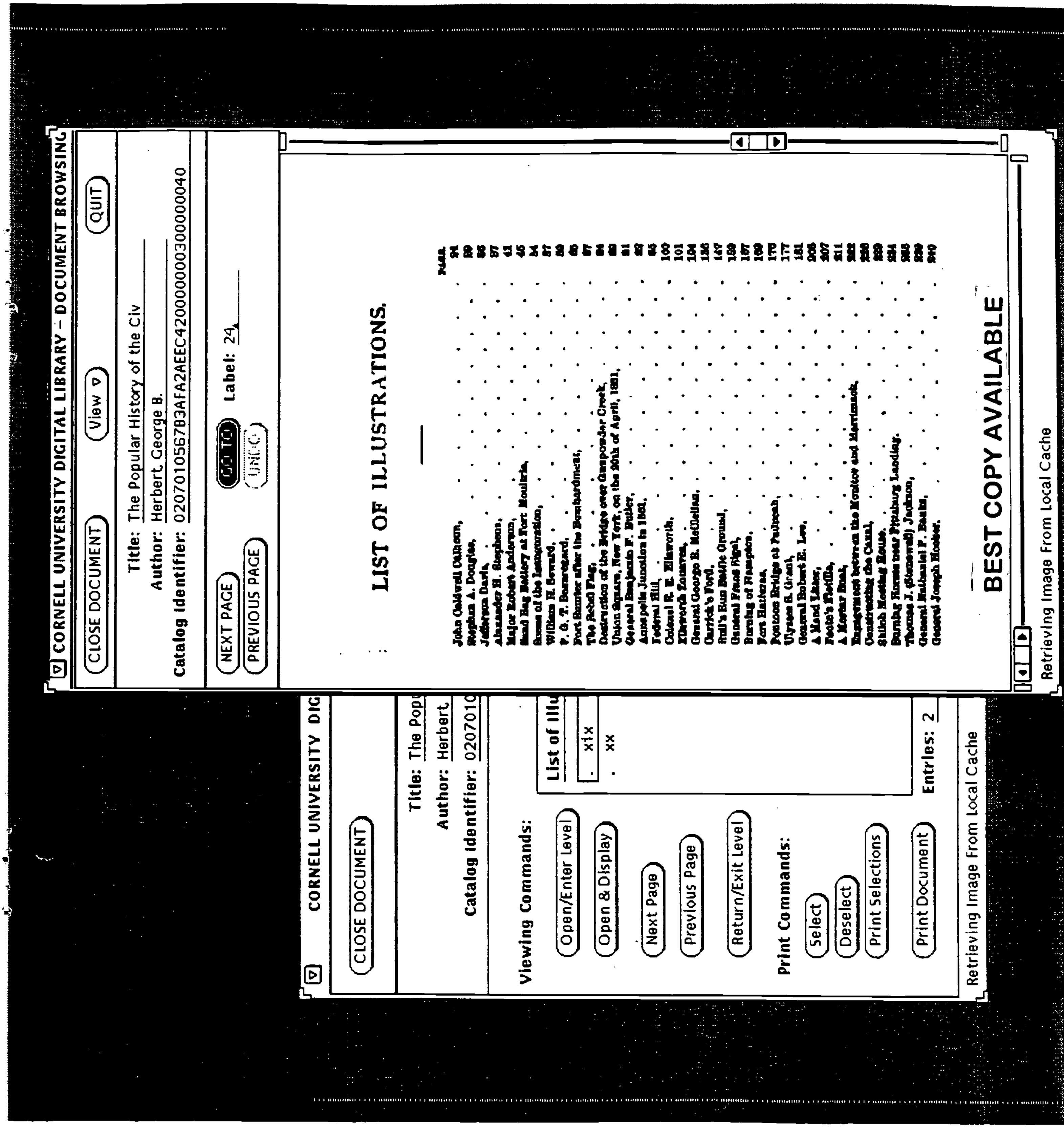
FIGURE 16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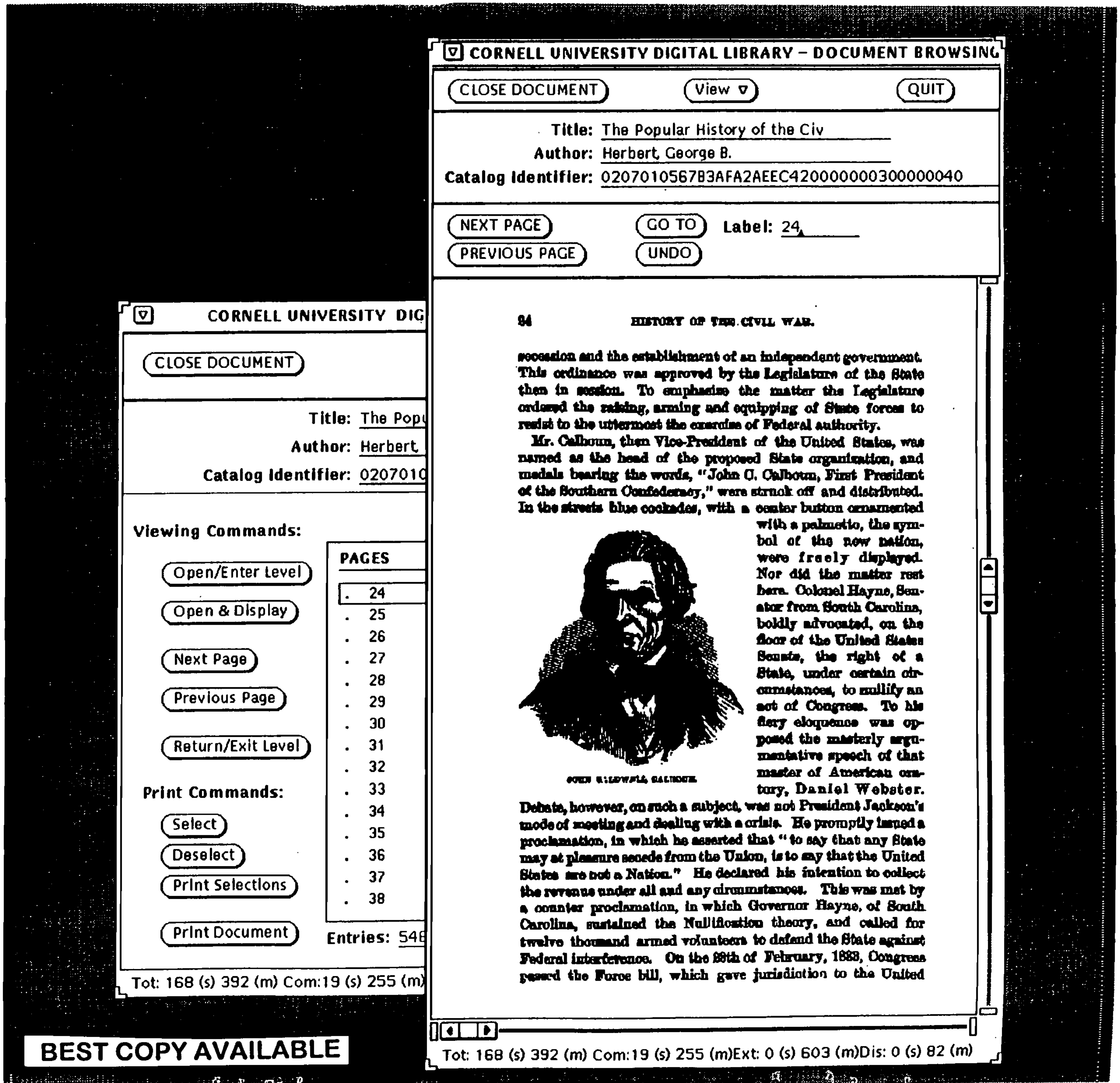
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94 HISTORY OF THE CIVIL WAR.
secession and the establishment of an independent government. This ordinance was approved by the Legislature of the State then in session. To emphasize the matter the Legislature ordered the raising, arming and equipping of State forces to resist to the uttermost the exercise of Federal authority.
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FIGURE 18

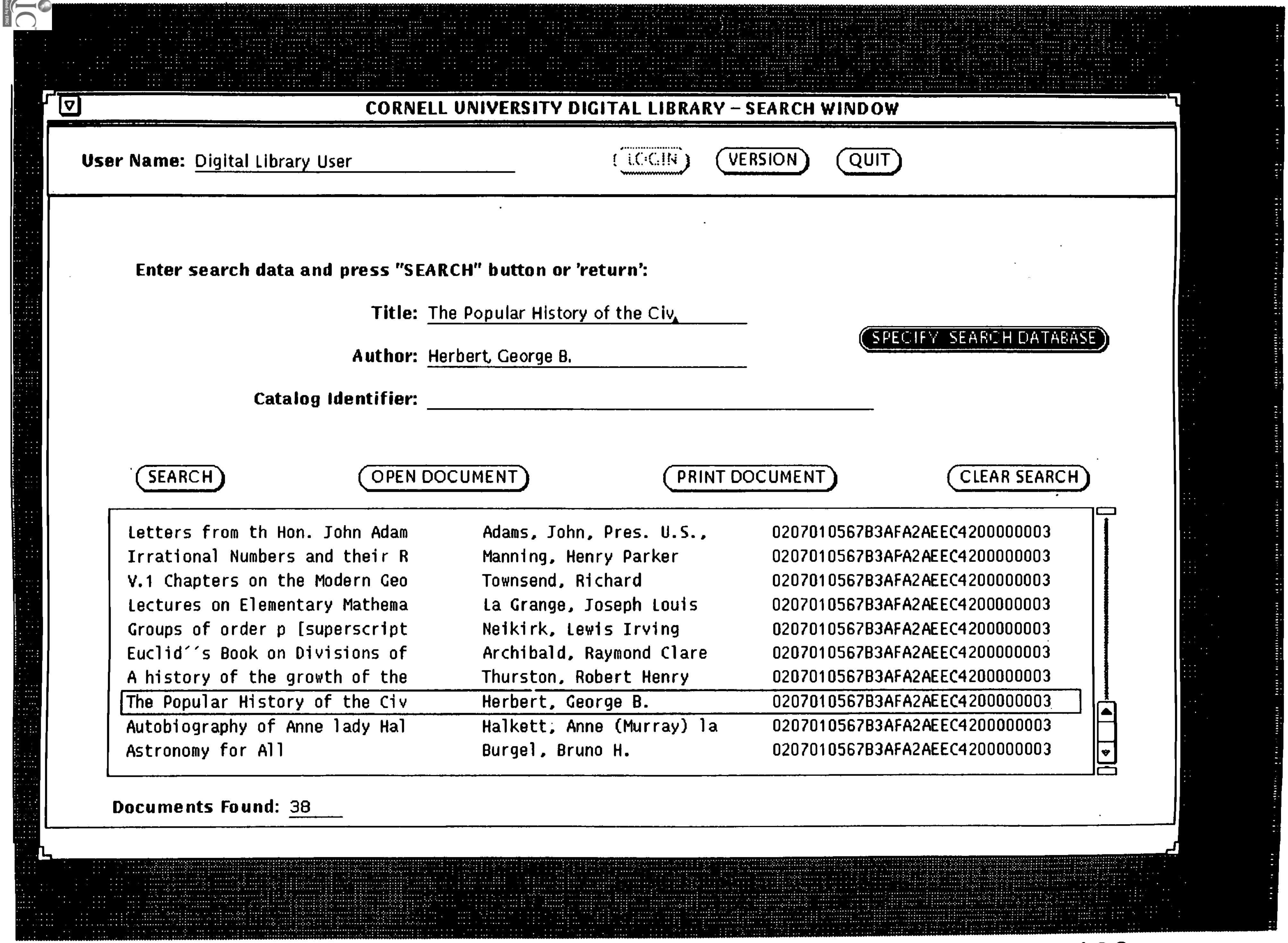
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FIGURE 19

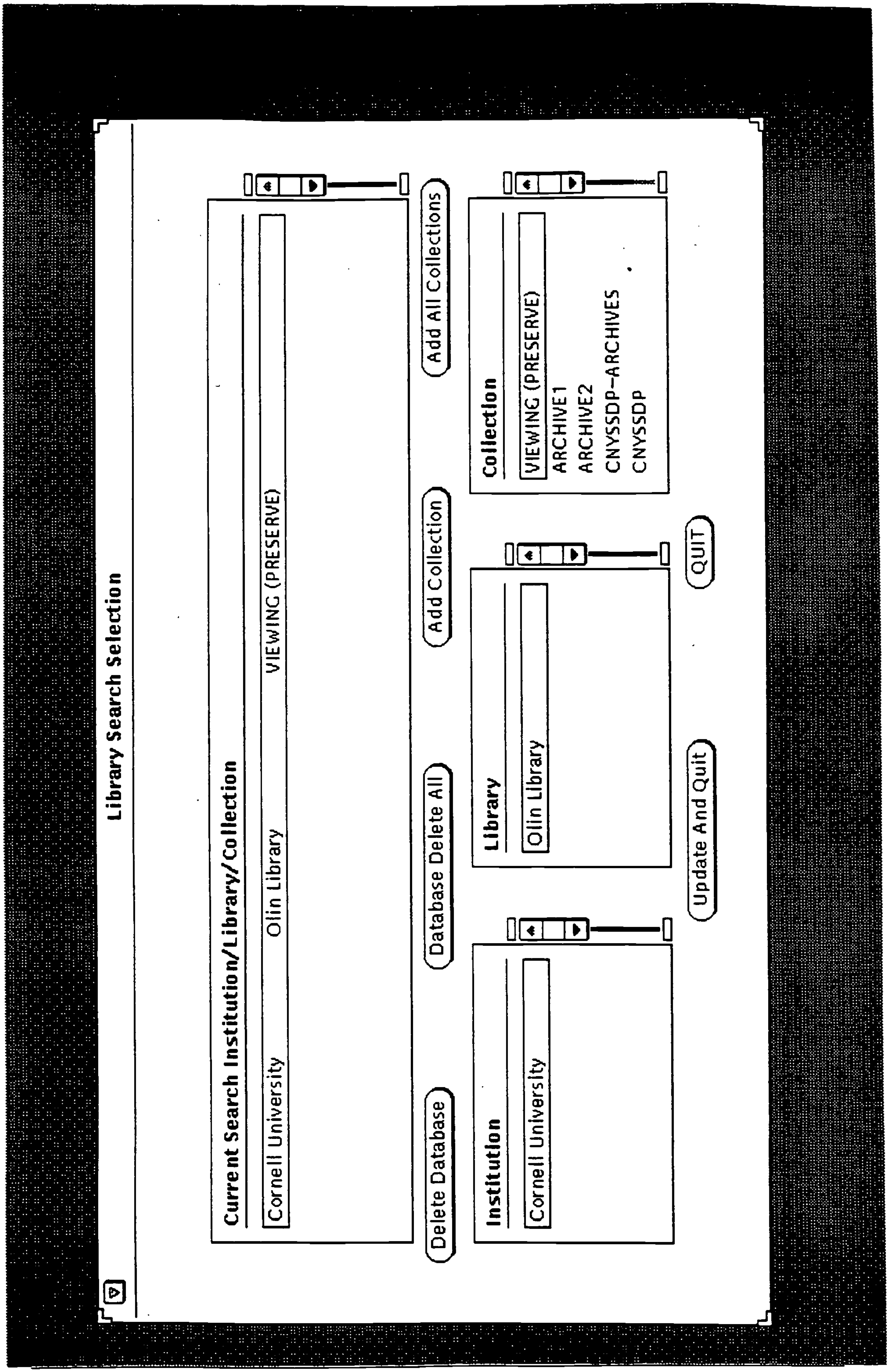
Library Search Selection
Current Search Institution/Library/Collection
Cornell University
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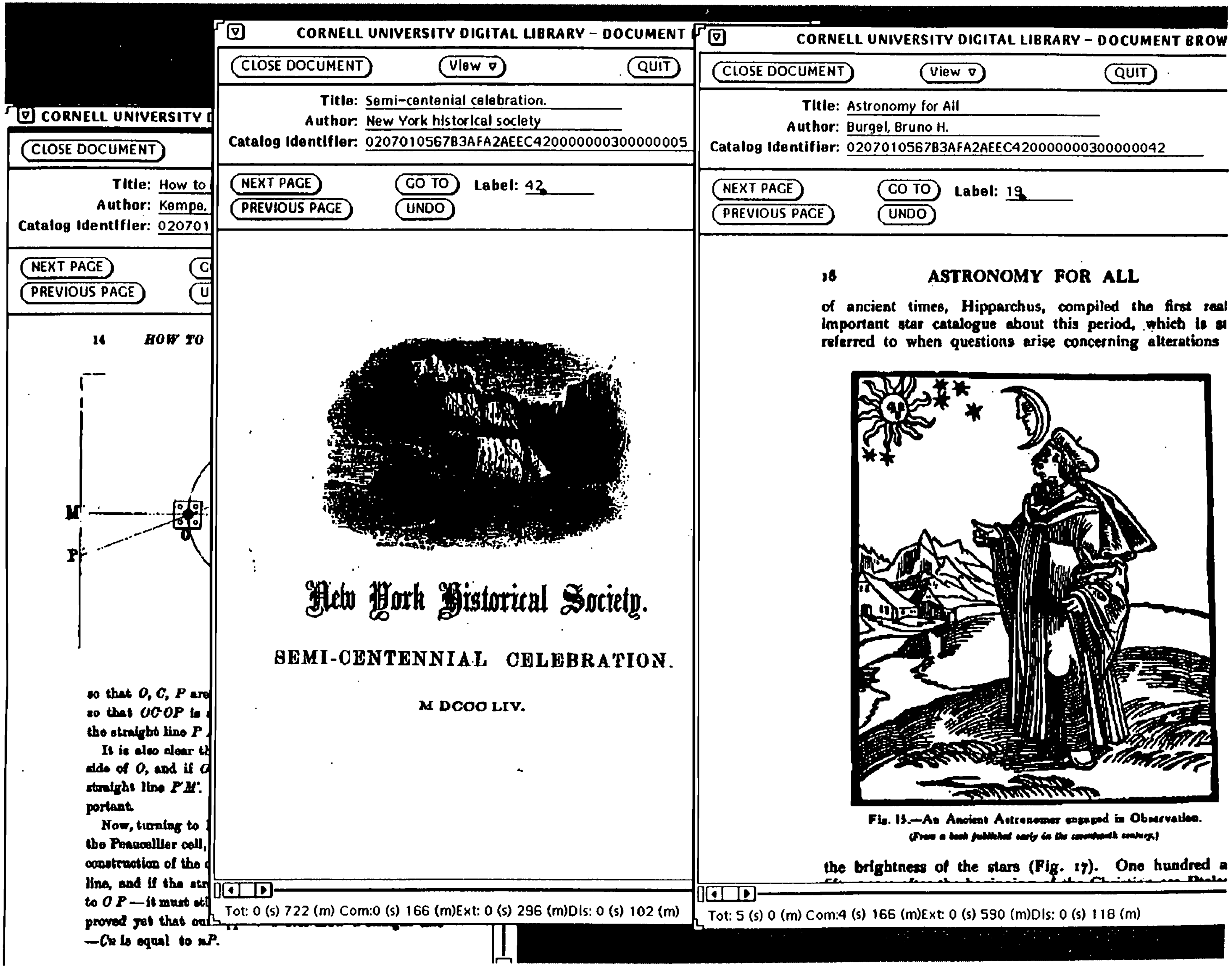
FIGURE 20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Title: How to
Author: Kempe,
Catalog Identifier: 020701
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14 HOW TO
so that O, C, P are
so that OC·OP is
the straight line P
It is also clear th
side of O, and if O
straight line PM'.
portant.
Now, turning to
the Peaucellier cell,
construction of the
line, and if the str
to O P — it must sti
proved yet that ou
—Cn is equal to nP.
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Author: Burgel, Bruno H.
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18 ASTRONOMY FOR ALL
of ancient times, Hipparchus, compiled the first real
important star catalogue about this period, which is st
referred to when questions arise concerning alterations
Fig. 15.—An Ancient Astronomer engaged in Observation.
(From a book published early in the seventeenth century.)
the brightness of the stars (Fig. 17). One hundred a
Tot: 5 (s) 0 (m) Com:4 (s) 166 (m)Ext: 0 (s) 590 (m)Dls: 0 (s) 118 (m)

FIGURE 21

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