A Bookscanner for Fragile Books

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Abstract

The enhancement of digital scanning technology in recent years has provided an attractive medium for the reproduction and transmission of book archives in libraries and museums around the world. While a number of commercial systems have been developed for the scanning of bound volumes, there has been a very few efforts to develop a system for the scanning of fragile books. Here we present a bookscanner system developed at Xerox PARC specifically for the scanning and preservation of rare and fragile books.

The initial requirements for the design were originally taken from guidelines proposed by the US Library of Congress for their preservation efforts. The present design consists of an operator controlled 90° book cradle and wedge platen which precisely defines the image plane; a 4kx4k 12 bit CCD camera with external color filters; a rotating mirror which allows for the computer to select which of the two opposing pages to capture. The combined camera, mechanical, optical and control systems allow the capture of 10x12 inch, 300DPI grayscale and color images. The optimal throughput of this system approaches that of current benchmark microfiche systems (500 grayscale pages/hour) without appreciably impacting the handling of the fragile books. Considerations during the design process and customer research results will be presented along with the present design and performance data.

Introduction

The confluence of electronic imaging, high capacity data storage, digital image processing, optical character recognition, computer networking, and the emergence of the Internet and on-line services has created a sizable market for the digitization of hardcopy documents of all kinds. A document scanning area that remains largely untapped involves the digitization of legacy and rare books. The increasing demand is being fueled by a deterioration of bindings, 19th century acid processed paper and the need of libraries, museums, and government institutions all over the world to archive their materials in a form that is amenable to on-line storage, search, retrieval, and browsing. The Library of Congress alone has literary millions of these types of books that are either too valuable or fragile to be subjected to the type of handling associated with currently available commercial scanners.

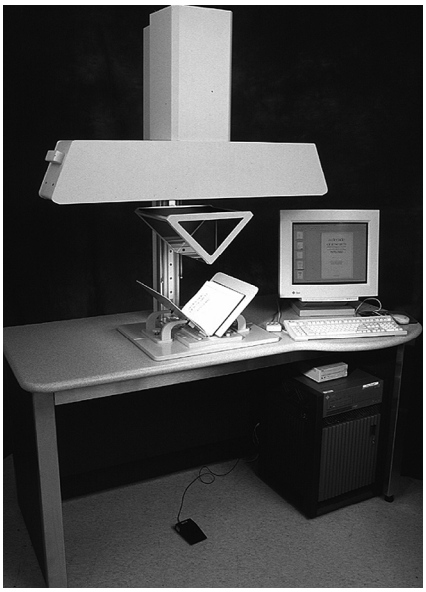

Figure 1, Bookscanner system

A prototype bookscanner system is presented here which is believed to address the concerns of librarians and archivist on the handling of fragile books, quality of the digitized archives, as well as the overall process control from capture to display. The initial fundamentals of the design were taken from the Library of Congress RFP69-18[1] document with further input from archivist in the US and Europe.

Analysis of the data from these information sources yields the following observations: 1) most rare and/or fragile books require a non-inverted 130 to 90 degree book cradle, 2) the use of a glass platen applied to flatten a page, while undesirable in some extreme instances, is allowable in the greatest percentage of cases if a trained operator has full control over the interaction, 3) while for most cases, grayscale images are sufficient, color images are desired for at least portions of most books (cover, binding, color containing drawings, etc.) 4) the shear number of bound volumes in need of preserving or just made available in digital format requires high throughput methods, 5) the quality and content (images and metadata) of the digital archive output is of paramount importance, 6) operator ergonomics and comfort is of great concern, and 7) no one capture device can do it all.

Description

The mechanical components of the bookscanner can be divided up into 3 sub-units: 1) the optical assembly, 2) the wedge platen, and 3) the book cradle. The optical assembly (see figure 2) consists of a camera mount assembly, vertical track roller assembly, rotating mirror, optical path cover, left/right page mirrors, illuminator, connecting rods, and rod stops. The optical assembly moves as a unit on a vertical track attached to a post.

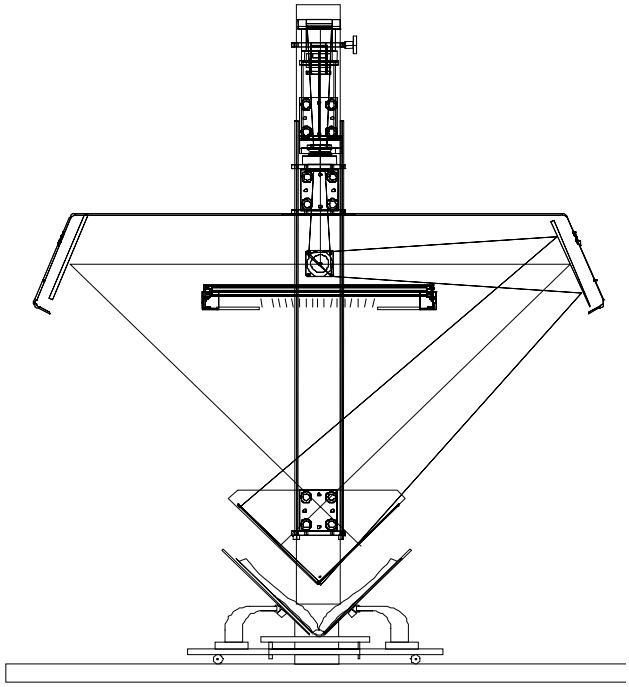

Figure 2. Bookscanner optical/mechanical design

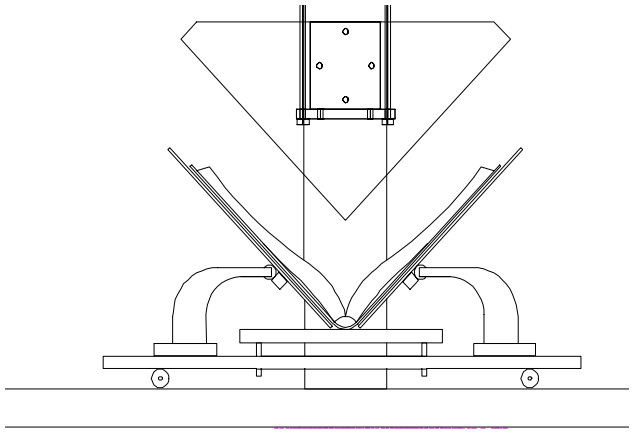

Figure 3. Wedge-platen and book cradle details

The wedge platen (figure 3) consists of a frame that forms a 90º wedge in which platen glass is attached. The frame is fastened to a vertical track roller assembly. The wedge platen assembly moves as a unit on an extension of the same vertical track on which the optical assembly moves and engages the optical assembly when it contacts the rod stops. The position of the rod stops adjusts to fix the optical path length, which assures a fixed image plane at the platen.

The book cradle consists of book side supports that are attached to adjustable hinges on a platform. The moveable hinges allow for adjusting the distance between the two book side supports to allow for different book thickness. The book side supports are supported by side support arms which are horizontally adjustable such that once the book side support hinges are adjusted for a particular book, the side support arms can be adjusted so that the point at which the side support arms contact the book side supports coincides with the support stops. Once adjusted the angle of each book side support in relation to the facing book side support is 100º. The platform rests on horizontally constrained spring-loaded posts. The spring-loaded platform and side support arms rest on a horizontally translating platform that moves on a wheel and track assembly attached to a table.

The basic operation involves placing the book in the cradle face-up, lowering of the platen onto the book which causes the cradle to partially close the book onto the 90° angled face of the platen, illuminate the book, capture one page, then rotate the switching mirror and capture the other page. Further scanning continues by lifting the mechanically assisted platen, turning the page, and repeating the process. In this configuration, two pages are captured without having to flip the book around, the book binding is supported by the cradle, and stress on the binding is also minimized by having the open book angle be 90° instead of 180°. The function of horizontally translating platform is to allow the book to center itself as the platen is lowered. The operator has the ability to exercise judgment as to the amount of pressure to apply to the book. If need be, the platen can be lowered to barely touch the gutter of the book while the operator brings the hinged cradle sides up with his/her hands to provide gentle contact of the pages to the glass platens. This concept combines high productivity with minimal stress on the book.

Measurements of the applied forces versus vertical platform displacement when applying pressure to the wedge platen are displayed in figure 4. The linear behavior of the platform data represents the spring constant of the platform support springs. The fact that the data for the force applied to the wedge shows an asymptotic behavior indicates that any additional force applied is directed through the platen, normal to the book pages, and onto the side support arms. Image studies of bindings during the application of pressure on the wedge platen confirm that no force is transferred to the binding of the book. At the point that the wedge data diverges from the platform data indicates the book pages fully conform to the platen surfaces and no further force is needed.

The book is illuminated by a bank of high frequency full-spectrum florescent lamps directly above the wedge platen and inset in the optical path cover. Directional

louvers in the lamp assembly provide for avoidance of specular reflection into the optical path and a uniform light intensity on the page. The intensity of the light from this system is quite mild and designed to be accommodating to the operator as well as the discriminating archivist who may have concerns of light damage to fragile books.

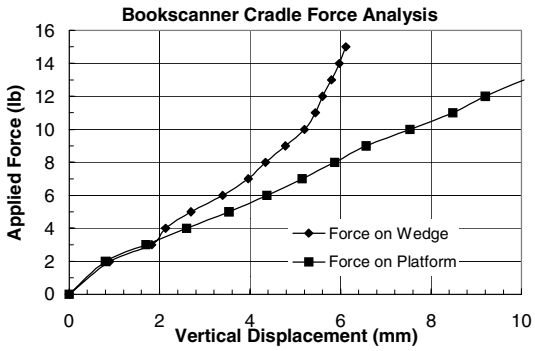

Figure 4. Applied force versus vertical displacement of the spring-loaded platform. The difference between the force applied to the platform alone versus the force applied to the wedge, through the book and to the platform is the additional force directed normal to the book pages

The imaging system consists of a Dicomed 4Kx4K 12 bit CCD integrated into a Hasselblad back mounted on a bellows, lens and electronic shutter assembly. Finger adjustment to the bellows provides fine focus for the fixed optical path of approximately 60 inches from the lens to the imaged page.

An electronically controlled filter selector assembly is located below the lens. The filter bank consists of an infrared filter for grayscale capture and red, green, and blue dichroic filters for the 3 color separations required for color imaging. A micro controller based circuit orchestrates the interaction between the operator, computer, CCD, shutter and filter selection. Different shutter integration times are integrated into the controller electronics to compensate for variation in the light throughput for each spectral filter (Table 1).

Commercially available LCTF and filter wheel were originally tried, however the LCTF filter proved to be unsuitable due to the introduction of aberration. The filter wheel used gel absorption filters that created uncontrollable misalignment of the color separations.

The CCD is interfaced to a Sun Enterprise 3000 dual processor computer via SCSI-2 interface that provides a transfer time for the 32-megabyte images to system memory of 4.2 seconds. The server class Unix platform was chosen at the time of initial development for its processor and disk performance (disk IO bandwidth and capacity). The 12 bit images are scaled by gain/offset calibration images, bad pixels are replaced by near neighbor averaging and then the image is saved to disk as an 8 bit grayscale or 24 bit color image by ignoring the least significant 4 bits of each separation.

The software user interface is Java based with image capture and processing routines written in C and C++. The operator is initially presented with an image viewing sub-window and a thumbnail selection portion of the application window. To begin scanning of a book, title, author name, disk location and reference data is entered into a properties dialog box. An image-processing template is then created or selected from previously saved templates. At this point, scanning is initiated either from the application, a 3-button scanner mouse (left page/both/right page), or a foot switch (both pages). The foot switch enables the operator's hands to concentrate on the book/platen interaction to minimize impact on the book and ensure the quality of the image during capture.

Table 1. Optical Specifications

Resolution	300 spot per inch (on page)
MTF	> 50% at 6.2 lp/mm (Nyquist frequency for 300dpi)
Magnification	0.1772 (5.64:1)
Aperture	F/11
Integration Time	0.12 sec –Grayscale 0.32 sec –Red 0.32 sec –Green 1.08 sec - Blue
Depth of Field	10 mm
Field	10.5"x 12.3"

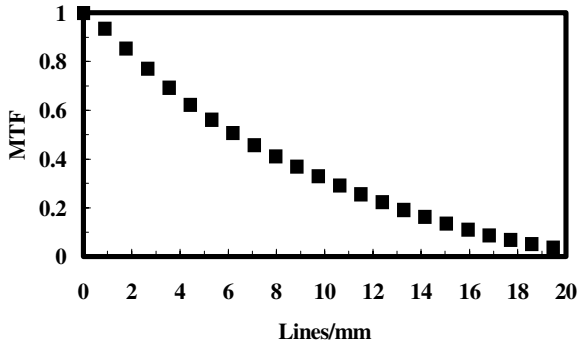

Figure 4. Modulation transfer function for the system optics

Discussion

Performance

The commercial lens selected was matched with the optical path to provide for suitable optical performance at 5:1 magnification needed to produce 300dpi images. The resolution performance is characterized by the modulation transfer function (MTF) shown in figure 4. A custom lens solution is under investigation to increase the resolution performance.

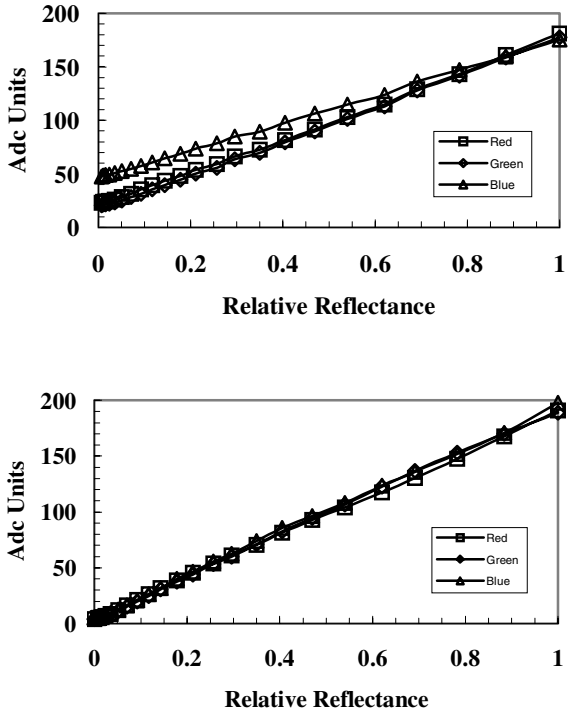

Figure 5. Dynamic range – top plot shows initial range for as-captured color images while the bottom plot shows range for color corrected images.

The dynamic range and noise characteristics of the RGB color channels shown in figure 5 and 6 are generated from a equal density gradient. The upper graph in figure 5 shows as acquired values while the data in the lower graph are from the same image but color corrected using lookup tables generated from an IT8 target and proprietary software which is a part of the bookscanner application software. The upper plot shows that the dynamic range of the blue channel rolls off in the low reflectivity regime. This may be due to the increase in integration time required for the blue separation in combination with the dissimilar reflective quality of the paper used for the gain calibration image and the target. However, the color corrected image corrects for this effect at the expense of a slight increase in noise as seen in Figure 6. While the maximum standard deviation noise figure for an non-gain/offset adjusted 8 bit image is ~1 gray level, the dynamic range adjustment from the gain/offset images contributes to additional noise to increase the value to 2-3 gray levels.

Operation

The operation of the bookscanner is designed for optimization of throughput and image quality. A scanning session begins with the capture of calibration images. Dark images and images of white sheets for each channel are used to calculate pixel wise gain/offset information to compensate for fixed system noise and inhomogeneous illumination. An IT8 color target is then imaged and analyzed to produce a color correction lookup table. The image of the target and lookup table is then saved to accompany the collections to be scanned to verify scanning accuracy at a later date. The subsequent scanning operations produce gain, offset, color and bad pixel corrected, full field images intended as archival quality images.

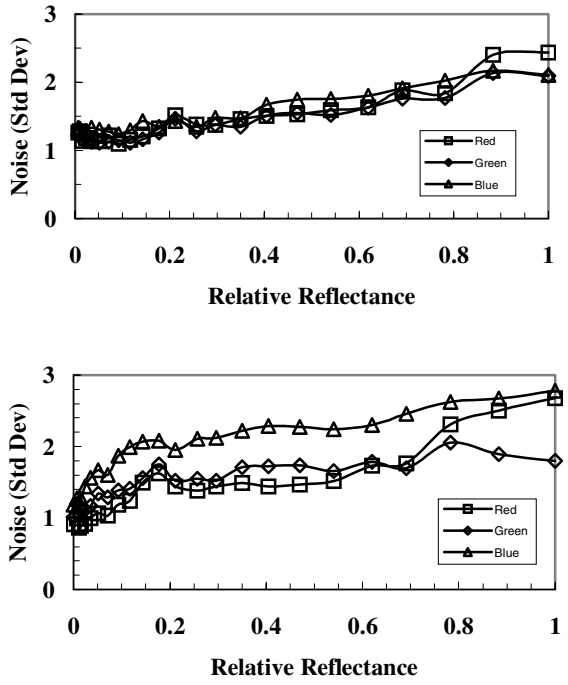

Figure 6. Temporal noise – top plot shows initial noise figure for as-captured color images while the bottom plot shows noise for color corrected images.

The process of scanning a page takes a minimum of 4.2 seconds for the CCD to capture and transfer the image to the computer. The software procedure for capture is organized such that the left hand page is captured, transferred and the right hand page is captured before the operator is signaled to proceed to the next two pages. The transfer of the second page and all image manipulation and display is performed while the next pages are being prepared. This is done to give the operator time to carefully turn the page and prepare for the next capture without impacting maximum throughput. At the present time 450 grayscale pages per hour have been demonstrated. Throughput for color images should approximately be 150 pages per hour.

The software enables the operator to capture additional textual information and metadata appropriate for each image. Once set, page numbers are incremented automatically in either Arabic or Roman numeral format. Page numbering can be suspended and reinitiated at any point appropriate to the book numbering structure. Section headings can be captured along with their possible

hierarchical relationships to five levels. Page metadata includes label, right or left page, filename of the archive image, date scanned, comment area, and profile template name.

The profile template describes a set of image processing routines geared for rendering the image in the best possible way. Initially, this may be set for viewing the images on the computer screen. At the present point, this includes crop area (right and left), orientation (auto-orient, flip, rotate), deskew, bitonal threshold, invert, sharpen, and the application of a tone reproduction curve (TRC) for background removal. A profile is setup as the default initially, but individual pages may have specific profiles as needed.

During the book capture process no image-processed images are saved. Processed images are rendered as needed on the fly from the "archive" images. The book image file index and associated metadata is saved as a text file. After capture, or at a later time, the book can be "published". In this manner predefined image-processing steps can be applied to the archived images in a manner best suited for the intended viewing device and audience, such as a printer or display with particular output characteristics.

One such publishing stream included is to a format highly suitable to Web viewing. For this we include a DigiPaper[2] format. DigiPaper is TIFF-FX based, which segments the image into a multi-layer representation and uses optimized compression methods such as JBIG2. This method enables a highly compressed format for network transmission while retaining the image fidelity.

Conclusion

A bookscanner developed to produce archival quality collections of rare and fragile books has been presented. Grayscale and color images are produced with noise figures of less then 3 levels and demonstrated linearity and resolution performance. Care has been taken to optimize fragile book handling and scanning throughput.

Acknowledgement

We would like to acknowledge the contribution of Dan Bloomberg, Paul Stewart and Armin Völkel for their great contribution to the software application.

References

1. The Library of Congress proposal can be found at http://memory.loc.gov/ammem/prpsal/rfp18.pdf
2. Information on DigiPaper can be found at http://www3.cs.cornell.edu/digipaper/

Biography

Steve Ready obtained his degree in Physics from the University of California at Santa Cruz in 1984. He then joined Xerox Palo Alto Research Center and has since studied the role of hydrogen in amorphous, polycrystalline and crystalline silicon, contributed to the development of large area amorphous and polycrystalline silicon imaging arrays for optical and x-ray applications, and is presently working on the development of organic semiconductor materials and devices.