Digitized photographs for illustrated computer output*

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INTRODUCTION

Much success has been achieved in the use of computers for the control and editing of various typesetting devices. At this Laboratory, similar techniques are employed in creating edited cathode-ray tube (CRT) output from information punched on Hollerith cards. Many internal documents are prepared by Xeroxing the reversed film from this output at a rate of around seventy frames per minute.

It was suggested that the preparation of Laboratory catalogs could be greatly facilitated by including in the system a file of digitized photographs. The catalog text together with edit information would be punched, taped and fed to a computer together with the tape file of digitized and labeled photographs. The editing routine would call for the needed photograph by label and position it in the text in a manner specified by the edit information. Because Xeroxing at this high rate was known to produce shifts in electrostatic charge with consequent information loss in the large dark areas, it was planned to use the Xerox output as proof only and to prepare the final copy from multilith masters made from the same film.

To establish the feasibility of such a system, a series of experimental programs were written. The first few were designed to digitize film at several emulsion density levels and to record the digital pattern on magnetic tape. The next few recreated the picture in three sizes on a larger computer equipped with a high speed CRT output. The last of the series added a few words of text to the recreated photograph output.

Photograph digitizing

The large amount of filmed analog data processed at this Laboratory led to the development of a computer controlled reading device. In its present state of a 5-inch CRT display, a beam splitting pellicle, and of evolution this device, called the eyeball, consists a pair of optical lenses, vacuum film holders, light condensing systems and photomultiplier tubes. These components are mounted on precision benches, housed in a darkroom and controlled remotely by a DEC PDP-1 computer ("Eyeball" - Film Reading System - Figure 1).

As may be seen in the figure, light from the CRT is split by the pellicle and directed toward both a primary and a reference photomultiplier tube. This light is focused against a film in the primary holder
and a neutral density filter or nothing in the reference holder. Light passing through is collected by each condenser for its respective photomultiplier.

Future plans call for the log-difference of the photomultipliers to be sampled by an analog to digital converter and made available to the computer program. It was originally planned that this scheme would be used to determine gray shades in the digitized film.

While technical difficulties with this plan are being looked into, gray scale determination is made by a programmatic variation in the beam intensity of the eyeball CRT. The photomultiplier outputs have been closely matched, so that for a single CRT beam intensity the eyeball output is a simple “yes - no,” reflecting the polarity of their difference. Eyeball sensitivity is a function of the high voltage to the photomultipliers and, more importantly, of the relative voltage between the two.

The CRT coordinates as well as the beam intensity are under program control. The eyeball CRT has 4096 by 4096 addressable points over a 3-inch square. Beam intensity is variable through eight equal voltage levels. For these experiments only five could be used satisfactorily.

The latest photograph digitizing routine follows the flow indicated in Figure 2. Once the operator has positioned a film and set the photomultiplier voltage to within a known tolerance, a programmed scan sweeps the entire face of the eyeball CRT. This and subsequent eyeball operations are visible to the operator on a 16-inch monitor CRT.

During the sweep a bit pattern of eyeball yes - no responses is stored in memory. The yesses are replayed for operator observation. The operator adjusts the reference with respect to the primary voltage until he is satisfied that the yesses cover what will be the reproduction’s darkest areas. (Because positives or negatives can be equally well used and can produce either positive or negative reproductions – polarity is unimportant, i.e., yes may be substituted for no, and lightest for darkest).

When the operator signals his satisfaction, the bit pattern is written as a single record on magnetic tape. The beam intensity is then reduced to the next lower level, the scan repeated, and the response pattern written as a second tape record. This sequence is repeated through the remainder of the lower beam intensities being used.

Resolution is necessarily dependent upon the mesh chosen for the programmed scan. A square array employing every sixteenth point was arrived at as a compromise between photographic detail on the one hand and time and storage on the other. It was found that the quality of the output picture was greatly improved by shifting the response pattern over and up fourth point. As on the scan, the playback pattern was shifted over and up for each subsequent record. At that time the reference coordinates were restored.

The computer time for digitizing a single film is less than a minute and can probably be reduced by a factor of two. The storage requirement is under a third of a million bits and can also be appreciably reduced by mapping out backgrounds or areas of no significance.

Photographic reconstruction

Although photographs were recreated for test purposes on the digitizing computer, plans for integrating the pictorial output with text made it advisable to use faster equipment with character generation capabilities included in the hardware. Accordingly, a CDC DD-80 was used for the output. It is interfaced to an IBM-7094 through a direct data channel.

For film recording, the DD-80 employs a 5-inch CRT with 1024 by 1024 points across a square a little under two and one-half inches on a side. Because there are four times as many points in both directions.
on the eyeball CRT, the reconstruction of film digitized at every sixteenth point is determined at every point. As on the scan, the playback pattern was shifted over and up for each subsequent record.

After commanding the plotting of a header frame and a film advance, the reconstruction program reads the digitized photograph from magnetic tape a record at a time. Following each read, all points corresponding to the pattern of yes responses are displayed. All records are displayed at a single intensity and on a single frame. The program uses less than 10 seconds of 7094 time.

Half and quarter size pictures were also recreated by displaying the response pattern with the increment between points reduced to two and one points respectively.

CONCLUSIONS

The experiments indicate the technical feasibility of including photographs with computer output. Some results are shown in Figures 4 through 6. Figure 3 is a print of the negative which was digitized for use in this paper. (The young lady is replacing the filter holder on the reference side of the eyeball.) Figure 4 is the Xerox output at full size. Figure 5 is a print made from the same DD-80 film. Figure 6 is a print made from a DD-80 film in which the text shown was included along with a half size reconstruction.

While a great deal of work is still to be done to achieve truly fine quality at low cost, the present output is satisfactory for many internal uses. It is probable that even a presentable Xerox copy may be attained by a proper prescreening of the negatives. The exaggerated flatness in shade is due largely to the use of an extremely high contrast film previously chosen for its good line reproduction characteristics.

To date, all negatives have been on 4" × 5" cut film. Plans in progress call for the use of 35 mm roll film. This change should eliminate most of the set up time without seriously affecting resolution.
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