AN ELECTRONIC PROCESS CAMERA

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Abstract

The Autokon* Electronic Process Camera is a flat-bed laser scanner-recorder widely used, particularly in the newspaper industry, to prepare original copy, both line art and continuous tone, for reproduction. It accepts opaque originals up to 12" wide by any length, and produces output on paper or film. It enlarges, reduces, reverses, makes halftones or line work, and performs a wide variety of additional "photographic" operations, including unsharp masking, all optically or electronically. Major design goals were low cost and ease of operation. It is also supplied with a computer interface so that it can be used as an input device for page composition or other image processing systems. As a computer output device, it can be used for proofing or, where its resolution of 722 pels/inch suffices, for final output. This paper discusses the major design decisions and their implementation.

The Autokon uses a common optical system for input and output. Four laser beams, from two (recently changed to one) lasers, are sinusoidally deflected by a galvanometer, using a grating reference system for geometrical accuracy in the scan direction. The scanning beams, sharp and unsharp, scan the original which is carried by a vacuum belt. The recording beam scans the output material as it passes over a synchronously-driven capstan, and the grating beam is used to produce a timing pulse train as it scans a glass grating. A phase-lock loop (PLL) produces a clock signal which is used to digitize the video signal and enter it into a buffer, in the scan cycle, and then to extract the data from the buffer and modulate the recording beam, in the record cycle. A second PLL controls the input copy speed using a digital tachometer. Anamorphic magnification is accomplished by varying the count-down ratio of

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the first PLL and the reference frequency of the second PLL, independently.

The unsharp beam is modulated at high frequency so that the sharp and unsharp signals can be separated in the video chain. A "highs" signal is formed for sharpening. Curve shape control is accomplished by analog circuitry, while half-tone generation is done by comparing the analog video signal with a screen reference signal retrieved from digital storage. Conventional, elliptical, straight line, mezzotint, pseudo-continuous tone, and other special screen patterns are available.

Introduction

The Autokon camera was conceived out of an effort to find new applications for the flat-bed laser scanner technology developed for the Associated Press Laserphoto* newspaper facsimile system(1) and the ECRM Autoreader* optical character recognition (OCR) machine. In the former case it had proven possible to replace obsolescent rotating-drum machines with a much smaller, more reliable, and easier to operate flat-bed laser scanner at about the same price. In the latter case six vidicon cameras were replaced by a single laser scanner, simultaneously improving reliability and reducing cost. A product which could be sold to the same newspaper market as the OCR was desired. Halftone generation seemed a possibility and an investigation was undertaken.

After some experimentation with exposing one dot at a time using shaped laser beams, it was concluded that it was preferable instead to delineate each dot precisely with a high resolution facsimile-type scan, in which case line work could also be done. By adding enlargement and reduction, all the principal functions of a process camera could be performed. At that point we addressed the question as to whether a laser/electronic process camera could be designed which would compete successfully with the conventional process camera. Eventually we found that it could, but along the way discovered that almost no one cared about the advanced technology under

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*Laserphoto is a trademark of the AP and Autoreader and Autokon are trademarks of ECRM, Inc.

the covers. What mattered in the marketplace was the image quality, the price, and the performance, and in the latter category, principally the speed and reliability. The operator, who was often a cameraman, the production manager, and the comptroller all had to be satisfied. Thus cost/effectiveness, reliability, and an attractive operator interface came to be the primary design goals.

Setting the Specifications

In a textbook-style new product development, the marketing department sets price and performance goals required for customer acceptability, and the engineering department predicts the cost and time of the development and the unit production cost. Even in a mature technology, both predictions involve a certain amount of uncertainty. In a rapidly-evolving technology, it is hardly clear at the outset whether such a totally new production tool will be bought at any price. From the engineering viewpoint, it is not known beforehand that such a machine can be made at all, and the cost predictions are largely guesswork. A management decision to embark on such a development must therefore be based on somewhat subjective judgments and the attendant risks must be accepted.

A conventional process camera is rather simple in principle. It tends, for good reason, to be large and to require a good deal of skill, dexterity, and even physical labor to operate. The screening method depends on the use of very high contrast photosensitive material which normally entails the use of a darkroom. Such a camera is very fast for some operations, such as simultaneous line copies of multiple subjects at the same magnification. Setup and processing time for more complicated operations is much longer. In the latter category are left-right and black-white reversals, anamorphic magnification, and unsharp masking. The electronic camera, on the other hand, is, above all, highly flexible. We elected, therefore, to compete by making it very easy for the operator to handle, in normal roomlight and in rapid sequence, a wide variety of complicated setups. Special pains were taken to insulate the operator from the inner workings of the machine.

He simply puts in the copy, operates knobs and switches, waits a short time, and then removes exposed material, in a cassette, and feeds it into a daylight-loading processor.

Once the broad outlines of the machine had been established and the technological feasibility of the various operations had been determined, final specifications were arrived at by surveying the picture-making needs of newspapers and the range of specifications available in existing conventional cameras. An important aim was to keep the price as low and the size as small as possible. As many features were included and as high a performance was attained as was consistent with these goals. Some features were made optional to keep the base price low. Unsharp masking, however, an unusual feature for a monochrome camera, was included in all machines even though it did increase the cost, because the quality improvement is so significant that it was thought that everyone would want it.

A highly important decision was the width limitation of 12 inches. This precludes full-page imagery but saves money and keeps the cabinet small. We had determined that virtually all potential users already had some kind of full-page machine, and that the proposed width would cover the vast majority of other picture-making requirements. As a web-fed machine, there is no limitation on copy length.

Throughput speed also has a substantial impact on cost. The basic machine architecture was chosen primarily on a cost basis, and within that constraint, the highest possible speed was achieved consistent with prudent design techniques. The speed was kept high enough so that the operator would not have a sense of a great deal of waiting time.

These consideration led to the following final specifications:

> Input: Continuous tone (contone) or line copy up to 12" wide by any length is accepted. Halftones up to 65 lpi can be reproduced very well as line copy and those of 100 lpi or over can be treated very well as contones and rescreened. (With some special care these

ranges can be extended.) Full density range output can be achieved, by tone scale manipulation, with input copy whose reflectance range is 25% or more of full scale.

Output: Output can be on almost any moderate contrast red-sensitive film or paper up to 12" wide by any length, in the form of 65, 85, or 100 line screens or line work, at five inches per minute. Standard screens have square dots at 50%; elliptical screens are available instead. Optional screens include straight lines and mezzotints of selectable coarseness. End-point dot sizes can be preselected to match any specific printing process.

Operator controls: Cropping is by means of cursors on the input copy table. Switches are used to specify the screening operation to be used, to select negative or positive output, right- or wrong-reading, and the degree of magnification from 5x down to 2x up, in steps of 1%, independently in each direction. Densitometer readings on the input copy are used to dial-set highlight and shadow endpoint reproduction; an independent midtone control is standard. Optional highlight and shadow contrast controls are available. Manual and optional automatic calibration against the densitometer is provided, as is an internal step wedge.

Technology Selection

General considerations regarding trade-offs in the design of laser scanners for the graphic arts can be found in (2) and (3). In the following section a more detailed treatment is given as to how these considerations relate to the electronic process camera.

Signal Processing

The most significant advantages of electronic over conventional cameras are due to the existence of the image information as an electrical signal which can easily be manipulated. Some manipulations can best be carried out in digital form and some in analog; the proper choice depends on the state of technology and the cost/availability of components at the time of design. In this case, the cost of video analog-to-digital converters (ADC's) was quite high so that it was elected to do much of the processing in analog form. Conversion to digital form is done only at the point where the output image, which can be represented by just one bit per element, is first produced.

Screening. The best electronic screening is done by comparison of the video signal with a dot pattern signal, recording a white picture element (pel) at points where the former is larger than the latter and vice versa, for a positive. This process is analogous to conventional screening. The required relative resolution of video and screen signals has been subject to much discussion.(4,5) In this case, no extra cost was entailed in making the two equal, which certainly gives the best results. Thus an independent comparison between an analog video signal and an analog screen signal, converted from digital data repetitively read from a small read-only memory, is made on each pel, the result of the comparison being stored in a buffer one scan line in length, as shown in Fig. 1.

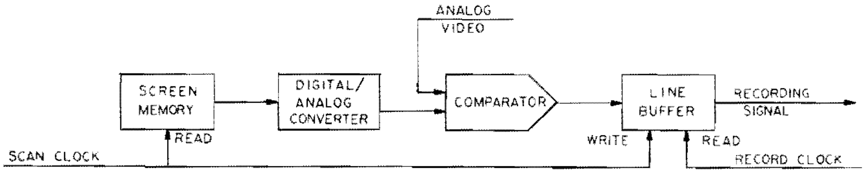

Fig. 1. Screening Method

Magnification. In the direction of copy motion, magnification is readily accomplished by using different web speeds for the input and output. In order to facilitate getting the correct spot size and exposure on the output medium, the speed and scanning standards of the latter are kept constant, the input speed and sampling density being varied for sizing. Synchronous drive is used for the output and servo-controlled drive for the input. The required 10:1 speed range is readily accomplished in such a loop without using a mechanical gear shift.

Tone reproduction. In order to avoid using an ADC, tone-scale control is accomplished in analog form. By simultaneously controlling the gain and offset of an amplifier, a signal level corresponding to a light tone (Dmin), dial-selected to be reproduced as a minimum dot, is set to a predetermined maximum voltage. A level corresponding to a dark tone (Dmax), to be reproduced as a maximum dot, is set to a predetermined minimum voltage, as shown in Fig. 2. The screen signal, which is similar to what would be obtained by scanning a contact screen, is adjusted in gain and offset, independently for each screen, to obtain the desired end-point dot sizes. Between the extreme levels of the controlled video signal, curve shape is adjusted by adding, more or less, positive or negative amounts of three waveforms, shown in Fig. 3, all of which are zero at the end points. In this way, highlight, midtone, and shadow reproduction is adjustable without affecting the extreme dot sizes.

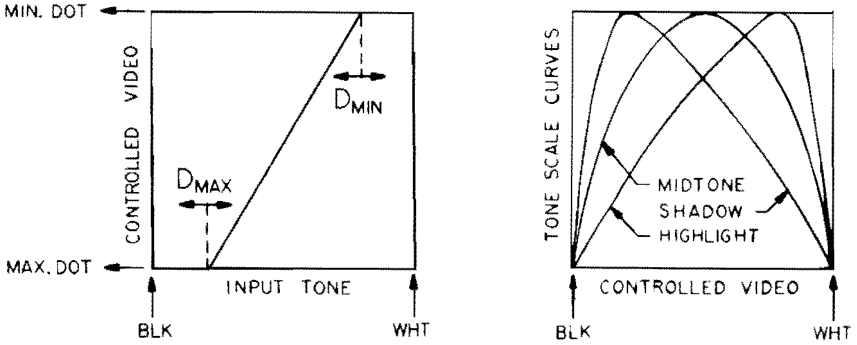

Fig. 2,3 Dynamic Range and Tone Scale Control

Sharpening. Isotropic emphasis of the high spatial frequencies is known to improve image quality greatly. It can be accomplished by two-dimensional signal processing, which eventually will become the method of choice as the cost of the required components continues to decrease. At the time of this design, optical methods were cheaper. Hence the copy is scanned with two colinear laser beams, one sharply focussed and the other about .05" in diameter and modulated at high frequency. An unsharp video signal, obtained by demodulation, is subtracted from the sharp, giving a "highs" signal which is added to the sharp signal to the degree desired, as shown in Fig. 4. It would be desirable to vary the diameter of the unsharp beam as a function of magnification, but this is costly. Similar results are obtained by adjusting the degree of sharpening, using more when minifying and less when enlarging.

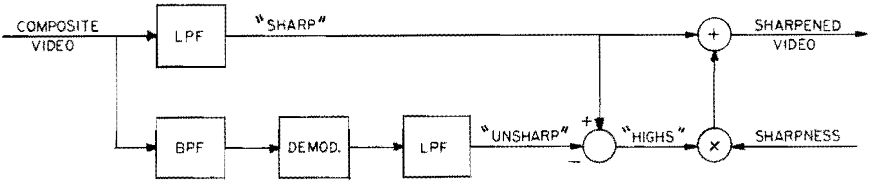

Fig. 4. Sharpening Method

Optical System

<u>Deflection</u>. Mechanical, i.e., moving mirror deflectors, are most practical for the speeds and resolution used here, although holographic deflectors may become the choice in the future.(6) Mirrors can be oscillated by galvanometers or rotated continuously by motors, generally in the form of multi-faceted spinners. The former are better for low-cost applications, but require scan-direction linearity control. The latter are superior for high-speed high duty cyle use, but require correction of line spacing errors due to wobble and spinner imperfections. In this case a combination of throughput speed and internal data rate was found which made the galvanometer practical.

<u>Focussing</u>. Flat-bed line scanners, in which the copy moves at right angles to the laser beam track, have clearly demonstrated their advantage with respect to both input and output copy drives. Flat, pasted-up material, very common in graphic arts work, can be inserted quickly and easily. The output material can be handled in roll form, being exposed as it passes over a capstan. The penalty for using this configuration is that the deflected beam must be kept in focus as it is deflected along a straight line. As shown in Fig. 5, this can be done either by pre-objective deflection using a wide-angle lens or post-

objective deflection coupled with a field-flattening element. The former procedure requires a more expensive objective lens, but is simpler and generally cheaper for resolution appropriate to newspaper practice.

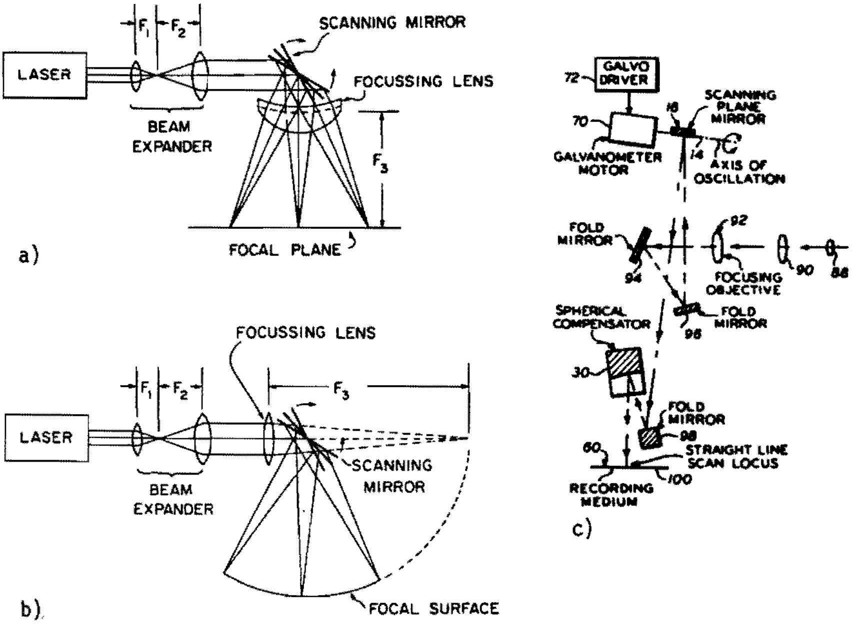

Fig. 5. Pre- and Post-objective Deflection
a) Pre-objective deflection with a flat field.
b) Post-objective deflection with a curved field
c) Field Flattener (USP 3,984,171)

<u>Modulation</u>. Mechanical, acousto-optical (AO), and electro-optical (EO) modulation are the possibilities, in order of speed and cost. In this case the AOM provides the needed bandwidth at considerably lower system cost than the EOM, which requires an expensive driver. However, the need to have a very small beam diameter at the AOM does complicate the optical design somewhat and makes adjustment more difficult both in the factory and in the field.

<u>Integrated scan/record optical system</u>. Considerable savings were found to be possible by using a common optical system for scan and record. The laser(s), objective lens, modulator, deflector, and many mechanical elements can be shared.

These savings must be traded off against the need to use the same scan angle for input and output, which eliminates the possibility of higher throughput by scanning just that portion of material to be used. More careful control of scattered light is also required, particularly since, with silver-based stock, the scan beam is normally much more intense than the recording beam.

The AOM, which is the most expensive component, is used to modulate the recording beam as well as the unsharp scanning beam. By scanning and recording line-sequentially, a single modulator can be shared. Scan-direction magnification requires video signal storage, in any event, in between scanning and recording. The galvo is particularly amenable to to-and-fro operation, scanning on the forward stroke and recording on the reverse stroke. The absolute geometry control obtained by the use of the reference grating makes it possible to achieve the required linearity. Ideally, one would prefer a linear sweep in both directions, since this would maximize the ratio of throughput speed to internal data rate. However, this is not possible with inexpensive galvos, so sinusoidal sweep is used. Existing machines utilize about 25% of each period for recording and 25% for scanning, but experimentally this has been raised to 35% or more.

The non-linear sweep requires exposure compensation for critical applications or if the duty cycle exceeds 25%. This has been accomplished by several techniques, including wedge filters, intensity modulation as a function of velocity, and by turning the recording beam on for a fixed short interval for each picture element.

Geometry Control

The precision required in the placement of each pel on the output copy depends on the application. Printed circuit art work is probably most demanding and monochrome halftones the least, with color separations somewhere in between. Since very accurate geometry can involve very high costs (as in rotating-drum color scanners), it is important to make sensible choices. In this case, the original application would have been satisfied with absolute accuracy of perhaps +/- .1" and relative accuracy just enough to eliminate visible defects such as banding. However, as in most other design choices, it was possible to find inexpensive solutions which gave much better performance.

Image geometry in the web motion direction depends on the relative velocity of input and output copy, while line spacing accuracy depends on the relationship between the line scan rate and the output material speed. Image geometry in the scan direction depends on the relative velocity of scan and record beams, while pel placement accuracy depends on the relation between the data flow and the deflection rate.

Input copy drive. The most precise method is the use of a rigid vacuum table in combination with a precision screw. This is not only expensive, it also requires that the copy be removed by the operator at the input station before a second item can be loaded. It is more convenient for the copy to pass through the machine, which is possible by the use of a vacuum belt drive. High absolute accuracy in the web direction is made possible by a digital tachometer, shown in Fig. 6, in which a pulse train from an optical disk on the motor shaft is compared in a phase-lock loop (PLL) with a signal counted down from a crystal oscillator. The phase error is amplified and applied to the servo motor, so that each revolution of the motor corresponds in time to an integral number of clock pulses. Relative accuracy depends on the reduction gears and on the belt uniformity. About +/- .003" is achieved.

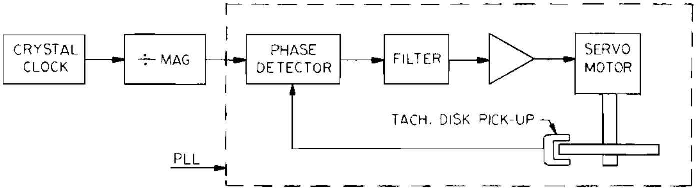

Fig. 6. Web-direction Magnification Control Using Phase-lock Loop

Output copy drive. This is different from the input drive, since the material is very uniform and in roll form. Spur or worm gear drive using a sychronous motor is satisfactory. The motor drive must be synchronized with the deflection, which is also synchronous in this case. In cases where the power line frequency is not sufficiently stable, an internal oscillator can be used.

<u>Scan linearity</u>. In the opinion of the author, the difficulty of achieving stable and sufficiently constant scan velocity for graphic arts work, by any known form of beam deflection, is so high that it should not be depended on to preserve image geometry or guarantee uniform pel placement. An alternative is to measure the beam position and adjust the data rate accordingly. (7) Since the magnification technique entails digital storage of the data in between scanning and recording, data-rate control involves little additional expense. Beam position measurement is accomplished by scanning a glass grating. The resultant pulse train is compared, in a PLL, with a second pulse train counted down from a voltage-controlled oscillator (VCO) which provides the clock which controls the rate at which data is written into and read from the buffer, as shown in Fig. 7. The phase error is used to control the VCO frequency in such a way that an exact number of clock pulses is produced for each grating bar.

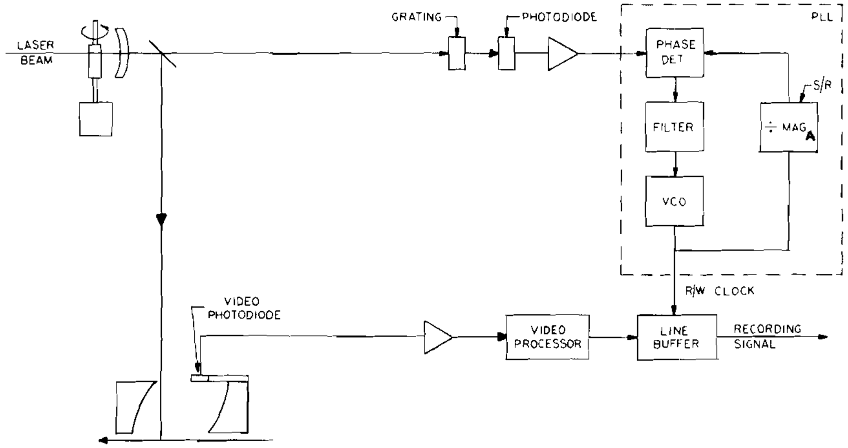

Fig. 7. Scan-direction Magnification Control with Reference Grating and Phase-lock Loop

While the grating system does add some cost, it results in an accuracy of a small fraction of a pel, essentially regardless of the variation of deflection velocity. In the Autokon, deflection is approximately sinusoidal, and yet the linearity achieved is nearly perfect. Lens distortion is eliminated as well, as would be the effect of motor hunting in a spinner system.

In the stand-alone machine, absolute sampling rate in either direction is irrelevant, so that the system is adjusted for correct output image geometry, taking into account paper shrinkage during processing. For computer input or output ("on-line" use) absolute sampling rate must be controlled. This can be done to an accuracy of about .1% by changing the path lengths between objective, grating, and copy plane by adjusting the positions of certain mirrors.

Skew and bow control. The record beam is on the optical axis and is sufficiently straight for all possible applications. Satisfactory squareness is achieved by adjustment of the galvo axis so that the laser beam track is accurately perpendicular to the web motion. In the integrated optical system, separation of the beams requires that the scan beam be several degrees off axis, resulting in a bow of about .025". While satifactory for stand-alone use, it is not adequate for computer input. This is corrected by means of an adjustable curved mirror, which makes the scan line straight to within one beam width.

Light Sensing. To avoid laser speckle and cut lines, from pasted-up copy, and to obtain the highest possible SNR for a given laser power, as much reflected light as possible must be collected, over the largest possible angle, as the copy is scanned. This can be done with the configuration of Fig. 7, 13, and 14. This makes use of a cylindrical reflector and a silicon photodiode strip. The scan line on the copy and the diode strip are placed at opposite focii of the elliptical cross section of the mirror. Specularly reflected light is ignored. Nevertheless, more than 50% of the reflected light falls on the diode. Note that this arrangement eliminates the photomultiplier tubes and fiber optic collection system often used in reflection copy scanners.

Since photodiodes so large have enormous capacitance, special preamplifiers having correspondingly low input impedance must be used to obtain the required bandwidth.

When the diode and mirror are properly adjusted, a uniformity of about +/- 10% is obtained across the page. For applications is which this is insufficient, an automatic calibration system has been developed which compensates the gain and offset of the amplifier at 100 or more points across the page. This is done while scanning a test chart, and also calibrates the front panel density control knobs against the densitometer used to measure the copy.

System Description

Mechanical

Overall layout. The main parts of the camera are shown in Fig. 8. The configuration is arranged for compactness, simple paper paths, and ease of operation. The original moves horizontally at table height from the input copy table to the receiving tray. The raw stock moves vertically from the supply cassette, located just inside the access door, over the drive capstan and into the receiving cassette on top of the scanner assembly. The signal-processing circuitry is located behind the control panel while the power electronics is in the pedestal. The optical system is in the scanner assembly and the paper drives are in the enclosure just behind it. The entire unit moves easily on casters through narrow doors, can be operated in any normal indoor environment, and needs no special installation.

Handling of originals. As shown in Fig. 9, the original is placed on the copy table with the left part over the vacuum belts. The portion of the image to be processed is framed by the cursors. In operation, the vacuum is first turned on, pulling the copy against the porous belts over the plenum. The belts then move the point on the copy indicated by the left cursor, rapidly to the scanning station, after which the servo motor moves the copy at a controlled speed, depending on the longitudinal magnification, to the point marked by the right cursor. Finally, the copy is moved rapidly to the output tray. The path is perfectly straight so that rigid and/or pasted-up copy can be used.

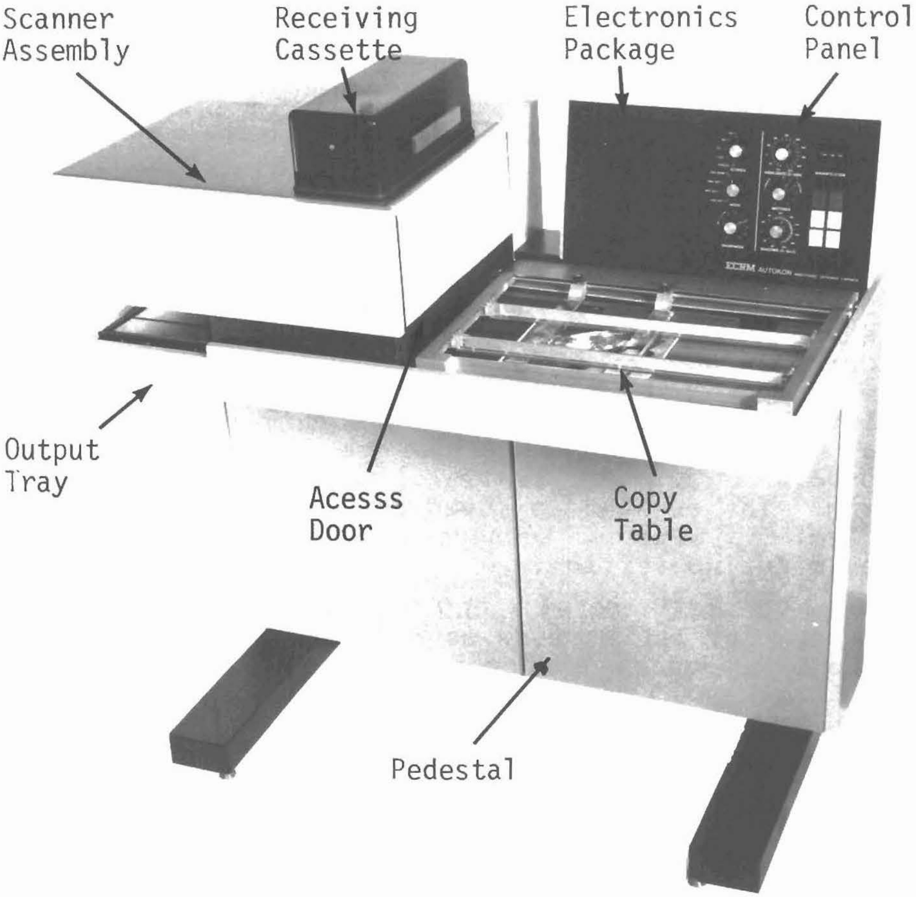

Fig. 8. General View of the Autokon Camera

Fig. 9. Cropping with the Cursors

Output material path. The raw stock is exposed as it passes at constant speed over a synchronous motor-driven capstan, as shown in Fig. 14. To minimize paper wastage during daylight loading and between separate pictures, the path between supply and receiving cassette is very short, particularly the distance from exposing station to cutter. A separate motor is used to quickly generate a trailer on the exposed material, before cutting, to facilitate loading into the processor. To save both paper and time, a number of pictures can be made in sequence before adding the trailer, cutting, and processing. The capstan is moved down for loading, which also facilitates focussing the recording laser beam during service.

Control panel and electronics package. Except for the cursors used for cropping, all controls necessary for operation are located on the control panel as shown in Fig. 10. Common controls used with every picture, i.e., magnification, tone scale, screen selector, mode selector (reverses, etc.), sharpness, and start/stop, are grouped together. Controls used less often are placed on an auxiliary panel behind a door. These include anamorphic magnification, special screens, calibration, cutter control, and a variety of special effects. In order to make the operation congenial to personnel of ordinary experience, all the controls are knobs or switches and, except for

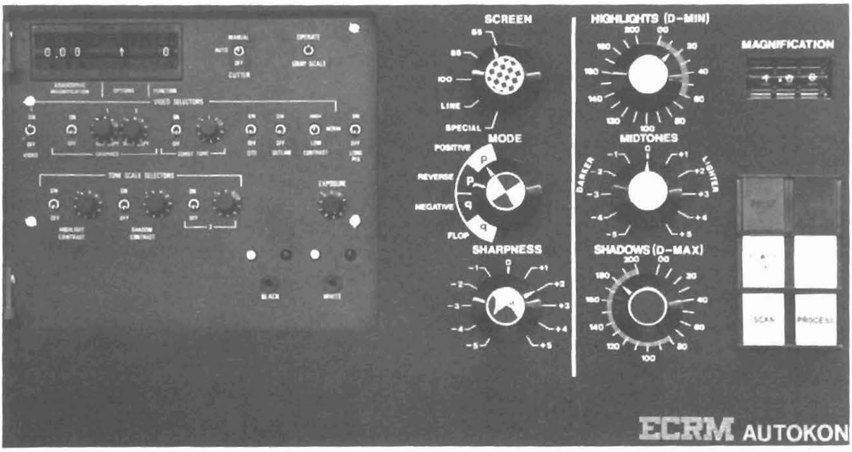

Fig. 10. Control Panel, Shown with Door of Auxiliary Control Panel Removed.

sharpness, pertain to and are labelled in the same manner as conventional camera functions. No video signals are present in the panel. Thus remote operation, as when used on line with a computer, is possible, in principle.

Signal-processing circuitry is packaged on a few large (9x15") boards in the assembly immediately behind the panel. All test points and adjustments are accessible through a cover at the top of the unit, without removing boards. To facilitate servicing and the use of options, any board can be used in any slot.

Optical

Beam layout. The recording density of 722 lines/in, required for producing 65, 85, and 100 line screens, determines the required spot size on the page, which in turn sets the f/ number in this diffraction-limited system. The video bandwidth establishes the required spot size within the AOM. The beam layout which meets these and other requirements is shown in Fig. 11. The sharp and unsharp scanning beams are combined at the aperture mirror, the center of which is focussed on the input copy.

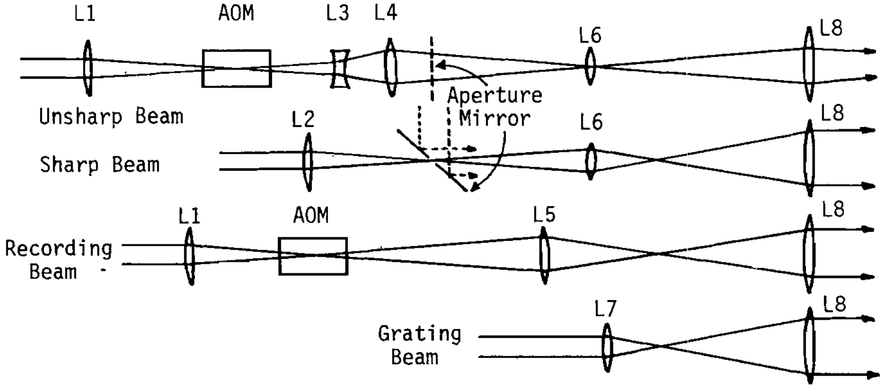

Fig. 11. Beam Layouts

Physical arrangement. The actual layout up to the galvo is shown in Fig. 12 (not to scale). The beam is modulated by a 2.5 MHz signal during the scan cycle and by the recording signal during the record cycle. The record beam is either on or off at each picture element (pel) since the output image is binary- either a halftone or a line copy.

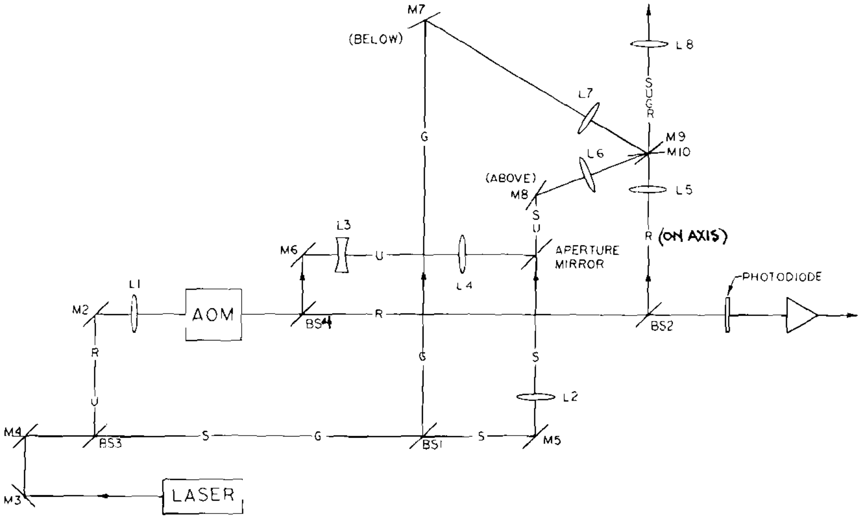

Fig. 12. Optical System, Before Galvo

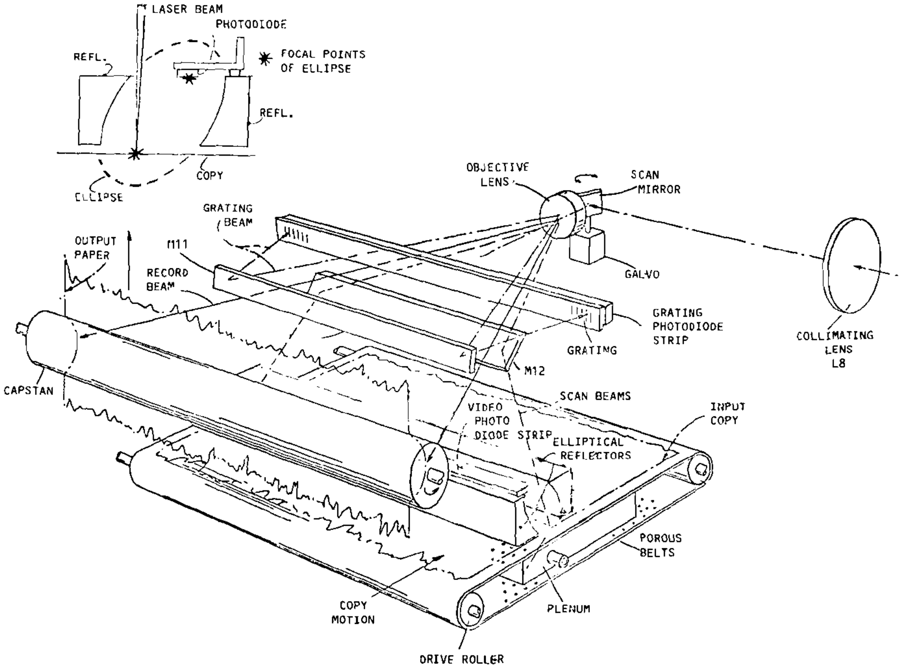

Fig. 13. Optical System, After Galvo

A 60 rps chopper (not shown) alternates the beams appropriately.

The laser is mounted under the single optical plate and all the other components are on top for easy accessibility. The beam is brought through the plate by M3 and M4 and divided by BS3. The grating (G) and sharp scanning (S) beams are transmitted and the recording (B) and unsharp scanning (U) beams are reflected. The former are split by BS1, and G is reflected to M7 just below the optical axis. S is transmitted by BS1 and reflected by M5 to M8, just above the axis. L8 is the common collimating lens for all beams. L7 and L8 form a beam expander for G. L2 focusses S in the center of the aperture mirror and L6 and L8 form a beam expander for S. L1 focusses the beam reflected by BS3 and M2 in the center of the AOM. The record beam (R) is transmitted by BS4 and reflected by BS2. On the optical axis, it is expanded by the combination of L5 and L8. A fraction of R transmitted by BS2 falls on a photodiode to be used for feedback control of the recording intensity. The unsharp scanning beam (U) is reflected by BS4 and M6 and expanded by L3 and L4. The aperture mirror, which of course does not affect S, is adjusted so that S and U are collinear. M9 and M10 are very small mirrors separated enough so that R passes between them. Thus all the beams are collimated, deflected, and focussed in common.

As shown in Figs. 13, the beams are separated after deflection by long mirrors M11 amd M12 so that S and U fall on the copy and G falls on the grating. Since these beams are slightly off-axis, their tracks are somewhat bowed. This has no effect on G, but in demanding applications, S and U can be straightened by imparting a small curvature to M12.

Electronic

A greatly simplified block diagram is shown in Fig.14. As is common in graphic arts electronic processing, providing for all the necessary functions and controls requires a rather complicated system which is costly to develop but cheap to manufacture.

Sequencing. This module controls the vacuum motor, the "fast-in" motor which moves the copy to the scan station and expels it when scanning is finished, the servo motor which moves the copy at controlled speed during scanning, the synchronous motor which moves the output material at fixed speed while recording, the "fast-out" motor which adds the trailer, the vacuum pump, and the cutter. It receives left (L) and right (R) voltages from the cursor assembly and print/stop signals from the control panel.

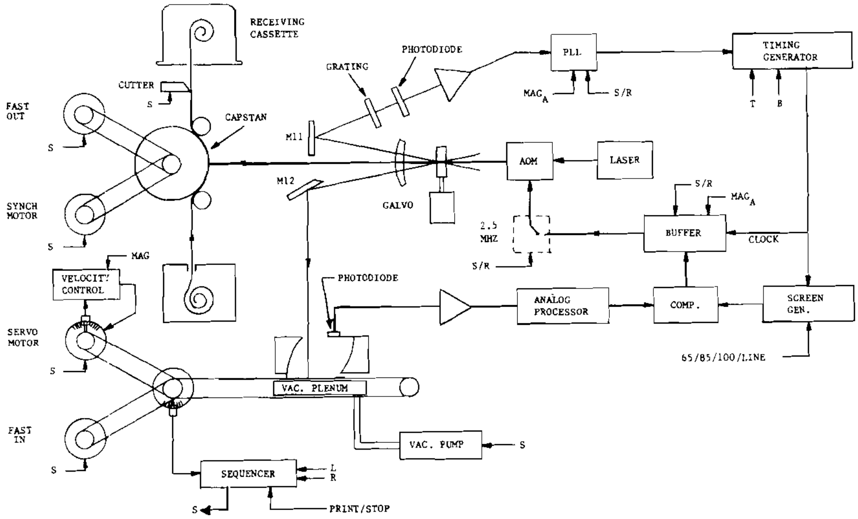

Fig. 14 Simplified Block Diagram

PLL, timing generator, and buffer. A long photodiode array receives light which passes throught the grating and feeds a preamplifier. After digitization of the grating signal, a PLL generates a high frequency clock. A density of 722xMa pels/in is used in the scan interval and 722 in the record interval to write/read data to/from the buffer, which can hold up to 8664 bits (12"x722 pels/in). These clocks, along with the top(T) and bottom(B) signals from the cursor, the magnification (Ma), and the sequencer, control the respective sampling densities and processing areas of the input and output pages.

Video processing and halftone dot generation. A second long photodiode array receives light reflected from the copy and supplies the input to a preamp. Its output is a composite video signal (sharp video plus unsharp video on a carrier) which is filtered in the analog processor to separate the sharp and unsharp signals. Their difference is the highs signal which is added to the sharp video in adjustable amounts for unsharp masking, i.e., sharpening. The Dmin and Dmax controls adjust the gain and offset of an amplifier (the gain also affects the highs) so that the selected light and dark tones on the input copy are processed into the minimum and maximum final video signals. The other tone scale controls shape the transfer characteristic, as desired, without affecting the endpoints.

The clocks are used to retrieve the screen signal, in digital form, from a small read-only memory. The retrieved signal is converted to analog form and compared with final video, the result being stored in the line buffer under clock control. Black/white inversion is accomplished by inverting the polarity of the buffer input and left/right inversion by controlling the incrementing of the write address counter. The clocks are timed in such a way that the output image is always centered on the page.

Operation

Persons familiar with densitometers can learn to use the Autokon to do line work and make "square" halftones with only brief instruction. No more than a few weeks are required to become an expert operator, especially for those with some background in photography. No electronics or computer knowledge is required at all. It does help to have some experience in evaluating photographs so that, if an unsatisfactory picture is produced, the direction and amount of required adjustment can be deduced without extensive trial and error.

Simple halftones. The highlight and shadow densities are read with a densitometer and set in on the Dmin and Dmax controls. The desired magnification is dialed in. The Midtone control is adjusted according to whether the picture is to be lightened or darkened, the screen count chosen, the Mode (positive, negative, reverse, etc.) chosen, and the sharpening set. Then the original is placed on the copy table and the area to be used delineated with the cursors. The Print button is pushed and processing is then completely automatic. A few seconds are required to move the original to the scan point, after which output is produced at 5"/min. When scanning is complete, the original is ejected, a trailer is put on the output material, and the cutter operates. The receiving cassette can then be removed for processing.

Simple Line work. The procedure is the same as above, but for good quality art, the Dmin and Dmax controls are simply set at 0 and 200 (i.e., 2.00 density), and the Midtones at zero. If the stroke thickness on the copy is too thick or thin, the Midtone control is adjusted accordingly. Sharpening is very helpful to the quality of line work. Poor quality originals sometimes require densitometry as for screen work.

Variations. Negatives and reverses are produced as fast as positives simply by setting the Mode switch. Anamorphic magnification, i.e., different scales in the two directions, is done by setting in the vertical magnification separately on the auxiliary control panel. Note that if the stretch is along a diagonal axis, slanted copy results; a table is available for producing the degree of slant desired. Posterization (quantized tone scale) is likewise available in a single step by switch selection, as is "Outlines", in which the highs signal only is converted into a line copy. Sometimes useful results can be produced by operating the Mode switch during scanning, or by using the first output as an input. A Graphics feature is available which, in one operation, converts the original to a line copy and then converts the resulting black and white tones to arbitrary dot percentages. A constant tone can be added to the entire tone scale, which, together with "Low Contrast" can be used to make low-key or high-key pictures. "High Contrast" can be used to cause highlights and/or shadows to go solid, i.e., to drop out or block up. Additional tone scale controls are available to change the tone separation in extreme highlights or shadows.

A number of special screens are optionally available. These are selected by setting "Special" on the main screen selector and then dialing the desired screen on the auxiliary panel. Straight line, mezzotint (random), and a "continuous tone" screen (one so fine that the image looks like a contone but usually is too fine for photomechanical reproduction), special counts (55, 75 lpi, etc.) and various special effects screens are available, again, all at the same speed as the standard screens. All the special screens can be enlarged by factors of 2, 4, and 8. In this way very coarse screens can be created for special effects, but, in addition, the minimum dot size can be set as needed for the printing process used. This is particularly important with the random screen.

Adjustment and calibration. An internal grey scale is provided which is useful in setting the exposure level of the output copy. Although the laser beam recording intensity is feedback controlled, exposure must be manually adjusted from time to time to account for the paper sensitivity and the state of the chemistry. The gain and offset in the video chain must also be adjusted to compensate for drift of the laser and circuitry. This is normally done by inserting a black and white chart of known density, setting in the density readings on the controls, and observing the indicator lights while making the adjustments. A completely automatic calibration system is available which does this at 100 or more points across the page while scanning a special calibration chart, not only calibrating the machine to the densitometer, but also assuring a degree of across-the-page uniformity otherwise very difficult to achieve with a flat-bed scanner.

Another kind of adjustment is needed when using the Autokon with a particular printing setup, as for example in a newspaper. In this case, the end-point dot sizes and the overall tone scale must be chosen so as to achieve the desired result on the printed page. Since dot size and tone scale tend to change, sometimes a great deal, in the many stages from Autokon output to press print, it is desirable to precompensate. This is normally done on installation, over a period of several days. Initially several subjects with different settings are printed and the best results selected by the customer. The process is repeated until satisfaction is achieved. Then the machine is adjusted to produce the desired end-point dots, and particular settings of the density controls are recommended. An optional feature called "Dial-a-dot" is available which guarantees the precise highlight and shadow dot sizes regardless of machine settings or image density.

Computer Interface

Although the Autokon was originally designed as a stand-alone machine, the essentially digital nature of its timing and control system simplified the development of a computer interface when it became evident that there was an increasing need for graphic input and output systems. What was particularly significant was the fact that page output data is stored in a buffer in between reading and writing. In addition, although the stand-alone machine is restricted to no more than 100-line screens, the analog video resolution, signal-to-noise ratio, and overall quality is fully adequate for any kind of monochrome printing. The specifications for the interface were developed largely out of our experience at MIT in developing image processing systems for facsimile and graphic arts applications. Four modes of operation are available.

Binary data input. Data at one bit/pel, produced by the Autokon in its normal manner, is collected into 8-bit bytes and stored in a buffer in the interface. This data can represent either line or halftone images, and the images can be produced exactly as if output were to be produced on the Autokon instead of being sent to the computer. (Actually, images can be printed out, if desired, simultaneously with computer input.) Subsampling by a factor up to 16 independently in each direction is possible. The interface buffer contents are sent to the computer main memory and then stored on disk or tape.

Contone data input. The analog final video signal is digitized at 8 bits/sample, and these 8-bit bytes are then handled exactly as line data, above. The sampling density can be as high as 700 per inch, and similar subsampling is possible. All of the Autokon's normal analog signal-processing capabilities are available.

Binary data output. Binary images, stored in the computer, representing either line or halftone images, or any combination thereof, such as fully composed pages, can be transmitted by the computer from disk to main memory and from there to the interface buffer, from which they are read and printed out in the normal manner. In this operation, the Autokon is acting as a simple printing engine, except that each bit can be repeated on the page up to 16 times, independently in the two directions. The Mode switch can also be used to produce left/right or black/white reversals.

Contone data output. Data representing continuous tone images at 8 bits/sample can be transmitted by the computer in a similar manner as binary data, above. In this case conversion to halftones is required for printout. The conversion process uses the standard 65, 85, or 100 line screens, but the screening operation is carried out digitally, in real time during the output process.

Input-only machine. Because of the expressed desire to have a less expensive scanner solely for input of graphic copy to computer systems, The Autokon 8200 was recently introduced. It has nearly all the features of the standard 8400, but for computer input only. Actually, many users prefer to use the original 8400 as an input machine, since it is often convenient to perform some preliminary camera work on the copy before input to the computer and because with appropriate tone-scale precompensation, the 8400 ouput print can serve as an accurate proof.

Speed in the on-line mode. For computer systems of the PDP-11 class, speed is generally limited by the computer, its peripherals, or bus contention, and not the Autokon. Two buffers of 4096 bytes each are provided in the interface, one section exchanging data with the Autokon while the other exhanges data with main memory via a DMA interface. Thus at maximum contone data rate, 4096 bytes must be transmitted on each of 60 scan lines per second, through the bus to main memory and again through the bus to disk. This data rate leaves very little time for anything else which may be going on at the same time. For situations where there is not enough capacity to absorb the maximum flow of data from the Autokon, the rate can be decreased by slowing the input copy speed and subsampling on a scan line basis. Since the output web speed is not adjustable and lines cannot be skipped while recording, the computer either must supply data fast enough to keep up or else the resolution must be lowered by pel and/or line repetition.

The Autokon scans at 60 lines/sec, and since the output resolution is 722 lines/inch, the web speed is 5"/min. For computer input of contone data, a resolution of more than 250 lines/inch is rarely required, so that the input speed is generally much higher than in the stand-alone mode. For example, a typical magazine page to be printed by gravure is scanned in less than one minute, while an 8" high facsimile page is input in 20 seconds at 150 lines/inch. On the other hand, for transmitting line data at the maximum resolution of 1444 lines/inch, the web speed slows to 2 1/2 "/min while the average data rate is no more than 17,328 bits every 1/60 second.

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