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SURVEY OF DIGITAL IMAGE SCANNING SYSTEMS.(U)
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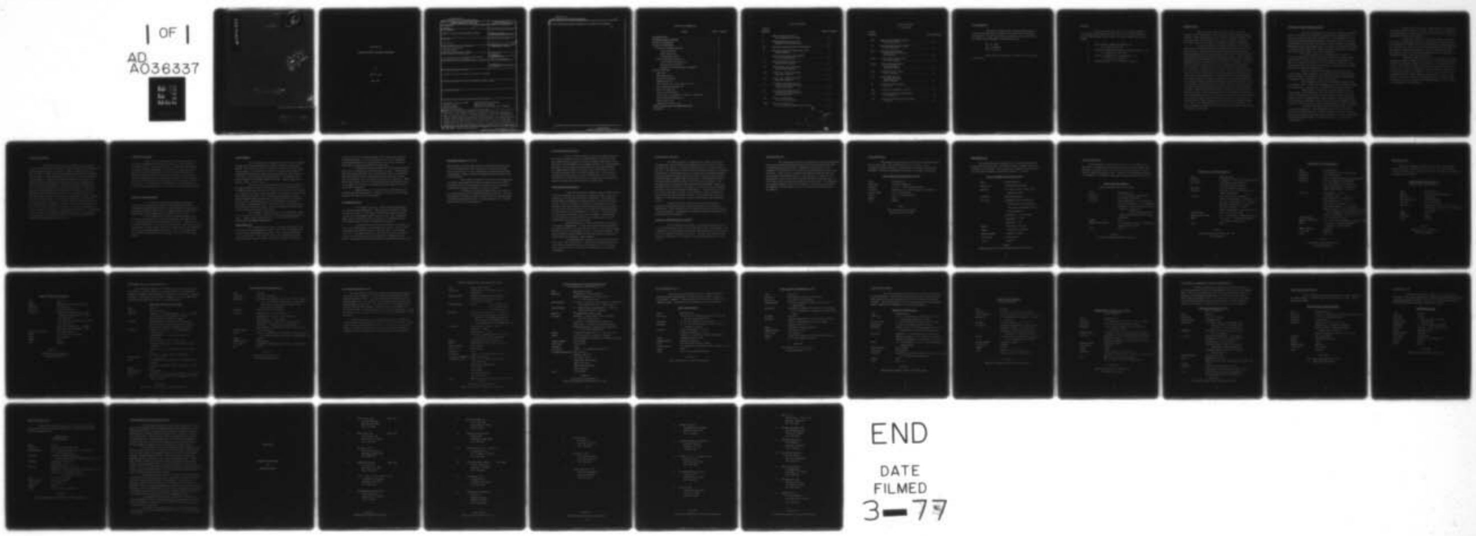

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SURVEY OF

DIGITAL IMAGE SCANNING SYSTEMS

by

M. M. Irvin

June 1976

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Electronic Scanning Systems
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Flying Spot Scanners
Flat Bed Microdensitometers
Rotating Drum Scanners
Rotating or Oscillating Mirror Systems

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report investigates currently available devices which digitize data from film to use as input to a digital computer. The report describes the general specifications for a scanning/digitizing system and describes the various available devices which meet the requirements. The report found that vidicon camera systems were the lowest cost scanners and the flying spot scanners were the most expensive. The most precise instrument, and the most expensive, is the flat bed microdensitometer. In conclusion, the application scenario must be known and the requirements carefully evaluated before any

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) of the digitizing systems described in the report are selected.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES
(Continued)

Acknowledgment

The survey of digital image scanning systems reported herein was performed at the request of the Engineering Topographic Laboratories. The personnel having cognizance over the effort from the Engineering Topographic Laboratories include:

Mr. W. Boge
Mr. L. Gambino
Dr. B. Schrock

The writer was assisted by C. Patterson in the conduct of the survey.

Forward

The survey reported herein is one of a series prepared for the Engineering Topographic Laboratory as an aid in the development of a major digital image facility. The other volumes in the series include:

1. "ETL Computer Optimization Study", by D. J. Theis, June 1976
2. "Survey of Digital Image Display Systems (Soft Copy)", by C. L. Patterson, June 1976
3. "Survey of Display Devices (Hard Copy)", by C. L. Patterson, June 1976
4. "Software Studies", by G. Buechler, June 1976

INTRODUCTION

This survey was undertaken to investigate currently available devices which digitize data from film to use as input to a digital computer. While much imagery may already be available in digital form, film may contain collateral data, such as maps, graphics or imagery from other sources, which must be compared with primary digital data.

In order to obtain pictorial data in digital form, an analog signal must be generated which is proportioned to the transmissive variations in a film. The analog signal is then sampled and quantized into discrete digital values for use as computer input. There are several types of scanning systems which can perform the desired task. Each scanning technique has its own capabilities and limitations which must be considered, depending upon the task which must be performed. In general, trade-offs must be made between the precision of the output data and the speed of data acquisition. Existing systems with the highest turn-around times do not provide the highest geometric accuracy or image density resolution; conversely, those with precision mensuration and gray-scale sensitivity suffer from low speed limitations. The prospective user must determine the relative importance of these parameters for his specific application. For example, maps and graphics generally have limited gray-scale content, so that density resolution may be of limited importance, while comparison of collateral imagery may require higher precision in measuring density variation. Mensuration precision may be required for precise location of details in a scene, but for many applications, exact positional information may be unimportant. Speed requirements vary greatly; a production facility may require the digitization of large amounts of data in a day, while in a research and development application speed may not be considered important. This report attempts to describe the general specifications for a scanning/digitizing system and to indicate how the various available devices meet these requirements.

GENERAL SYSTEMS SPECIFICATIONS

An ideal image digitization instrument would provide infinite geometric and gray-scale resolution, along with high scanning speed, to exactly reproduce this film data in digital form. Unfortunately, there are theoretical and technological limitations to building a scanner. Practical system designs involve trade-offs between various realistic requirements, depending upon the desired application. These general requirements include resolution, aperture/spot size, sampling criteria, quantization, linearity and orthogonality, signal to noise ratio, and speed.

The resolving power of a system should be equal to or greater than half the size of the smallest resolvable objects on the input film; thus the collateral film size should be known before determining what the resolution requirements are for a particular application. Resolution is generally specified in terms of lines or line pairs per unit length which may be separately distinguished.

Aperture or spot size and shapes are also film size as well as image content dependent. The aperture should be small enough to permit resolution of fine details in the film while collecting enough light to minimize noise and random variation in the signal.

The sampling criteria are not necessarily dependent upon the aperture criteria. The Nyquist ampling rate must be considered within the constraints of a possible loss of bandwidth due to aperture effects.

Quantization levels must be consistent with the overall density range of the input films. Since bit contouring which can cause a visible mottling effect in an image, is generally unacceptable, the total number of bits for sampling must be large enough to minimize this effect. It is generally accepted that at least six bits (64 levels) of intensity quantization is necessary for an acceptable representation of a gray-scale image.

Linearity and orthogonality are important considerations for geometric precision. The orthogonality of the scan axes must be precise to eliminate skewing or warping of the scanned image. Linearity precision is required to maintain proper resolution. Accurate mensuration tasks, such as map-making, require high geometric accuracy from a scanning device.

Inherent in all of the above requirements is a consideration of the signal-to-noise ratio of the system. Effects which are dependent upon this parameter include edge blurring, positional accuracy amplitude degradation and gray scale rendition.

Speed requirements are another parameter which must be given careful consideration relative to the operational needs of the user. A production-type facility will need a scanner which can digitize images at a very high rate, while in a research and development environment the speed may be relatively unimportant. Since the signal-to-noise ratio generally decreases with increasing throughput speed, the operating conditions must influence this trade-off decision.

Additional considerations for a system include color scan capability if collateral imagery is on color film. Since information differs between spectral bands, comparison between color information may be of value. The ability to digitize from an opaque sample may also be important, since creation of a transparency may modify the image data to an unacceptable degree. In addition, a scanner must be capable of discriminating a density range compatible with the density range of input images. If the film contains a wide density range (over 4 density units), the system may require cooling for the photomultiplier in order to minimize thermal noise in this detector.

SURVEY TECHNIQUE

The initial step in the survey of digital scanning systems involved researching various technical journals to determine manufacturers of instruments which might be of interest. This resulted in a list of more than 75 firms. Because of this large number and limited time constraints, it was decided to contact only those most likely to meet the requirements considered above. Written and telephone requests for information were made of sixteen of these firms; some data was already available in our files from four other companies. Brochures and system descriptions were received from twelve of the contacted companies, one firm was no longer in the microdensitometer business, one company verbally stated they had no applicable instrument, while three firms failed to follow through on their promise of documentation. Of the fifteen firms considered for the following summary, it was determined that three of these did not build an instrument of interest. A detailed analysis of data available from the remaining twelve companies was made. No on-site investigations of devices was made because direct observation of the various instruments was not considered necessary for evaluation and comparison . The appendix contains a list of the companies considered in the survey. Also included in the appendix is a list of firms which were not contacted but probably should be surveyed sometime in the future.

TYPES OF SCANNERS

There are two basic groups of instruments being manufactured for digitization of film data, electronic scanners and electro-mechanical devices. All of these operate in a beam addressable raster scan mode. Matrix addressable scan systems are a potential for the future, utilizing solid state devices, but are not currently available. Electronic scanners on the market may use cathode ray tube devices, vidicons, image dissectors, or flying spot scanners. Electro-mechanical systems include flat-bed microdensitometers, rotating drum scanners, and rotating or oscillating mirror instruments. A brief discussion of each of the basic scanning devices is included in the following paragraphs.

Electronic Scanning Systems

In electronic scanning systems, light transmitted or reflected from an image is projected onto a photosensitive surface. Variations in light intensity generate a current signal which is processed and passed through an A/D converter for digital storage. Useful film density range of these instruments is limited to about 0-2.5D.

Some limitations of electronic scanning systems involve problems of beam defocus over the flat image plane, pincushion distortion, spot halo and relatively low signal-to-noise ratio. In general, the linearity is limited to 1 - 2 percent. Resolving power of this type of system is generally lower than with an electro-mechanical device as the signal-to-noise ratio is generally significantly lower. However, the digitization speed of these instruments can be very high, up to several frames per minute.

Vidicon Systems

In a vidicon system, the light reflected from or transmitted through a film sample impinges upon the photoconductive target of the vidicon. The variation in the local charge concentration due to the image on this surface is converted into an electrical voltage (video signal) by repeatedly scanning with an exploring spot formed by the electron beam of the tube. This signal is transmitted through a video amplifier and signal conditioner to a sampler/digitizer system. Digital image size is limited to 1200 - 1500 TV lines.

There are several limitations inherent to vidicon systems. The photoconductive surface is, in general, not of constant thickness. Variations of this type cause an effect known as the coherent noise problem, i.e., the signal will vary in the same manner from frame to frame according to geometric position. Also, because the photoconductive surface does not instantaneously discharge the current produced by the exploring electron beam, charge storage increases the signal-to-noise ratio of the system. Beam landing error, an effect due to the variation in shape of the spot due to deflection angle, causes a varying geometric distortion which is largest at the edges of the image.

An advantage of vidicon systems is high digitization speeds of a few seconds per frame, which may be needed in a production environment. Typical vidicon scanning systems are manufactured by EMR Photoelectric and Spatial Data Systems.

Image Dissectors

In an image dissector system, an image is projected from a film sample on a photoemissive surface. Electrons are emitted from the back of the photocathode in proportion to the varying light intensity of the optical image. These electrons are accelerated through a high potential toward an aperture plate. The "electron image" is positioned by deflection coils so that any small part of the image may be passed through this aperture. The resulting aperture current is amplified, integrated and digitized for a given position. Successive deflections may produce a raster scan pattern over the image.

Resolution of the image dissector is determined primarily by the electron aperture and associated electron optics. Digital image sizes from image dissector devices found in this survey are limited to 4096 pixels square or less. Resolution is higher than with a Vidicon tube but is limited, e.g., less than 20 line pairs per millimeter. Digitization speed varies; for a 512 x 512 pixel image the time ranges from a few seconds to five minutes, depending on integration time selected by operational constraints.

DBA Systems Inc., Dicomed Corp., EMR Photoelectric and Photo Digitizing Systems Inc. manufacture devices using the image dissector as a detector/scan mechanism.

Flying Spot Scanners

In a flying spot scanner, a CRT provides the light spot for scanning a film transparency. The film may be mounted in contact with the tube surface, or the image of the CRT spot may be optically focused onto a film sample away from this surface. The transmitted light from the scanned film is then focused onto a photodetector and the resulting electrical signal is sampled and quantized.

Flying spot scanners have the advantage of very high scan rates. The systems have various limitations, however. For one, the spot shape varies with the location in the scan, due to beam landing error, i.e., the angular deflection of the beam causes the spot shape to vary from circular at the center of the CRT to ellipsoidal at the edges. To minimize this error, the deflection angle should be kept small.

Flying Spot Scanners (continued)

The linearity of a flying spot scanner is usually limited to about 2%; correction techniques to improve this factor to about 0.05% exist, as are corrections for focus, astigmatism and pincushion distortion. Incorporation of these correction techniques increases costs as well as performance.

There may be a limitation to the size of film which may be scanned, particularly if the film is mounted on the tube surface. An optical system for projecting the spot onto a film sample may be complex and costly but does allow for larger film sizes.

In summary, flying spot scanners may vary widely in price depending on the care and quality put into the device. The only instruments of this type encountered in this survey are manufactured by Information International, Inc. These systems are of very high quality, and are also very expensive.

Electro-Mechanical Scanners

Electro-mechanical devices utilize dual optical systems. The illuminating optics focus a regulated light beam upon the sample film, while the pick-up optics focus the transmitted light (from a transparency) or reflected light (from an opaque sample) onto a photomultiplier tube whose current output is proportional to the input light intensity. The output signal is amplified, sampled, and passed through an A/D converter in preparation for storage in digital form. These systems provide high quality imagery, but speed of digitization is slow relative to CRT devices. This slow speed may be an advantage for high density imagery as density is a direct function of exposure time.

Flat Bed Microdensitometers

A flat bed scanner has a stationary optical system through which the image plane is moved on two orthogonal stages. The film is mounted on a precise flat glass platen in this plane. The stages are moved, using a stepping motor or high speed servo motor-driven lead-screws. X and Y coordinate increments are controlled by encoders attached to the stages, which provides high positional accuracy (within a few microns over several inches), and excellent resolution (typically several hundred lines per millimeter). In general, a wide assortment of scanning aperture shapes and sizes are available. Digital image sizes may be precisely selected and large sampling matrices (up to 200,000 pixels square) may be generated.

The main drawback of these instruments is a limitation in the speed of digitization. A typical instrument takes approximately ten minutes to digitize a 35 mm film frame into a 512 x 512 pixel image. this slow speed is an advantage, however, in high density images. The longer integration time available increases the density range of these instruments up to, typically, 0-4D or higher.

Firms manufacturing precision flat bed systems include GCA Corp., Marco Scientific Inc., Optronics International and Perkin Elmer Corp. Photometrics Inc. also manufactures a low cost (and lower precision) flat bed raster scanner mainly used for biomedical applications.

Rotating Drum Scanners

The optical system of a rotating drum scanner is located on a C-shaped carriage assembly through which the drum rotates at several revolutions per second. The film is mounted securely to the perimeter of the drum. The light source focused on the film may be coherent or incoherent. Film density or transmission values are measured at preselected sampling intervals along the circumference of the drum. Once each revolution the optical carriage is stepped in the axial direction. Rotating drum systems are positionally accurate to within a few microns per centimeter. The resolution is not as precise as with flat-bed type instruments. Apertures are usually limited to three or four square or circular sizes and sampling matrices to ten or twenty thousand pixels square. Generally the scan area may only be designated to within a few millimeters, so that output image sizes can only be approximately selected. It takes about five minutes to digitize a 35 mm film frame into an image approximately 700 x 480 pixels in size.

Typical example of rotating drum scanners utilizing an incoherent light source are built by Marco Scientific Inc. and Optronics International. CBS Labs built a laser rotating drum system which is in use in several facilities. Unfortunately, production of this coherent light source device has been discontinued.

Rotating or Oscillating Mirror Systems

Mirror systems utilize either a rotating, multifaceted mirror or an oscillating flat mirror to move a light beam across a film sample. The transmitted or reflected light is focused on a photomultiplier and the current signal is amplified, sampled and digitized. The light source may be either coherent or incoherent. No scanners of this type were discovered in this survey.

SURVEY RESULTS

The results of this survey are summarized in the following pages. The various instruments manufactured by each firm are summarized and various specifications are listed. Comparable specifications are not available for all devices due to limitations in the manufacturers' descriptive literature. It was found, for example, that signal-to-noise ratio data are only available on electronic devices. Cost figures are, in general, only approximate values, due to various options available on many devices. In some cases, price data were not given by the manufacturer. The addresses and telephone numbers of the firms considered in this survey are listed in the appendix for those who desire more detailed information about any of the systems.

CBS Laboratories

CBS designed and manufactured the only laser scanning system found in this survey. The following data are in our files. It is a rotating drum type of scanner; no information on computer interfaces was available. It has been learned that this device is no longer in production.

Laser Image Processing Scanner (LIPS)

Type:	Rotating drum
Film Size:	70 x 100 millimeters
Aperture:	1.25, 2.5, 5.00 micrometer spot
Accuracy:	Resolution - up to 300 line pairs per millimeter
Density Range:	0-2.56 density units
Speed:	4 1/2 - 18 minutes/frame
Output:	8 bits
Cost:	$300 K

Table I

CBS Laboratories Laser Image
Processing Scanner (LIPS)

DBA Systems Inc.

The information on the image dissector scanner manufactured by this firm was in our files. The data was rather limited, and no cost information was available. The instrument is designed for use with user specified optics and uses a Varian 620L computer for control.

Series 104 Digitally Controlled Scanner

Type:	Image Dissector
Scan Area:	43 millimeters diameter
Aperture:	0.75 mil circular, effective size depends on optics
Scan Size:	4096 x 4096 pixels
Accuracy:	Modulation Transfer Function — 20 line pairs per millimeter at 50% relative amplitude (18 micrometer aperture)
	Resolution - > 700 TV lines
	Uniformity - ± 20%
	Distortion - 2%
Speed:	10^6 points per second
Output:	6 bits (8 bits available)
Opaque Sample:	Available as option
Color Scan:	Not available
Cost:	Unknown

Table II

DBA Systems Inc. Series 104 Digitally Controlled Scanner

Dicomed Corporation

Several models of image dissector scanners are available from this firm. They include a basic model which has no optics or light source provided, two models which scan 35 mm and 70 mm film and one model which can digitize larger film areas. Interfaces to most digital computers are available: no controller or tape unit is provided with the instruments.

Model 50B Image Digitizer

(Optics and light source not provided)

Type:	Image Dissector
Scan Area:	0.8 x 0.8 inches at photocathode
Scan Size:	Up to 2048 x 2048 pixels
Accuracy:	Scan Nonlinearity $\pm$ 1.5% maximum Scan Line Curvature $\pm$ 0.2% maximum Resolution - 1400 TV lines per inch at center of scanned area - 1200 TV lines per inch at edge of scanned area (at 50% relative amplitude)
Output:	8 bits
Signal to Noise Ratio:	24 - 42 decibels nominal, depending on point integrate time
Cost:	$25.5 K

Table III
Dicomed Corporation Model 50B Digitizer

Models D55, D56 Image Digitizers

Type:	Image Dissector
Film Size:	35 millimeter (D55) or 70 millimeter (D56)
Scan Area:	36 millimeter square (D55) or 54 millimeter square(D 56)
Aperture:	.0005 inch diameter (typical)
Scan Size:	256 x 256, 512 x 512, 1024 x 1024, or 2048 x 2048 pixels
Accuracy:	Scan nonlinearity - less than 1%
	Position repeatability - less than one pixel
	Scan axis orthogonality - ± 0.5% degree
	Rotational alignment - ± 0.5 degree
	Scan line curvature - < 0.15%
	Density repeatability - less than one in 64
Density Range:	0.05 - 2.45 density units
Signal-to-Noise Ratio:	23.4 - 41.6 decibels, depending on speed
Speed:	2.3 seconds - 91 minutes depending on scan matrix speed setting
Cost:	$44 K

Table IV

Dicomed Corporation Models D55, D56
Image Digitizers

Model D57C Color Image Digitizer

Type:	Image Dissector
Film Size:	Accommodates up to 24 inches wide
Scan Area:	57 x 57 millimeter
Apertures:	.0005 or .001 inch diameter aperture plates
Scan Size:	256 x 256 samples every 8th pixel
	512 x 512 samples every 4th pixel
	1024 x 1024 samples every 2nd pixel
	2048 x 2048 samples every pixel
Accuracy:	Orthogonality - ± 0.5%
	Scan line curvature - ± 0.2%
	Scan nonlinearity - less than 1.5%
	Scan position drift - ± 0.1%
	Scan position color shift - ± 0.15%
	Rotational alignment - ± 0.5 degrees
	Signal resolution - 1220 TV lines/inch at 50% relative amplitude at photocathode surface
	Density repeatability - less than one in 64
Density Range:	0.05 - 2.45 density units
Signal to Noise Ratio:	37 - 42.5 decibels, depending on speed setting
Speed:	3 seconds - 90 minutes depending on matrix size, speed setting
Opaque Sample:	Standard
Color Scan:	Standard
Cost:	$55 - 65 K

Table V

Dicomed Corporation Model D57C
Color Image Digitizer

EMR Photoelectric

This firm manufactures both a vidicon system and an image dissector system. The data sheets were in our files. The image dissector uses a PDP 8 as a controller; the vidicon controller is not specified. Cost data was not available.

Model 658 Optical Data Digitizer
(Tentative Data, dated April 1972)

Type:	Image Dissector
Optics:	Specified or provided by user
Film Size:	35 millimeter
Scan Matrix Size:	4096 x 4096 pixels
Aperture:	0.75 mil standard
Accuracy:	Addressing accuracy - 0.5% of field
	Uniformity across field - $\pm$ 15% absolute
Color:	Not available
Output:	8 bits
Controller:	PDP 8
Cost:	Unknown

Table VI

EMR Photoelectric Model 658
Optical Data Digitizer

Model 659 Optical Data Digitizer

Type:	Vidicon
Optics:	Specified or provided by customer
Film Size:	35 millimeter
Scan Area:	28 x 28 millimeter
Accuracy:	Modulation transfer function - 50% amplitude response at 13 TV lines per millimeter 5% amplitude response at 44 TV lines per millimeter Data point repeatability .2% RMS Linearity and Orthogonality ± 2%
Signal-to-Noise Ratio:	36 decibels (peak)
Speed:	16 - 32 seconds per frame
Color:	Not available
Output:	8 bits
Cost:	Unknown

Table VII

EMR Photoelectric Model 659
Optical Data Digitizer

GCA Corporation - D. W. Mann Co. Div.

This company manufactures two models of precision flat-bed microdensitometer. The basic model is an analog readout system with digital output and computer control available to a PDP 11/05 or equivalent computer as options. The deluxe system includes computer control by a PDP 11/05 and rotatable dual bilateral slit jaws as standard features.

	Mann Type 1140 Microdensitometer
Type:	Flat bed
Film Size:	Up to 4 x 10 inch
Apertures:	Fixed slit, as specified by user, from 1 x 24000 micrometer to 3000 x 24000 micrometer
	(other apertures available as options)
Sampling:	Selectable from 1 micrometer in X direction
	In the standard system Y axis motion is manual;
	Y axis servo system is available as an option
Accuracy:	Straightness of travel - ± 5 micrometers over 10 inch stage
	Orthogonality - ± 5 seconds of arc over 10 inch stage
	Density stability - ≤ 0.01 density units
	Positional repeatability - 1 micrometer per 100 millimeters
	Stage flatness - ± 0.0002 inches over measuring area
	Resolution - 250 line pairs per millimeter
Density Range:	0 - 5 density units
Speed:	.025 millimeters per minute to 25 millimeters per minute
	(maximum rate equal to 2000 samples per second)
Output:	10 bits
Opaque Sample:	Not available
Color Scan:	Available as custom engineered option (cost unknown)
Cost:	$60 K (without digital control and readout or Y axis servo control)

Table VIII

GCA Corp. - Mann Type 1140 Microdensitometer

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Mann Type 2832 Microdensitometer

Type:	Flat bed
Film Size:	Up to 10 x 10 inches
Apertures:	Adjustable and rotatable slits from 1 x 50 micrometers to 3 x 24 millimeters, fixed slits, fixed circular apertures, circular spot (microspot - "few micrometers in diameter")
Sampling:	Selectable from 1 micrometer
Accuracy:	Orthogonality - ± 5 seconds of arc Straightness of travel - ± 2 micrometers Repeatability - ± 1 micrometer Density stability - less than ± 0.01 density units Resolution - >250 line pairs per millimeter Stage flatness - ± 0.0002 inches over measuring area
Density Range:	0 - 5 density units
Speed:	From .125 millimeters per minute to 1250 millimeters per minute (maximum rate equal to 2000 samples/sec)
Output:	10 bits
Opaque Sample:	Not available
Color Scan:	Available as custom engineered option (cost unknown)
Cost:	$392 K

Table IX

GCA Corporation Mann Type
2832 Microdensitometer

Information International, Inc.

This firm utilizes a flying spot scanning system in their high precision film reader/recorders. The currently produced system is designated by the firm as PFR-3. An updated version, the PFR-4, has not yet been released as a new product, but the technical specifications were made available for this survey. The scanners have an internal deflection computer which provides dynamic correction for size and shape of the CRT electron beam, focusing, pincushion distortion and astigmatism. This procedure provides vast improvement over conventional flying spot scanning techniques.

The PFR systems include a CRT display monitor, a Triple I-15 control computer manufactured by this firm, as well as a memory, a magnetic tape unit, and other peripheral devices. Basic software is also included. The PFR series reader/recorders thus represent a relatively complete image processing system for black and white transparencies.

PFR 3- Programmable Film Reader/Recorder

Type:	Flying Spot Scanner
Film Size:	16 millimeter, 35 millimeter and 70 millimeter
Addressability:	16384 x 16384 points with 0.00018 x 0.00018 inch raster interval over 3 x 3 inch CRT display
Density Range:	Options 0-3.15 density units 0-1.26 density units 0-2.56 density units
Spot Size:	Programmable between 0.6 - 8 mils. Minimum size at film plane - 3.6 micrometers for 16 millimeter film, 8.4 micrometers for 35 millimeter film, 19.6 micrometers for 70 millimeter film.
Accuracy:	Measurement accuracy - 0.05% Linearity - 0.05% Repeatability - 0.025% Resolution - approximately 6000 TV lines per inch across the 3 inch CRT
Output:	6 bits (up to 9 bits via software)
Speed:	300,000 points per second, maximum
Opaque Sample:	Not available
Color Scan:	Not available
Playback:	6 bits
Controller:	Triple I-15 computer with 8 K core.
Peripheral equipment: (included in cost)	Magnetic tape unit Disc memory 330K - 18 bit words 21" CRT monitor Paper tape reader/punch Card reader Line printer Incremental plotter Film transport
Cost:	$460 K base price, including basic software

Table X

Information International, Inc.

PFR-3 Programmable Film Reader/Recorder

PFR-4 Programmable Film Reader/Recorder

(Preproduction Technical Summary)

Type:	Flying spot scanner
Film Size:	16 millimeter or 35 millimeter
	Optional attachment for 5 inch rolls or 7 x 9 inch glass plates
Addressability:	65,536 x 65,536 points with 0.000046 x .000046 inch raster interval over 3 x 3 CRT display
Density Range:	0 - 3 density units, expandable to 0 - 4 density units with software correction
Spot Size:	Programmable from 0.6 mils
Accuracy:	Resolution - 2500 line pairs per full field of view for all film sizes
	Linearity - 0.05% of full scale deflection
	Drift noise: - 0.025% of full scale deflection
	Density Resolution - program selectable from 0.005 to 0.64 density units
Output:	Program selectable as 1, 2, 3, 4, 6 or 9 bits
Speed:	4×10^5 points per second for 9 bit data,
	2×10^6 points per second for 1 bit data (maximum)
Opaque Sample:	Not available
Color Scan:	Not available
Playback:	6 bits
Controller:	Triple I - 15 computer with 16 K core
Peripheral Equipment:	Disc memory
	Magnetic tape unit
	17" CRT monitor
	Paper tape reader/punch
	ASR-33 Teletype
	Data (digitizing) tablet
	Film transport
Cost:	Not provided

Table XI

Information International Inc.

PFR-4 Programmable Film Reader/Recorder

Marco Scientific Inc.

This firm now manufactures the Joyce Loebl flat-bed and rotating drum microdensitometers which interface to PDP 11, Nova or "any suitable" computer. These systems are in the low-cost range for their respective types. The flat-bed system operates at a very slow speed.

Joyce Loebl Scandig 3

Type:	Rotating drum
Film Size:	Up to 232 x 225 millimeters standard, 360 x 430 millimeters optional ($9 k)
Apertures:	25, 50, 100, 200 micrometer circular
Sampling:	25, 50, 100, 200 micrometer (12.5 micrometer available as option)
Accuracy:	Density resolution - 1 in 256
	Density repeatability - 2 in 256
	Linearity - 1 in 256 from best straight-line fit
Speed:	20,000 pixels per second
Opaque Sample:	Available as option
Color:	Interchangeable filters available
Density Range:	0-3 density units (0-4 density units available as option)
Output:	8 bits
Cost:	$36 - 40 K (including interface)

Table XII

Marco Scientific Inc. Joyce Loebl Scandig 3

Joyce Loebl Microdensitometer 3 CS

Type:	Flat bed
Film Size:	Not specified, larger than scan area
Scan Area:	Up to 240 x 115 millimeters
Density Range:	Full scale deflection variable from 0.2 to 6.0 density units
Apertures:	Continuously variable slit from 50 x 1 micrometer to 6 x 1 millimeter, optional slit rotation attachment
Sampling:	Selectable
Accuracy:	Density repeatability: 0.5% of full scale deflection Position repeatability: 0.5% of scan length Density linearity: ± 1%
Speed:	20 points per second maximum
Opaque Sample:	Available as option
Color Scan:	Not available
Output:	3 digit BCD number (9 bits) representing density
Cost:	$35 - 40 K (including interface)

Table XIII

Marco Scientific Inc. Joyce Loebl Microdensitometer 3 CS

Optronics International

Optronics manufactures rotating drum systems and a flat-bed microdensitometer. The rotating drum systems include a black and white scan system with optional playback and a full color scanner with optional playback. The flat-bed scanner has color scan capability and B/W playback option. Interfaces are available to various minicomputers.

System P-1000 Photoscan

Type:	Rotating Drum
Film Size:	12.5 x 17.5 centimeters (other sizes to 35 x 43 centimeters optionally available)
Density Range:	0-2 density units or 0-3 density units selectable
Apertures:	25, 50, 100 or 200 micrometers square
Sampling:	Options: 12.5, 25 & 50 micrometers; 25, 50 & 100 micrometers; 50, 100 & 200 micrometers
Accuracy:	Positional — ± 2 micrometers per centimeter Density resolution - 2/256 (0-2D) or 3/256 (0-3D) Density repeatability - 2/128 (0-2D) or 3/128 (0-3D)
Speed:	2.5 - 40 minutes for 12.5 x 12.5 film depending on speed setting
Opaque Sample:	Not available
Color Scan:	Not available
Playback:	Available; the scan and playback system is designated as P-1700 by the manufacturer
Output:	8 bit
Cost:	$25 - 35 K

Table XIV

Optronics International System P-1000 Photoscan

System S-3000 Specscan

(Scan and Playback)

Type:	Flat bed
Film Size:	Up to 10" x 10" (14" x 14" available)
Density Range:	0-4 density units (0-5 density units available)
Apertures:	8 selectable slits (rectangular, circular or square)
Sampling:	Variable, down to 1 micrometer
Accuracy:	Positional repeatability: ± 1 micrometer Density linearity: ± .02 density units Resolution: greater than 600 lines per millimeter at 100X magnification
Speed:	Variable from .25 millimeters per minute to 12.5 centimeters per second
Opaque Sample:	Available as option
Color Scan:	Standard
Output:	10 bits
Cost:	$69 K (10" x 10", scan only) $118 K (color scan, B/W playback)

Table XV

Optronics International System S-3000 Specscan

C-4000 Series: Colorscan, Colormation

(Scan & Playback)

Type:	Rotating Drum
Film Size:	5 x 7 inches, 10 x 10 inches, or 14 x 17 inches
Apertures:	25, 50, 100 & 200 micrometers square
Sampling:	25, 50 & 100 micrometers or 50, 100 & 200 micrometer options
Density Range:	0-2 density units, 0-3 density units switchable
Accuracy:	Positional - ± 2 micrometers RMS per centimeter Density resolution - 2/256 (0-2D), 3/256 (0-3D) Density repeatability - 2/128 (0-2D), 3/128 (0-3D)
Opaque Sample:	Available as option
Color Scan:	Standard
Output:	8 bits
Playback:	Density range: 0-2 density units Resolution: 5 bits per color, 6 bits for black and white
Cost:	$40 - 50 K (10" x 10" scan only) $85 - 95 K (10" x 10" scan and playback)

Table XVI

Optronics International C-4000 Series
Colorscan, Colormation

Perkin-Elmer Corporation - Boller & Chivens Division

The microdensitometer manufactured by Perkin-Elmer is a flat bed system which has a new simultaneous color scan and color playback option. The color scan utilizes a three channel photomultiplier while color playback is accomplished through the use of a three-gun black and white CRT and narrow bandpass filters. The standard system utilizes sequential scans through selectable filters and provides black and white playbacks. This device interfaces to either a PDP 8 or PDP 11/05 minicomputer.

Model 1010A Microdensitometer (Scan & Playback)	
Type:	Flat bed
Film Size:	Up to 10 x 10 inches
Density Range:	0-4 density units
Apertures:	8 circular, square or rectangular slits may be selected from options which vary from 1 - 1000 micrometers
Sampling:	Selectable in one micrometer increments from 1 micrometer
Accuracy:	Positional repeatability: ± micrometer Straightness of travel: ± 5 micrometers Orthogonality: ± 5 seconds of arc Resolution: greater than 600 lines per millimeter at 100X magnification Density stability: less than ± .02 density units in 10 hours
Opaque Sample:	Available ($2.4 K)
Color:	Sequential color scans Optional tricolor read, simultaneous scan ($15.5 K)
Output:	10 bits
Playback:	Black and white playback - $5.5 K Simultaneous tricolor playback option - $19 K
Cost:	$50 K (Standard system without interface) $65 K (Standard system with interface)

Table XVII

Perkin-Elmer Model 1010A Microdensitometer

Photo Digitizing Systems Inc.

This firm manufactures an image dissector system interfaced to a Nova 800 computer. The data on this company were in our files. No cost data were available.

Series 200 Photo Digitizing System

Type:	Image Dissector
Film Size:	"Any size" depending on optics specified by customer
Scan Area:	0.5 x 0.5 inches at photocathode
Aperture:	1 mil standard
Accuracy:	Uniformity - ± 5% over scan area
	Orthogonality - less than 0.5 degrees
	Image resolution - 1000 x 1000 pixels (with 0.5 mil aperture)
	Deflection linearity - ± 0.5% over scan area
Scan Size:	4096 x 4096 pixels
Speed:	100,000 pixels per sec
Output:	8 bits
Opaque Sample:	Standard
Color Scan:	Not available
Cost:	Unknown

Table XVIII

Photo Digitizing Systems Series 200
Photo Digitizing System

Photometrics, Inc.

The Photometrics raster scanner is a flat bed scanner, developed for biomedical applications. Details of the instrument's operation and specifications were limited. This is a low-cost system compared to other flat bed devices, but the precision is not as high.

EDP Raster Scanner

Type:	Flat bed
Film Size:	70 mm
Apertures:	1 - 800 micrometers circular
Density Range:	0 - 3 density units
Sampling:	1 - 500 micrometers adjustable
Accuracy:	Position - ± 2 micrometers/inch
Speed:	100 lines/minute
Opaque Sample:	Available
Color Scan:	Not available
Controller:	Interfaces to minicomputer
Output:	8 bits
Cost:	$26.5 K

Table XIX

Photometrics Inc. EDP Raster Scanner

Spatial Data Systems Inc.

Spatial Data manufactures a low-cost vidicon system which provides low-resolution images at high speed. The unit can be interfaced to various minicomputers.

Computer Eye
108 Image Digitizer

Type:	Vidicon
Film Size:	Up to 9 inches, on light table
Density Range:	Output range adjustable from 0.5 density units to 2.25 density units
Apertures:	(Equivalent Scanning Spot Size) 5 micrometers (120 X) to 440 micrometers (1.3 X)
Sampling:	512 points across image 480 lines per image
Accuracy:	Quantization error ± 1/2 bit Resolution at 50% square wave response: 500 TV lines Linearity: ± 1% in central circle ± 2% outside central circle
Speed:	35 seconds per image
Opaque Sample:	Available as option
Color Scan:	Not available
Output:	8 bits
Cost:	$16.5 K (without controller)

Table XX

Spatial Data Systems Computer Eye 108 Image Digitizer

CONCLUSIONS AND RECOMMENDATIONS

Vidicon camera systems are the lowest cost scanners. Their speed of digitization could be an advantage where high resolution and large images are not needed. Image dissector scanners are higher in cost but offer improved resolution and larger image sizes at essentially the same rate of digitization. The flying spot scanners investigated in this survey are expensive, due in part to the inclusion of controller and peripheral devices in the price, but provide the highest data rates encountered, and have the highest resolution of any of the electronic scanning devices.

In the category of electro-mechanical devices, rotating drum scanners were found to be in the same price range as image dissectors and offer at least an order of magnitude increase in resolution. Scan speed, however, is significantly decreased. The most precise instrument, and generally the most expensive, is the flat bed microdensitometer. Where high resolution images are required, this is essentially the only choice; resolution is approximately three times greater than for a rotating drum system. Flat bed scanners have the slowest scan speeds of all the instruments survey, and could probably not be used in a production environment where large amounts of imagery must be digitized.

Based upon the above criteria, the potential user must decide upon the type of system most applicable to his needs. Funding limitations, resolution requirements and speed of throughput are the three primary parameters which must be considered. In a production environment, the speed of an electronic scanning system may offset the limitations to precision scanning. If price considerations are not of critical importance, the precision of an electronic scanner may be augmented, although geometric precision can probably never reach that of an electro-mechanical system.

If a research and development environment is required, an electro-mechanical scanner could provide the desired precision at the cost of throughput speed. Funding criteria would be the determining element in the type of device considered.

In summary, the application scenario must be known and the requirements carefully evaluated before the selection of a digitizing system can take place.

APPENDIX

NAMES AND ADDRESS
OF
ORGANIZATIONS

1. CBS Laboratories (file data)
227 High Ridge Rd.
Stanford, CT 06901
203 / 327-2000

2. DBA Systems Inc. (file data)
P.O. Drawer 550
Melbourne, FL 32901
305 / 727-2020

3. Dicomed Corp.
7600 Parklawn Ave.
Minneapolis, MN 55435
612 / 888-1900

4. EMR Photoelectric (file data)
P.O. Box 44
Princeton, NJ 08540
609 / 799-1000

5. GCA Corp. - D. W. Mann Co. Div.
174 Middlesex Turnpike
Burlington, MA 01803
617 / 272-5600

6. Information International Inc.
5933 Slauson Ave.
Culver City, CA 90230
213 / 390-8611

Table AI

Manufacturers Evaluated in Survey

7. Marco Scientific Inc.
P. O. Box 2699
Santa Clara, CA 95051
408/ 739-9418

8. Optronics International
7 Stuart Rd.
Chelmsford, MA 01824
617 / 256-4511

9. Perkin-Elmer Corp. - Boller &
916 Meridian Ave.
So. Pasadena, CA 91030
213 / 682-3391

10. Photo Digitizing Systems (file data)
820 So. Mariposa St.
Burbank, CA 91506
213 / 849-6251

11. PhotoMetrics Inc.
442 Marret Rd.
Lexington, MA 02173
617 / 862-8050

12. Spatial Data Systems Inc.
Box 249
500 S. Fairview
Goleta, CA 93017
805 / 967-2383

Table AI (Cont.)
Manufacturers Evaluated in Survey

1. Carl Zeiss Inc.
   444 Fifth Ave.
   New York, NY 10018
   212 / 730-4400

2. Photronics Corp.
   70 Cantiague Rk Rd.
   Hicksville, NY 11801
   516 / 822-8480

3. Systems Research Lab
   2800 Indian Ripple Rd.
   Dayton, OH 45440
   513 / 426-6000

Table AII

Firms Not Responding to Survey Request

1. Baird-Atomic Inc.
   125 Middlesex Turnpike
   Bedford, MA 01730
   617 / 276-6420

2. Image Analyzing Computers Inc.
   40 Robert Pitt Dr.
   Monsey, NY 10952
   914/356-3331

3. Fisher Sci. Co. - Jarrell Ash Div.
   590 Lincoln St.
   Waltham, MA 02154
   617 / 890-4300

4. Schoeffel Instrument Corp.
   24 Booker St.
   Westwood, NJ 07675
   201 / 664-7263

5. Eocom Corp.
   19722 Jamboree Blvd.
   Irvine, CA 92664
   714 / 833-2781

Table AIII

Firms Contacted With Instruments Not Applicable

1. Antech Inc.
   Defina Bldg., - 252 Calvary
   Waltham, MA 02154
   617 / 891-5800

2. Gaertner Scientific Corp.
   1201 Wrightwood Ave.
   Chicago, IL 60614
   312 / 281-5335

3. Gamma Scientific Inc.
   3777 Ruffin Rd.
   San Diego, CA 92123
   714 / 279-8034

4. Gelman Instrument Co.
   600 So. Wagner
   Ann Arbor, MI 48106
   313 / 665-0651

5. Ortec Incorporated
   100 Midland Rd.
   Oak Ridge, TN 37830
   615 / 482-4411

6. SDA Industries Inc.
   7955 Haskell Ave.
   Van Nuys, CA 91406
   213 / 989-5330

7. Telemation Inc.
   P.O. Box 15068
   Salt Lake City, UT 84115
   801 / 487-5399

Table A IV

Firms Recommended to be Surveyed in Future