NCE & TECHNOLOGY:

WORKSHOP ON STANDARDS FOR IMAGE PATTERN RECOGNITION

NBS Special Publication 500-8

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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[2] Located at Boulder, Colorado 80302.

COMPUTER SCIENCE & TECHNOLOGY:

Workshop on Standards for Image Pattern Recognition

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ABSTRACT

Automatic image pattern recognition techniques have been successfully applied to improving productivity and quality in both manufacturing and service applications.

Automatic Image Pattern Recognition Algorithms are often developed and tested using unique data bases for each specific application. Quantitative comparison of different approaches and extrapolation of existing techniques to new applications is difficult or impossible.

To facilitate data interchange in this area a two day workshop was held at the National Bureau of Standards in Gaithersburg, Maryland on June 3 and 4, 1976.

The workshop considered the issues involved with interchange of images as data in standard formats on magnetic tape. Specifically, the workshop addressed the following objectives:

1. To define mechanisms for achieving a standard format for magnetic tape interchange.
2. To define requirements for documentation of the recording environment of an image.
3. To recommend mechanisms for selecting and distributing prototype images.
4. To consider the requirements and to explore the prospect for a language to describe image content and structure.

KEY WORDS: Automation; calibration; data formats; documentation; image content language; image processing; pattern recognition; prototype images; standards.

INTRODUCTION

Automatic image pattern recognition techniques have been successfully applied to improving productivity and quality in both manufacturing and service applications.

Automatic Image Pattern Recognition Algorithms are often developed and tested using unique data bases for each specific application. Quantitative comparison of different approaches and extrapolation of existing techniques to new applications is difficult or impossible.

At the suggestion of the Electronic Industries Association (EIA) and with the support and cooperation of the IEEE Computer Society Machine Pattern Recognition Group and the Association for Computing Machinery (ACM) Special Interest Group on Graphics the National Bureau of Standards conducted a two day workshop on problems concerned with the adoption of the standards for the interchange of image pattern recognition data. The interests of the various collaborating groups derived from concerns in the industry for advancing the state of development in the pattern recognition and image processing art, concerns in the engineering community for the adoption of standards for testing equipment and concerns in the computing community for the adoption of standards relating to the testing of algorithms.

A steering committee consisting of the chairman of the various sessions of the workshop developed, over a period of several months, a program which would deal with several issues that seem central in various ways to the question of adoption of standards for image interchange. The members of this group were:

William Alford, National Aeronautics and Space Administration
John Dehne, US Army Night Vision Lab, representing NATO
John M. Evans, Jr., National Bureau of Standards
Russell Kirsch, National Bureau of Standards
James B. McFerran, Sperry Univac, representing IEEE
Roger N. Nagel, National Institutes of Health, representing EIA
Theo. Pavlidis, Princeton University, representing IEEE
Judith M. S. Prewitt, National Institutes of Health, representing IEEE
Azriel Rosenfeld, University of Maryland, representing the Journal Computer Graphics and Image Processing
Gene Thorley, US Geological Survey ERDS Program

There were four distinct problem areas the workshop addressed itself to:

1. The adoption of standards for magnetic tape formats.
2. The documentation of the recording environment for image scanning and transducing.
3. The acceptance of prototype image data bases.
4. The description of image content and structure.

The first and most clearly necessary problem for concern in the workshop was the question of agreeing upon formats for magnetic tape recording. Clearly any form of interchange among research and development workers would be advanced by the existence of an agreed upon format or set of formats for recording images when they are interchanged among groups and between those producing image data and those using data for pattern recognition and image processing purposes. This was therefore the topic of the first session of the workshop.

The second session arose from a concern particularly in the academic research community for documentation of the recording conditions under which images are produced. In many cases images produced with specialized equipment, (particularly transducers and devices which are peculiar to a particular environment) are exchanged between the laboratory producing the data and other laboratories having no familiarities with the recording equipment. Much valuable information is lost in the case where the characteristics of the recording equipment and the whole environment are not documented. It was in an attempt to heighten sensitivity to the need for documenting the recording environment conditions that this second session of the workshop was conducted.

The third session addressed itself to the production of prototype data bases. There are at least two clear needs for such prototypes of data bases. The first is the analog of the problem in testing ordinary optical instrumentation where test patterns are used for specifying such properties as resolution. For testing various types of devices the need for prototype data bases is fairly evident. So are prototype data bases necessary for testing algorithms since the useful intercomparison of algorithms for doing pattern recognition could be enhanced if agreed upon prototype data bases could be interchanged for testing these algorithms.

The fourth session of the workshop concerned with describing image content and structure arose from a need expressed occasionally in the academic community where images of a very specialized sort are recorded. Typically these images are produced in laboratories where specialized talents exist for interpreting those images. Obvious examples occur in the biomedical community. When these images are interchanged between the producers, typically biomedical scientists, and the computer scientists attempting to do pattern recognition research, there is often a failure to communicate, along with the images, the suitable descriptions of the articulated structure sufficient to enable the computer scientists to understand what the content and structural descriptions of these images are. It was in an attempt to investigate the possibility of compiling such structural descriptions that this last section of the workshop was conducted.

The reader of these workshop proceedings will easily note that none of these four areas are yet advanced to the stage where consensus exists, despite the widespread recognition of the need for such a consensus. He will also note equally clearly that the different areas of concern are in different stages of development. Perhaps this differential status of the different areas can serve as a source of motivation for increasing activities in those areas which are more backward and for encouraging the continued pace in those areas which have already showed noteworthy progress.

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Introductory Comments
at the
Workshop on Standards for Image Pattern Recognition
June 3, 1976

by

Dr. Ruth M. Davis
Director, Institute for
Computer Sciences and Technology

I am delighted to welcome you to the National Bureau of Standards, and particularly to this landmark Workshop on Standards for Image Pattern Recognition.

Your meeting here - to explore some of the issues in standards development for image pattern recognition - is a most appropriate activity for the National Bureau of Standards.

NBS has long been involved in standards development and improvement, the interchange of information and the application of technology for public benefit.

This year the Bureau is celebrating its 75th anniversary as the Nation's physical science and measurement laboratory. Throughout its history NBS has provided the basis for the Nation's measurement standards. In addition to a traditional role in the area of weights and measures, NBS has long been involved in product testing and research on test methods and specifications.

NBS has been at the forefront of new technologies in order to provide the foundation for science and commerce and to effectively serve government and the public. Computer technology is one of those areas in which NBS has been at the forefront. In the 1940's and 1950's Bureau scientists designed and developed SEAC, the first general purpose, stored program computer operated in the U.S.

Continuing technological developments in ensuing years coupled with growing Federal Government dependence on computers for information processing led to legislation in 1965 to establish Department of Commerce responsibility for improving the utilization of computers by Federal agencies.

By that legislation, the Brooks Act, NBS is directed to set standards for Federal procurement and use of computers, to advise other agencies on the efficient use of computers and to carry out research and development in computer science and technology.

One area in which we carry out these functions is the application of computers in automation technology. The particular aspect you will be discussing in this Workshop, automatic image pattern recognition, is especially relevant to growing concerns about productivity and quality of goods and services in the U.S. today.

There have been dramatic shifts in the make-up of the labor force in the U.S. over the past few decades. Between 1960 and 1970 the increase of workers in the service industries was about 12 times the increase of workers in the goods producing industries.

Today about 2/3 of the labor force is employed in the Service Sector which includes Federal, state and local government employees and people engaged in services such as health care, wholesale and retail trade, services and financial and legal work.

The rise in importance of the Service Sector has been accompanied by some disturbing problems:

Productivity in the Service Sector has been lagging. The annual growth rate of labor productivity in the Service Sector has been significantly lower than the growth rate in the goods sector: 2.7% vs. 3.4% between 1960 and 1970.

Secretary of Commerce Elliott Richardson is especially interested in this aspect of services. He says that available technology to improve productivity has not been adequately applied, and he cites health care specifically as a service which he believes can be improved by the application of technology.

Services have contributed to increased costs. As an example, the costs of health care have increased faster than any other component of the consumer price index during the past two decades. Between 1950 and 1974 medical costs increased by 180% while the CPI rose by 105%, causing health care costs to increase from 4.6% to 7.6% of the GNP.

Salary increases in the Service Sector have outpaced increases in the goods sector. In the years from 1953-74, pay increases in manufacturing were 141%, while increases for State and local government employees were 188% and for other services 171%.

There is widespread dissatisfaction with the quality of services. A report on Automation Opportunities in the Service Sector for the Federal Council for Science and Technology found that about 87% of the consumer complaints received by Better Business Bureaus and the Office of Consumer Affairs were directed toward the service industries with 66% directed toward services actually bought in the marketplace.

Automation technology can play a key role in attacking the problems of the Service Sector by improving productivity and quality of services.

The application of automation in agriculture has greatly improved productivity. As a result we spend the smallest percentage of our annual income for food of any nation in the world, and, in addition, we provide for most of the food aid shipments in the world.

Automation in manufacturing is widespread with applications of assembly-line automobiles and appliances. Numerically controlled tools, industrial robots and computer-aided manufacturing techniques are now beginning to be used in the rest of manufacturing industry, with potential increases in productivity running to thousands of percents.

The principal experiences with automation in the Service Sector have been in the applications of computers and the mechanization of paper handling. The capability of computers to process information quickly and accurately is utilized by service industries such as banking, credit, financial and insurance. Most large organizations use computers for payroll calculations, health and employee records and financial and inventory records. Real-time services such as air travel are dependent upon computers. There have also been successful applications of automation processes for automated bank tellers, garbage collection, automobile diagnosis, automated warehouses, vending machines, direct distance dialing and computer-assisted instruction.

Automatic image pattern recognition is one aspect of automation with particular significance for improving productivity and improving quality in the Service Sector.

Image pattern recognition technology has been successfully used to automate fingerprint identification, weather prediction, photographic interpretation, and molecular and cellular pattern analysis.

Automation, via image pattern recognition, has the potential for improving productivity and services in many additional areas such as:

- automation of analyzing x-rays and cytology: applications in the health field
- space applications and resource discovery and management
- safety systems for public transportation systems
- automated mail and parcel post recognition and handling systems in the post office
- automated maintenance and repair systems for consumer services
- automated security systems
- inspection and quality control for manufacturing industries

However, the barriers to the successful diffusion of automation to these and other service and manufacturing applications are many. Research and development in automation technologies are fragmented and the lack of standards hampers the transferability of existing technology.

Very often, applications are developed using unique data bases, making transfer of existing techniques to new applications difficult or impossible.

The development and diffusion of image pattern recognition technology requires a coherent technical foundation or infrastructure that allows people to communicate with others and to efficiently utilize available technology. That is why this Workshop is so important. We are hopeful that additional attention to standards for image pattern recognition will advance research and development in this field by improving communication and data interchange. This, in turn, will help government agencies and private sector organizations to improve productivity and service quality by applying this technology more rapidly and more efficiently.

I wish you success in your Workshop. I hope that you enjoy this visit to the National Bureau of Standards and that you will come back again.

STANDARD TAPE FORMATS

Chairpersons: John Dehne, Army Night Vision Lab
William Alford, Goddard Space Flight Center

Panelists: Theo. Pavlidis, Princeton University
John Sos, National Aeronautics and Space Administration
Sandra Hawley, ESL Incorporated

Discussion

The general consensus of the attendees supported defacto adoption of a limited number (1-5) tape format standards. This was evident both in the general discussion following the presentations and in the results of a survey questionnaire. There was, however, considerably less unanimity as to the detailed design of such formats.

One major area of disagreement centered around the issue of whether it is practical to have one standard tape format or not. Those favoring the adoption of a single standard (one third of questionnaire returned) generally favored choosing a self-documenting meta-standard with sufficient flexibility for a broad variety of applications. A majority of this group (according to the questionnaires) ranked the NATO standard most highly and felt that such a standard could be adopted within their own organization in one year or less. Those favoring more than one standard generally anticipated greater time delays (2-3 years) before a standard could be adopted within their own organization.

A key issue within this group is the desire for a format which can be read and written by ANSI FORTRAN programs. This is important to users who lack systems programming experience or support and tends to place several restrictions on format design as follows:

1) There is great resistance to incorporation of the self documenting header records needed for a meta-format in the same file as the image. These users prefer the use of a header file (which generally reduces the data integrity of the meta-format approach) so that available system functions may be used to skip it - as opposed to the user program functions needed to by-pass similar header records.
2) Single file (image sans header) tapes are preferred by some in this group due to system/programmer difficulties with multi-file tapes.
3) Fixed record length is required to insure that tape blocking can be controlled at a JCL level on all operating systems. In addition, the length should be small (2K-4K bytes) to allow buffering on minicomputer systems and should probably be an integral multiple of some small number (128-256) to allow use

of long records via format buffered I/O using system logical/physical record blocking control. Use of a fixed record length on all files in the same tape is desirable, but not necessary.

4) This group shows strong preference for simple formats which could be used for processing within an installation as well as for transmittal between installations. Thus use of any line by line ancillary data (line numbers, non-video calibration levels, etc) is disliked. This group generally favors the use of formatted (alpha-numeric coded) or binary word length data over other schemes for coding the picture element values - though differences in machine codes and word lengths makes these approaches difficult as well. The hope here is to use I, E, F, or A formats.

With all these factors it was generally concluded that it might be possible to generate one or at most two candidate formats which could then be published for critical review and which would form the basis for any further standardization effort. To this end interested parties representing the entire spectrum of opinions reconvened about one week later to attempt to formulate the candidate formats. The simple format was designed first and may be described as follows:

The Simple Format

1. No headers or other ancilliary information on the tape. All such data is transmitted as separate written documentation which is sent with the tape.

2. Each file contains one picture. Each picture is a regular two dimensional array of single valued integers (i.e. only 1 spectral band per picture).

3. Each image line is one record and all records in a given file are the same length. The maximum record length is 4096 bytes. (1 byte = 8 bits).

4. Each picture element (pixel) is encoded as a positive integer in one byte. Picture elements within a line are stored sequentially with a record.

5. Multi-file (multi-picture) tapes are permitted. Record lengths may vary between two files on the same tape. Files (pictures) are separated by one EOF mark. The last file

is followed by two or more EOF marks.

There was much discussion on the topic of a meta-format and an attempt to design one. A major conceptual difficulty raised was the desirability of having yet another proposed meta-format, especially one proposal by a group not actively involved in generating or exchanging large data bases. It was generally concluded that such an attempt might not be worthwhile, especially in light of continuing internationally coordinated activities by NATO and NASA, unless it resulted in a format near enough to one or more of the existing ones to cause an acceptable design impact. Candidate meta-formats include the NATO format, the NASA VICAR format, and the NASA proposed new CCT format (see SOS paper). Each has its strong and weak points.

The NATO format has been internationally coordinated and is the only one that makes provision for transmittal of non-imagery data, real and complex valued imagery, and negative value image points. It is a very good example of a meta-format, especially in light of the fact that image format and tape format are completely decoupled and treated as separate issues. This allows great flexibility including very long image lines with simultaneous limits on maximum tape buffer length. However, this format places limits on ancilliary data (none in an image line and only 4K max. characters in free format per image header) which severely limit its utility in NASA type data bases.

The NASA VICAR format is currently the only one in operational use and allows unlimited amounts of ancilliary data per image. However, it has only been used to date as a processing and storage (not transmittal) mechanism and is currently quite machine dependent in pixel storage codes. Further it is not designed for use with non-image data (feature vectors, etc) and retains only limited flexibility for distinctions between tape and image formats.

The proposed new NASA CCT format can be expected to be very heavily used and widely dispersed owing to large scale distribution of the tapes by NASA. It is currently the least settled (hence easiest to impact) of the three. As currently proposed it would allow maximal use of ancilliary data, but would only contain provision for transmittal of positive integer, imagery type data. A relatively inflexible relationship between tape and image format is proposed which would make use of smaller tape buffers more difficult. Furthermore, most applications do not require such extensive ancilliary data (line by line) and many users are quite concerned about finding simple ways to eliminate it from the tapes they use.

After lengthy discussion centering around a varient of the VICAR format it was generally concluded that design of a separate new meta-format was not reasonable in light of the uncertainties of acceptance by the current major users of such formats. As a result, no meta-format was drafted. However, it is hoped that the comments about existing meta-formats may help to guide their further developments.

The NATO RSG-4/SGIP TAPE FORMAT

By

John S. Dehne

US Army Night Vision Laboratory

Acting US Project Officer, NATO RSG-4/SGIP

Under the NATO Defense Research Group (DRG) cognizance of and cooperation in the field of Pattern Recognition is covered by AC/243 (Panel III) Research Study Group 4. In recent years, this group (RSG-4) has been very active in assessing various military application areas for pattern recognition and in fostering cooperation and coordination among participating governments in each of these areas. Dr. David Hodge of the US Army Human Engineering Laboratory serves as the US Delegate to RSG-4.

The first area which RSG-4 assessed was Image Processing. A substantial interest for cooperative efforts in this area was discovered among all participants. As a result a Subgroup on Image Processing (SGIP) has been formed to plan and coordinate cooperative projects. This group consists of a Project Officer from each participating country. Mr. John S. Dehne of the US Army Night Vision Laboratory is currently the Acting US Project Officer.

It was immediately clear to all participants that cooperative efforts would depend on ready interchange of image data bases and algorithms. This interchange was hampered by the fact that each installation had generated its own image processing software system specifically for its own computer facilities which differed enormously. Thus, each installation had developed one or more unique tape formats and based a large software and data base investment on the use of that format. Because of this, adoption of a single format for use in all installations would have been quite expensive. Instead, it was decided to develop a tape format to be used only for transferring digital imagery from one installation to another. Each installation need write only two simple programs to begin exchanging imagery - one to translate between the transfer format and the format and the format of that specific installation and another to do the reverse.

The choice of this approach, development of a transfer format, had two other very nice aspects. First, it relaxes some of the constraints which must normally be considered in designing a tape format for imagery. For instance, since the format is to be designed for transferral of image data rather than storage, constraints on packing density are somewhat relieved. Similarly, since the format does not have to be used for the actual processing of the images, constraints relating to the use of headers, trailers, and attempts to design for minimal tape motion and processing time are also relaxed.

Second, development of a format just for transferral of image data tends to focus attention on the real problem - transfer of all image related data. In this light it becomes important to consider the transferral of other imagery related data when designing the format. Such data include image transforms, calibrated imagery (which may be composed of non-integer values), feature vectors, classification parameters, documentation of the recording environment, and even the image processing source programs.

It was with these considerations in mind that the RSG-4/SGIP developed a draft format at its first meeting in July 1975. The NATO group was also made aware of similar efforts then on going in the US by the EIA and an IEEE panel on Biomedical Pattern Recognition. The draft format was circulated to all contributing defense laboratories in participating countries, and was made available to the EIA and IEEE group in the US for comment. This resulted in the final approval of the format as shown below at the second RSG-4/SGIP meeting in February 1976. Experimental testing of translation programs is scheduled to begin shortly with the exchange of a test tape able to flex all options (actually two tapes - one 7 track and one 9 track). This tape will be circulated among participating countries before the next meeting now scheduled for November 1976.

Several things should be noted about the format. First, it is generally entirely self-documenting. This is achieved by the use of two headers at the start of each file. Header 1 documents the origin, structure and data organization of the file in a fixed format. Header 2 allows free format documentation of all other parameters pertinent to the data (e.g. documentation of recording environment, location of significant image features, recording of image processing techniques already applied, etc.). This is achieved without the need of extra EOF marks, which usually cause a problem in such cases by making each header a record rather than a separate file. Thus, header processing may be ignored, if the file structure is otherwise known, merely by skipping the first two records of each file.

Second the format is unusual in that it separates the format of the data as recorded on the tape from the format of the data when considered to be an imager. Thus, while each image (which may be multi-spectral) is written on the tape as a separate file (there may be one or more on a tape), it is not necessarily true that each record contains one image line (though this is a particular form). This not only allows the format to be used for transferral of data other than images, but also allows very long image lines (e.g. 12 channel, pixel interleaved, 4k by 4k pictures) to be transferred without requiring overly large tape buffers (4k max. allowed). This makes the format applicable to small computer owners as well as those with large installations.

The basis for the entire tape format is the tape character or byte. This is taken to be 8 bits on a 9 track tape and 6 bits on a 7 track tape. Alphanumeric data is encoded in BCD on 7 track tapes and in a truncated version of ASCII on 9 track tapes (one tape character or byte in either case). This results in a format specification for both 7 and 9 track tapes which can be read on a very wide range of machines (French MITRA, IBM, CDC, DEC to name a few) and which requires actual translation (not just repacking) to convert between 7 and 9 track tapes.

Header 1 may be broken into three principle parts based on what is being described. Bytes 1-24 concern the origin and identity of the image. This includes bytes 17-24 which is an 8 byte alphanumeric identifier given uniquely to this particular image file by its originator. Bytes 25-80 describe the format of the rest of the data in the file. Bytes 81-104 detail the format of the data in the image (x and y sizes and type of data). Bytes 105-128 are currently unassigned and remain for future modification and expansion (some could be used to specify multi-image files, for instance, though this is not currently under consideration).

Header 2 is in free format and constrained to non-zero length to encourage good documentation. Exact contents of Header 2 will depend on the important factors of the problem at hand.

The basis of the format for the actual image data is the integer format. Integers are recorded in ones complement binary in consecutive tape bytes, most significant byte first on tape. Real numbers are recorded as separate integers for mantissa and exponent (both to base 2 with no bias) where the length (in tape bytes) may be different for mantissa and exponent. The exponent is recorded first. Complex numbers (which may be recorded as integers or reals) and multi-channel pixel interleaved data are straightforward expansions of the basic format.

The resultant format can be generated or read using CDC 6600 utility programs, and US standard fortran subprograms are being written by the author to effect the translations in an almost machine independent fashion. The only machine dependent portions will be one routine to read or write the long tape records required (impossible to do with A formatted or unformatted reads and writes on many machines) and one routine to create the ones complement format for numbers from the internal format of the machine being used. Both these routines may require assembly programming depending on the installation. In addition, positioning to the correct file will remain installation dependent and it is recognized that some installations may only be able to handle single file tapes.

Distribution of tapes within the NATO, RSG-5/SGIP group will be made on a bilateral decentralized basis as one participating installation requests data from another directly or through the national Project Officers. The Project Officers will however make surveys of the imagery data available for transferral from their countries. This information will be available to all participating installations, in all countries. The effectiveness of this distribution method remains to be tested and may depend on the specific projects undertaken and the schemes used to manage them - which are not yet determined. In any case, it may be the only viable scheme within the equalitarian framework of NATO.

NATO (RSG-4) Tape Format

General: Data is recorded on 1/2 inch wide magnetic computer tape.

Format allows either 7 or 9 tracks at 800 BPI, NRZI

Maximum record length allowed is 4k tape characters (6 or 8 bits)

A tape contains one or more files.

Files are separated by single EOF marks.

Last file on tape is followed by at least two EOF marks.

Each file contains a whole image. Images too large for one tape must be divided into sub-images which are then handled as individual images.

Each file consists of two header records followed by N image data records.

Header 1: The 1st record of any file (Header 1) is 128 bytes long.

Header 1 is coded in BCD for 7 track tapes, even parity and in ASC II (modified) for 9 track tapes, odd parity.

Allowed characters are shown below:

Symbol	Equivalent 7 tracks	Octal Number 9 tracks
0	12	060
1	01	061
2	02	062
3	03	063
4	04	064
5	05	065
6	06	066
7	07	067
8	10	070
9	11	071
A	61	101
B	62	102
C	63	103
D	64	104
E	65	105

Symbol	Equivalent Octal Number	
	7 tracks	9 tracks
F	66	106
G	67	107
H	70	110
I	71	111
J	41	112
K	42	113
L	43	114
M	44	115
N	45	116
O	46	117
P	47	120
Q	50	121
R	51	122
S	22	123
T	23	124
U	24	125
V	25	126
W	26	127
X	27	130
Y	30	131
Z	31	132
=	13	075
.	73	056
/	21	057
(	34	050
)	74	051
$	53	044
*	54	052
,	33	054
'	14	047

	Equivalent Octal Number	
Symbol	7 tracks	9 tracks
-	40	055
+	60	053
ƀ (blank)	20	040
new line	57	015

A symbol is recorded in one byte on the tape.

Header 1 contains the following information:

Bytes	Meaning
1-8	Identity of Originator: 4 symbols for country, 4 symbols for the laboratory. Example: USA NVL
9-16	Date of Data: Year Month Day Example: 76 06 03
17-24	Name/Number of File/Image Example: GRAF PG1
25-32	Number of Records/File (R) (R = N+2 to account for 2 header records)
33-40	Number of tape characters in header 2 (L2) (L2 > 0 required)
41-48	Number of tape characters/image data record (L3)
49-56	Number of channels/sample (C) (One channel complex data is treated as two channel data with C = 2 x no. of channels)
57-64	Number of tape characters/channel for integer data (I) (I = 0 for real values)
65-72	Number of tape characters for mantissa of a real valued channel (E_m) (E_m = 0 for integer values)
73-80	Number of tape characters for exponent of real valued channel (E_E) (E_E =) for integer values)

81-88	Number of samples per line (S)
89-96	Number of lines per image (L1)
97-104	Type of data values (T): T = 0 non-complex, integer T = 1 complex, integer T = 2 non-complex, real T = 3 complex, real
105-128	Currently not assigned

Header 1 example: An image of 1024 x 1024 sample points has 32 different grey levels for each channel (1-6 bit tape character) The image is registered in 3 colors. Header 2 is 128 bytes long. Image generated today.

Bytes	Contents	Alternate Contents
1-8	USA NVL	USA NVL
9-16	76 06 03	76 06 03
17-24	EXAMPLE1	EXAMPLE2
25-32	ƀƀƀƀƀ770	00001026
33-40	ƀƀƀƀƀ128	00000128
41-48	ƀƀƀƀ4096	00003072
49-56	ƀƀƀƀƀƀƀ3	00000003
57-64	ƀƀƀƀƀƀƀ1	00000001
65-72	ƀƀƀƀƀƀƀ0	00000000
73-80	ƀƀƀƀƀƀƀ0	00000000
81-88	ƀƀƀƀ1024	00001024
89-96	ƀƀƀƀ1024	00001024
97-104	ƀƀƀƀƀƀƀ0	00000000
105-128	Blanks or zeros	

Header 2: The 2nd record of any file contains a free form description of the image. This may include specification of the physical significance of the various channels, description of scanner, meterological conditions when image taken, location of objects of interest in image, etc.

Header 2 has variable length as specified in Header 1 (L2)

($0 < L2 \leq 4096$ tape characters)

Coding is same as header 1.

Image Data: Image data is coded in binary, odd parity, one's complement.

Integer format is basic to all others.

Integer Format: Most significant part is recorded as 1st tape character.

Most significant bit of 1st tape character is sign bit

($0 \Rightarrow$ positive, $1 \Rightarrow$ negative)

Most significant bit is the left most bit

Example: For 2 tape characters/channel, 7 track tape:

$$5 \rightarrow 000000000101$$

$$-5 \rightarrow 111111111010$$

Real Format: The exponent and mantissa (base 2) are reduced to integers. Both these are then stored as separate integers on the tape for each sample.

First E_E tape characters for the exponent, then E_m tape characters for the mantissa.

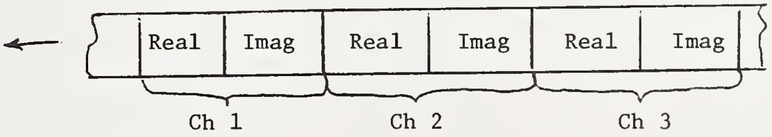
Example: $14.5_{10} = 01110.1_2 \times 2^0 = 011101_2 \times 2^{-1}$

IEXP = 111110 IMANT = 011101 where $E_E = E_m = 1$

and 7 track tape is used.

Complex Format: Integer values (T=1) stored as integers. Real values (T=3) stored as real values. Each channel consists of two values. The first value is the real part, the second is the imaginary part.

Example:

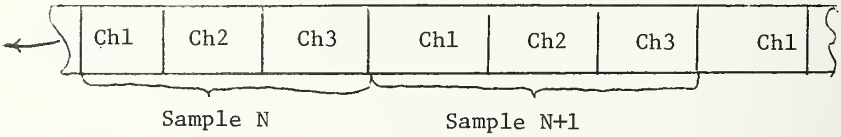


Multi-Channel Data: Non-registered data stored as separate images in separate files.

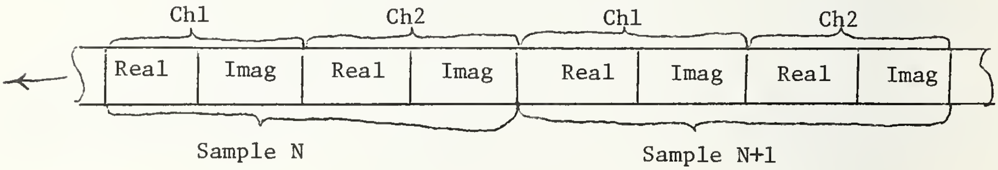
Registered data stored on pixel interleaved basis.

(For one sample the values of the different channels are recorded adjacently).

Examples: 3 color, non-complex data



2 channel, complex data



PHYSICAL TAPE CONVENTIONS

- INDUSTRY STANDARDS FOR WIDTH, IRG, BOT, EOT, ETC.
- 9-TRACK RECORDING (8 DATA BITS WITH ODD PARITY)
- 800 OR 1600 BITS PER INCH - BY REQUEST
- 6 INCH, 8 INCH OR 10 INCH REELS - BY REQUEST
- PHYSICALLY LABELED; NO STANDARD LABEL

RECOMMENDED DATA FORMAT

IMAGE FORMAT	• ONE IMAGE PER FILE (SINGLE BAND) • EOF BETWEEN FILES • TWO EOF'S AFTER ALL FILES • SINGLE FILE PER TAPE - ON REQUEST
FILE FORMAT	• FIXED RECORD LENGTH WITHIN A FILE • ONE IMAGE LINE PER RECORD IF <4096 BYTES • MULTIPLES OF 4096 BYTES FOR LONG RECORDS (ZERO FILL LAST RECORD) • TRAILER FILE (IF REQUIRED) FOR NON-IMAGE DATA (ASC II)
RECORD FORMAT	• MINIMUM LENGTH; 16 8-BIT BYTES • MAXIMUM LENGTH; 4096 8-BIT BYTES
PIXEL FORMAT	• 16-BIT INTEGER, IN 2 CONSECUTIVE BYTES, HIGH ORDER BYTE FIRST OR • 8-BIT BYTE PER PIXEL, IF DATA PERMITS

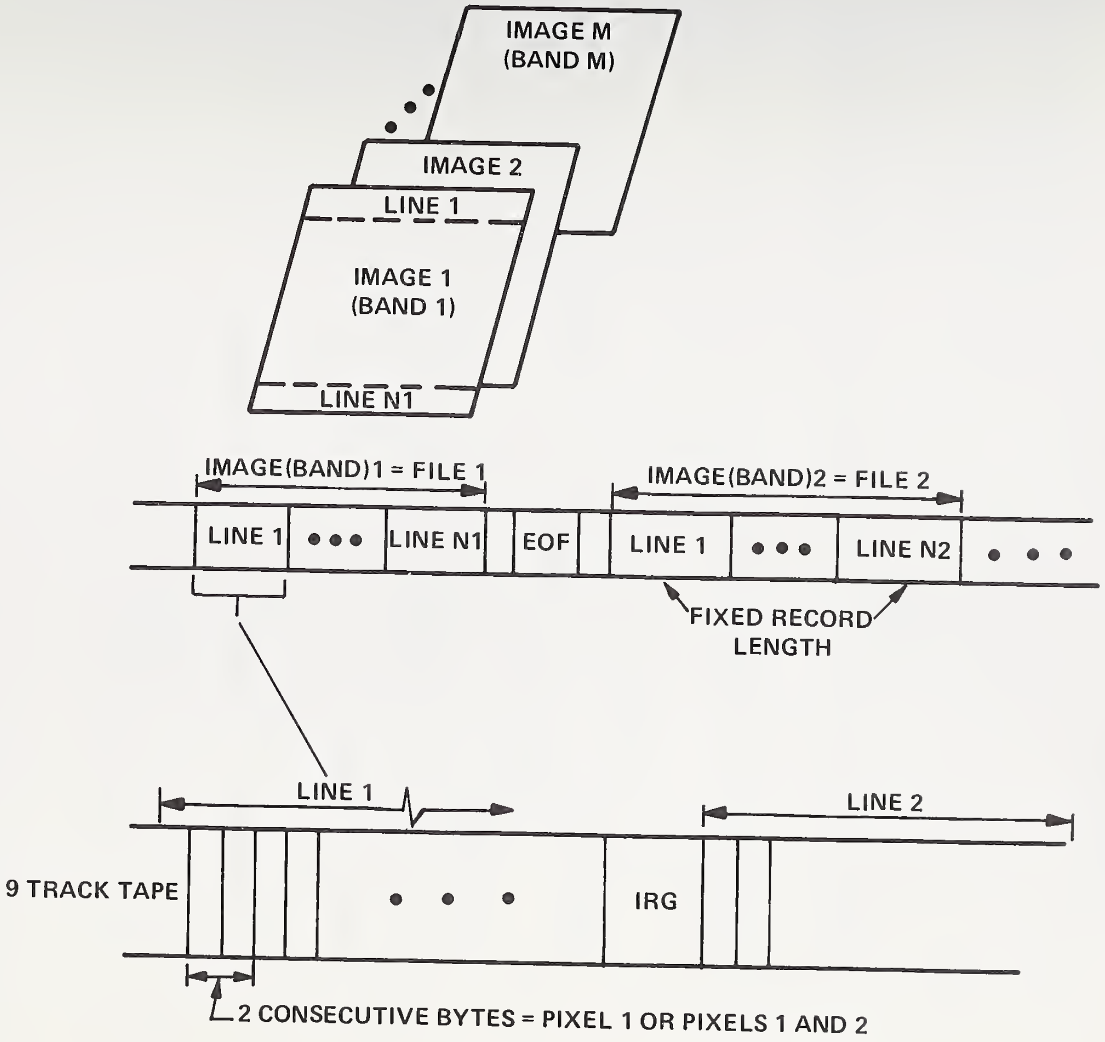


IMAGE M
(BAND M)
IMAGE 2
LINE 1
IMAGE 1
(BAND 1)
LINE N1
IMAGE(BAND)1 = FILE 1
IMAGE(BAND)2 = FILE 2
LINE 1
LINE N1
EOF
LINE 1
LINE N2
FIXED RECORD LENGTH
LINE 1
LINE 2
9 TRACK TAPE
IRG
2 CONSECUTIVE BYTES = PIXEL 1 OR PIXELS 1 AND 2

Image Tape Formats Questionnaire

1. Please specify your organizational affiliation:

   ___ Academia ___ Industrial ___ Governmental ___ Other ________________
   Specify

2. Please characterize your image processing interest(s):

   ___Biomedical ___ ERTS, LANDSAT ___ Real Time Sensors (FLIR,TV, etc.)

   ___OCR ___ Reconnaissance ___ Fingerprint, Handprint

   ___Other ____
   Specify

3. Do you think it is possible to have one standard format for all applications?

   ___Yes ___ No

   How desirable is it to have only one standard?

   The only good way The worst possible way

   _____ _____ _____ _____ _____
   5 4 3 2 1

4. Do you favor a limited number of standard formats for different application areas?

   ___Yes ___ No

   If so, how many do you think would be required? _____

5. Would your organization be willing to use a defacto standard? ___Yes ___No

   If so, how long would adoption of such a standard take?

   ___1 mo. or less ___1 yr or less ___ 2-3 yrs ___ 5 yrs or more

6. Is your organization an image data consumer or producer?

   ____Consumer ____Producer

   What sort of image data might your organization furnish?

   What sort of image data would your organization desire to receiver?

7. What is the best method for distributing image data tapes?

____ One or a few central distribution points

____ Exchange between individual institutions

____ Both of the above

____ Other ______________________________
Specify

8. An acceptable format must include the use of:

____ 9 track tapes

____ 7 track tapes

____ DECTAPES

____ Other ______________________
Specify

9. Comment on the strong and weak points of the <u>formats</u> presented and indicate your preference:

a. NATO format (Dehne) ____ Best ____ Least Useful

b. Large Image Format (SOS) ____ Best ____ Least Useful

c. User Format (Hawley) ____ Best ____ Least Useful

d. Biomedical Format (Pavilidis) ____ Best ____ Least Useful

10. Additional Comments (Use back of sheet if necessary):

Tape Formats

by

Theo Pavlidis
Dept. of Electrical Engineering and Computer Sciences
Princeton University

Last year a task force on Data Bases and Portable Software was formed within the Biomedical Pattern Recognition Subcommittee of the Machine Intelligence and Pattern Analysis Committee of the IEEE Computer Society. The problem of tape format came up quite early in our deliberations and after considerable discussion we felt that it was best to avoid specifying the format in too restrictive a fashion and instead rely on good documentation. The following general specifications were adopted.

Tape and Data Format

(1) The data should be stored on ½ inch magnetic tape, NRZI mode, odd parity, IBM compatible, 7 or 9 tracks, with 9 tracks preferable.

(2) Suggested density 800 bpi with 556 bpi and 1600 bpi also acceptable.

(3) Block size (physical record length) should not exceed 4K (4096 8-bit bytes). (This requirement was imposed in order to allow the reading of tapes by minicomputers with limited buffer size).

(4) First file on the tape should specify in EBCDC or BCD format the contents of the tape.

(5) Each item must be preceded by identification, preferably in separate record.

(6) For gray scale pictures of size greater or equal to 64 x 64, each pixel should be a byte, each line a physical record, each picture a file.

(7) EBCDC or BCD formats are preferable to binary.

The above specifications are quite loose and can hardly qualify as a standard. However there might be situations where even they can still be too strict. For example there are applications where one deals with very large binary pictures, 512 x 512 or even greater. Printed wiring boards are one such instance. Storing one pixel per byte would require 8 times as much space as storing the maximum 8 pixels per byte. If an unpacking program is available, the information can be retrieved easily. Such a program should be also part of the processing one since storing in core 512 x 512 bytes can be quite a problem for most installations.

This points out the problems which must be dealt with in establishing standards. The variety of picture sizes and types makes a universal standard impossible. At one end we may have data bases consisting of many thousands of small (e.g. 24 x 24) binary pictures. At the other end we may find very large (e.g. 1024 x 1024) grey scale pictures, like radiographs with each data base consisting of not more than 100 of them. The one picture per file specification may be reasonable in the second case but not in the first. Also bit packing is possible only in the first case. (IEEE Data Base 1.2.2 which contains alphanumeric data is of this nature and it packs 3 bits per integer. The bit retrieval is quite easy using a high level language like FORTRAN).

A major problem in reading tapes from other installations is the handling of special symbols entered by the operating system when a tape is written by a high level language. Binary tapes would not pose this problem if written with proper care. However such tapes would be very difficult to read when transferring data between machines having bit-byte configurations (e.g. IBM and CDC).

It seems that we may need more than one standard and that for the immediate future the best hope in facilitating transfer of data bases may be good documentation. The establishment of separate standards for each application (e.g. satellite pictures, radiographs, alphanumerics etc.) may also be a possibility. Areas where a standard has not been established could use one from their "nearest neighbor."

Earth Observation Image Data Format

by

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Experience with processing and disseminating Landsat imagery within the NASA Data Processing Facility (NDPF), located at the Goddard Space Flight Center (GSFC), has been applied to the development of a flexible format for Computer Compatable Tape (CCT) containing multispectral Earth observation sensor data. The driving functions which comprise the data format requirements are summarized in Table 1. Using these drivers as a guide, coupled with four years of experience in Landsat image processing, the following general data format guidelines emerge:

- Open workspaces must exist within the tape format so that all subsystems in a data processing chain could easily append, delete or modify information
- The tape format should be organized and segmented along the following logical lines:
    1. The first information encountered should be introductory and provide self identification standards in byte convention
    2. Afterwards a generic description of all data fields and data within those data fields should be provided in standard byte conventions
    3. Specific information should be provided to decode and interpret data fields and data within those data fields in byte conventions
    4. Ancillary and annotation information should be provided in compact form to accompany the actual imagery
    5. The imagery itself should be presented in a compact form with a minimal amount of unique identification
    6. The blocking of data should be optimized around the units of imagery acquisition
    7. A summary should follow to conclude a major image data set

The implementation of the above guidelines are shown in Figures 1 through 3. Figure 1 illustrates the organization and structure of individual CCT records. Figure 2 shows a high level layout of a multispectral CCT with detailed CCT features shown in Figure 3. Examples of three possible arrangements (or interleaving) of Landsat MSS image data are presented in Figure 4. More detailed information concerning these features are found in the "Quick Look Processor CCT Data Format Specification" dated July 31, 1975, prepared under contract NAS5-24033, Mod 26 for GSFC by Operations Research, Inc.

It is planned to introduce the proposed formats in 1978 as a new digital Image Processing Facility (IPF) becomes operational at GSFC. As a first step in the systematic approach to image data format standardization, a data format which meets the general requirements will be introduced by NASA, the U.S. Department of Interior's EROS Data Center,

TABLE 1

EARTH OBSERVATION IMAGE DATA FORMAT DRIVERS

- MULTIPLE IMAGE SENSORS
  - LANDSAT (MSS, RBV)*
  - NIMBUS (CZCS, THIR)*
  - SMS (VISSR)*
- VARYING SENSOR CHARACTERISTICS
  - NUMBER OF SPECIAL BANDS (1-10)
  - NUMBER OF PIXELS/LINE (1,000-20,000)
  - NUMBER OF LINES/SCENE (1,000-20,000)
- MULTIPLE USERS
  - R & D
  - PRODUCTION
- VARIOUS USER PROCESSING REQUIREMENTS
  - MULTISPECTRAL CLASSIFICATION
  - BLACK & WHITE FILM PRODUCT GENERATION
  - FALSE COLOR COMPOSITES
  - SPATIAL FILTERING
  - PATTERN RECOGNITION
- DATA VOLUME
  - HIGH IMAGE DATA VOLUME (10^7)
  - LOW ANCILLARY DATA OVERHEAD
- MULTISPECTRAL IMAGE DATA FORMATS
  - BAND INTERLEAVED BY LINE (BIL)
  - BAND INTERLEAVED BY PIXEL (BIP)
  - BAND SEQUENTIAL (BSQ)

* MSS – MULTISPECTRAL SCANNER
RBV – RETURN BEAM VIDICON
CZCS – COASTAL ZONE COLOR SCANNER
THIR – TEMPERATURE HUMIDITY INFARED RADIOMETER
VISSR – VISIBLE AND INFARED SPIN-SCAN RADIOMETER

FIGURE 1.

CCT RECORD FORMATS

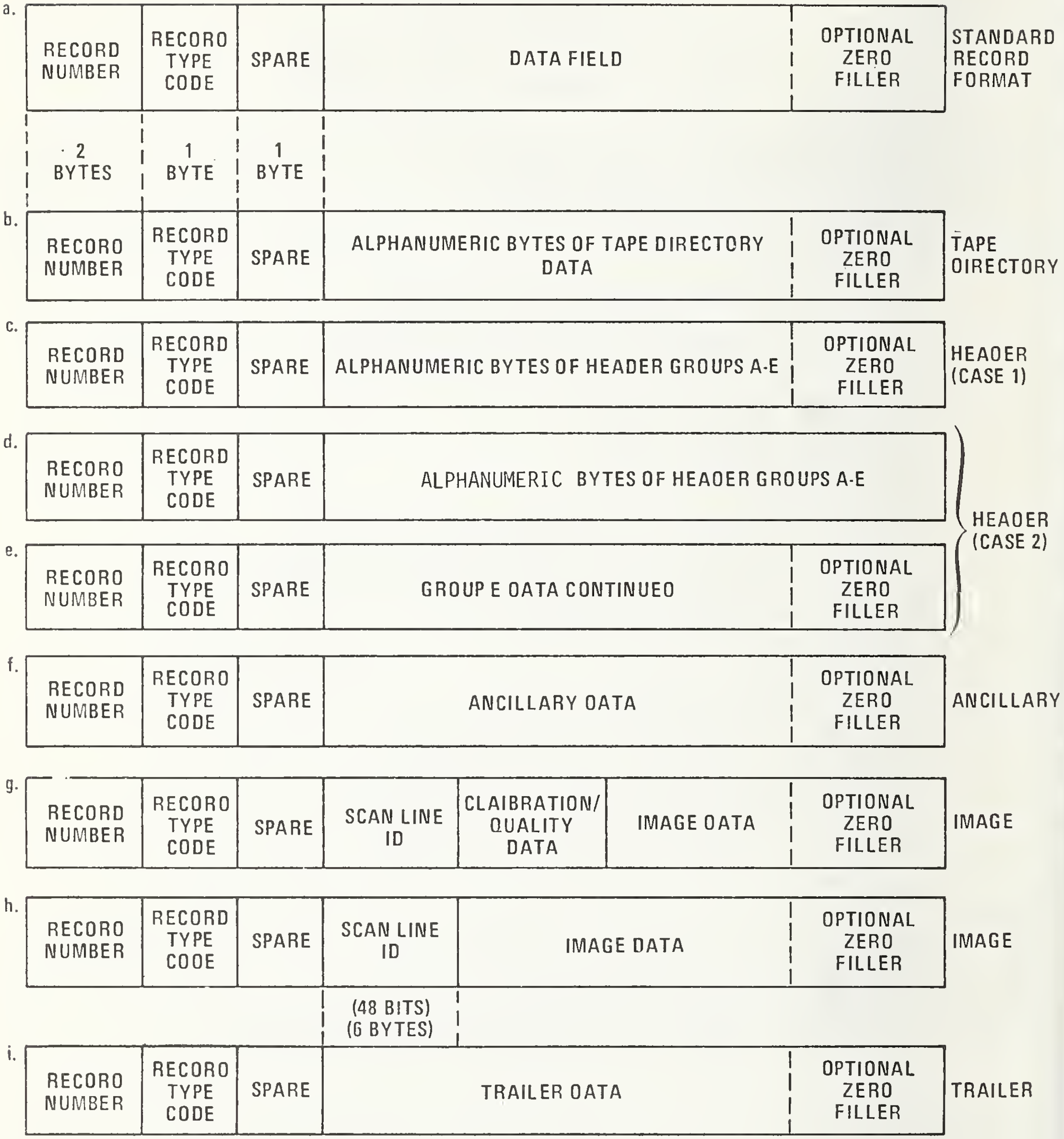


FIGURE 2.

HIGH LEVEL REPRESENTATION OF A MULTISPECTRAL CCT

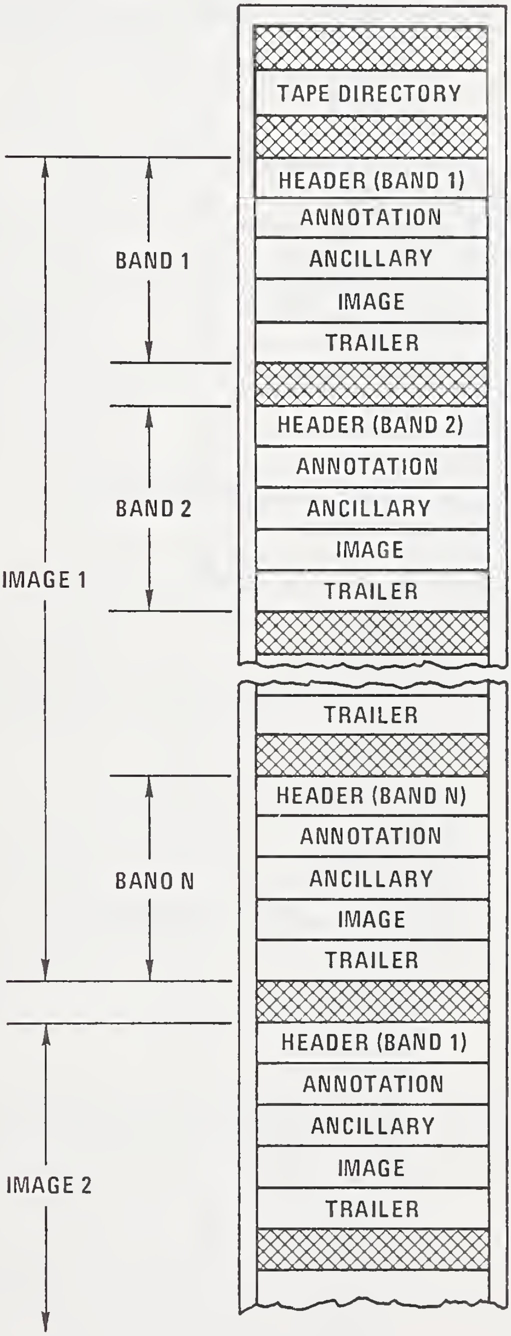


FIGURE 3.

DETAILED CCT FORMAT

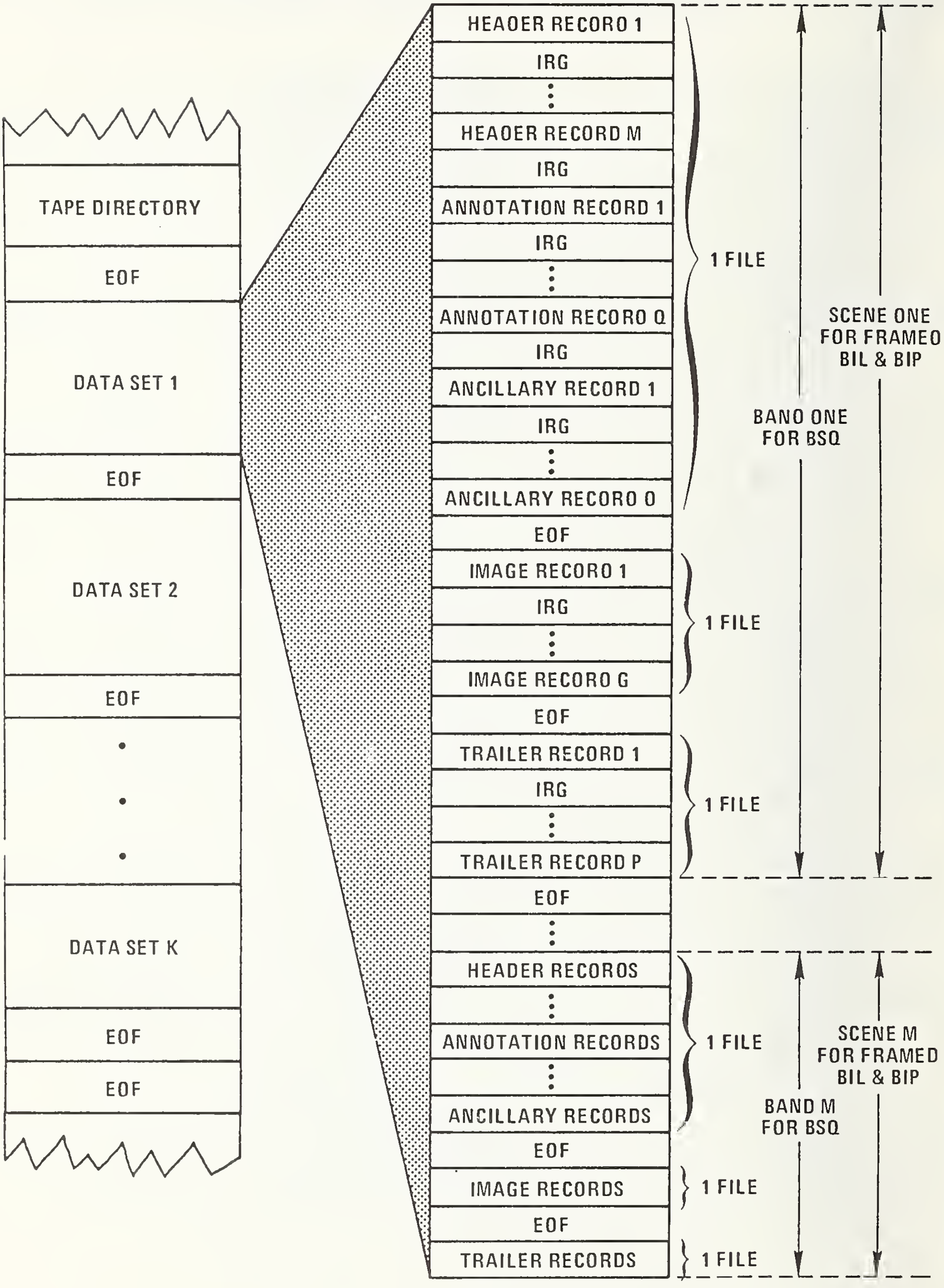
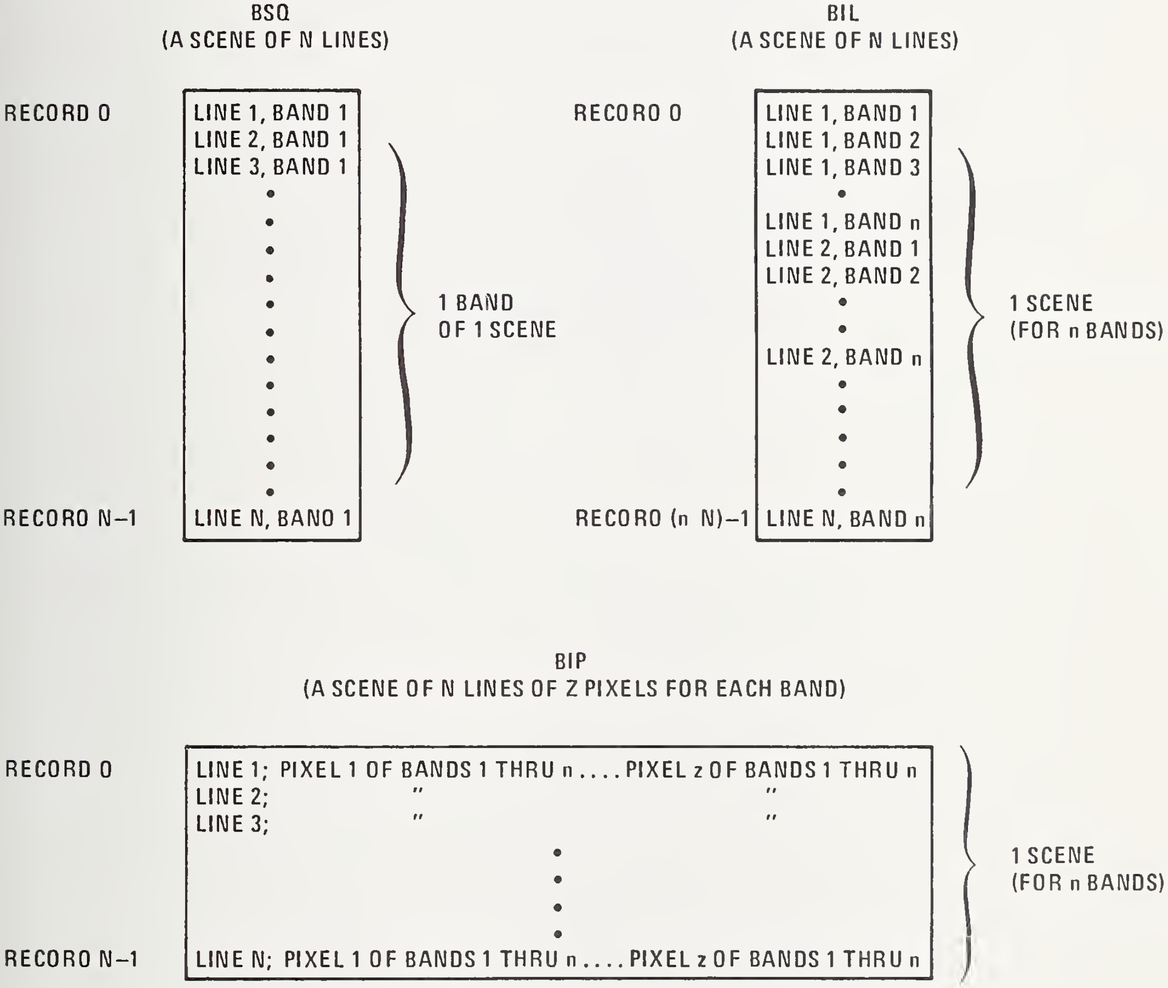


FIGURE 4.

THREE ARRANGEMENTS OF MSS IMAGE DATA



and the Canada Center for Remote Sensing late this year. This format however will be limited to the Band Interleaved by Line (BIL) format of Landsat MSS image data and will not contain several features such as the record number field, record type code, and the spare data field as shown in Figure 1. This specific format is described in the following two documents: 1) "Format Specifications for Canadian Landsat MSS System Corrected Computer Compatible Tape", Research Report 75-3, dated July 1975, by the Canada Center for Remote Sensing, Department of Energy, Mines, and Resources, Ottawa; and, 2) "Format Description of the U.S. Landsat MSS Universal Computer Tape", by Lottie E. Brown, GSFC Document X-563-76-40, June 1976, (to be released July 1976).

IMAGE CONTENT AND STRUCTURE

Chairpersons: Azriel Rosenfeld, University of Maryland
Russell A. Kirsch, Applied Mathematics Division, NBS

Panelists: M. A. Fischler, Lockheed Research Lab
K. S. Fu, Purdue University
J. O'Callaghan, CSIRO, Australia
R. F. Sproull, Xerox Corp.

Image Content and Structure

Chairpersons: Azriel Rosenfeld and Russell A. Kirsch

To make images maximally useful for interchange, it is necessary for the provider of the data to furnish descriptions of the image content. At the simplest level such descriptions refer to the image as a whole, but most interesting and important image sources require articulated descriptions of the image structure giving the relations of the parts of the image as well as their names. Such image descriptions are useful not only for image data base management, but also as standards for evaluating the success of pattern recognition algorithms.

One current research problem is the development of suitable languages in which to embed descriptions of image content and structure. This session of the Workshop was devoted to a discussion of the status of research and related work in graphic languages to provide the needed basis for image content and structure description.

The panelists were Dr. Martin A. Fischler from Lockheed Research Laboratories, Professor K. S. Fu from Purdue University, Dr. John O'Callaghan from Commonwealth Scientific and Industrial Research Organization in Australia, and Dr. Robert F. Sproull from Xerox Corporation. The Chairpersons of the session were Professor Azriel Rosenfeld from the University of Maryland and Russell A. Kirsch from the National Bureau of Standards.

Rosenfeld began the session with a set of cautionary remarks concerning the difficulty of image description. At the first level, descriptions can be associated with whole images; an example of such a description would be the kind of header information included in the tape formats that were described in the previous session, but the typical header would not include subject matter associated with the content of the image. Furthermore, the content can include anything, and may have various interpretations depending on who the user is for an image. At a somewhat deeper level of description, images can be described in terms of the names of their parts; map overlays are a good example. But here we confront the problem that noise for one purpose may be signal for another. Furthermore, the parts of objects in real world images are very often fuzzy with respect to their boundaries. Finally, specialized descriptions can be very subtle, and they can be nonsyntactic, referring to extra-pictorial information. The very general purpose descriptions, for example, "to the left of," can be very difficult to implement in recognizers. (Winston at MIT discussed this example in his Ph.D. thesis).

Dr. Fischler then discussed scene description for images of real scenes. After distinguishing scenes from their images he discussed the possibility of describing scenes with picture description languages. Since a picture description language describes a single image and does not describe all aspects of a real scene, for example, hidden objects and hidden relations, it seems difficult to see how a picture description language can be used to describe a real scene. Furthermore, insofar as a picture description language is symbolic, there are many implied relations in the real scene which cannot be represented in the symbols unless the symbols themselves are isomorphic with the real scene. He then discussed certain psychophysical visual illusions, and argued that image perception includes the consequences of visual illusions which must also be comprehended within image description. He suggested that although symbols might be difficult to use in describing pictures, the pictures themselves or pictorial counterparts such as overlays might serve such a purpose. In the discussion Dr. Sproull pointed out that one should be concerned with either describing pictorial scenes or psychological artifacts, not both simultaneously, and that the problem of describing scenes can be separated from that of describing the perceptual processes for viewing them. Dr. O'Callaghan suggested that once the context for describing an image is given, this simplifies the problem of one image being many things to many people.

In Professor Fu's discussion he directed his attention to hierarchical languages. A description that might be good for characterizing the structure of an image might not be good for classification purposes. He showed tree and graph structures for describing images and gave examples for both earth satellite imagery and for fingerprint classification images. He showed how a fingerprint may be partitioned into disjoint regions which can themselves be easily classified, although this partitioning does not correspond to that used by fingerprint experts. He showed a similar graph structure for describing a LANDSAT picture classified for land use purposes.

In Dr. O'Callaghan's remarks he agreed that descriptions are relative to the context and purpose that they serve. However, for certain pictures, we can sufficiently describe the context and purpose to enable structural descriptions to be furnished. Such structural descriptions can be based on objects, relations, and their attributes. Although such descriptions can be adduced from images, the descriptions cannot necessarily be used to direct automatic analysis or synthesis of images. Dr. O'Callaghan made the important distinction between picture description languages which can be processed by computer mechanisms and those which need not have computer implementations if they are to serve as the basis for human interchange. He exhibited a solution to the problem of image content and structure description in the application of wood morphology, in which he exhibited the microstructure of wood tissue in terms of the constituent parts and their relations. In the discussion David Milgram commented that there is a conflict between Professor Fu's computer languages and O'Callaghan's human languages, one presuming the possibility of computer implementation and the other making no such presumption. Fischler agreed that there need not be a single universal language ranging over different subject matters and ranging from computers to people. John Dehne concurred that there are perhaps two kinds of languages, those for describing a class of images and those for describing a particular one.

Dr. Sproull began his remarks by pointing out that some people believe if you can understand something than you can synthesize it. This is somewhat the approach taken in the computer graphics field with respect to image synthesis. However, in computer graphics, the effects depend more on iconic properties than they do on realism. He gave a brief survey of computer graphics activites in the areas of modeling and description, which are mostly concerned with geometric and topological properties, and hardly with photometry; in the area of image synthesis, which has dealt primarily with such problems as hidden line and hidden surface removal; the area of synthesis and analysis, in which the key to analysis of images is a comparison at higher levels than the individual pixels of image pairs; and finally, the area of representation, in which the different types of data structures that serve for computer graphics purposes were described. He summarized the problem of structural characterization as the problem of deciding what questions should be asked of an image. Once such a decision is made, the problem of structural characterization becomes simplified.

Kirsch concluded the session with some remarks concerning description of actual scenes. He suggested that very few serious attempts have been made at describing real scenes. Most such attempts have been concerned primarily with artificial scenes as in the computer graphics area. O'Callaghan's example for wood morphology would be one of the rare instances in which a successful attempt has been made. With respect to mechanisms for picture description he offered a caveat to Sproull's proposal that programming languages be used since programming languages are sufficiently powerful that structural descriptions embedded in them need not lead easily to analysis procedures. He suggested that Fischler's difficulty in including psychological properties in image description goes beyond the purposes the image description should serve. He concluded by suggesting that the question of whether image content and structure can be described in suitable artificial languages is still an open question largely through lack of serious large scale attempts to deal with the question.

ON COMMUNICATING ABOUT PICTURES

Martin A. Fischler
Lockheed Palo Alto Research Laboratory

This session of the workshop is concerned with evaluating the prospects for finding a suitable Picture Description Language (PDL) to facilitate communication among Image Pattern Recognition (IPR) researchers. It is therefore appropriate to ask whether such a language is necessary, and what specific functions it could serve.

Specification of Classification Rules

The most obvious use for such a language would be to specify classification rules for the imagery being processed. However, a representational scheme general and powerful enough to effectively satisfy this objective would probably also provide a solution for most of the remaining IPR problems (a rather ambitious goal). If such a scheme lacked the required generality, it would hinder rather than aid communication. While the near term prospects for finding such a language do not look promising, it is still useful to consider what characteristics such a language must have.

Description For Scene Reconstruction

A second possible use for a PDL is related to the fact that in most current IPR work (especially by workers having a "syntactic" orientation), no distinction is made between a scene and an image. Indeed, for line type drawings, there is no difference. However, for real (or natural) scenes, a single image is not an adequate representation for many purposes (e.g., for determining whether or not two images correspond to the same scene). Not only does a real scene have a 3-dimensional aspect which cannot be captured in a single image, but most scenes are dynamic entities to some extent (e.g., leaves on trees appear and disappear with the seasons, move in the wind, etc.); further, an image is a function of the sensor, illumination source, transmission medium, and a host of other factors in addition to the actual scene content.

If, as indicated above, we cannot adequately describe a scene with a single image, then how can an IPR researcher communicate or record a suitable representation of the subject of his investigations. Perhaps some PDL, or more likely, a combination of both imagery and linguistic representation can prove suitable.

Desirable Characteristics of a PDL

Let us now address the question of the characteristics of a PDL which could simplify the two scene description tasks mentioned above (i.e., specification of classification rules, and description suitable for scene reconstruction). In particular, can a purely symbolic language (i.e., one in which the relationship between the symbolic tokens and their real world referents is completely arbitrary) serve this function? We might note that in spite of the combined power of natural English and mathematical notation, we still find it difficult to communicate about many subjects without resorting to graphics and use of pictorial materials. Symbolic languages pose three problems which I believe makes them (by themselves) unsuitable for general picture description.

These are:

a) The need to explicitly enumerate the various relationships between scene primitives, as well as the need to define and completely decompose a scene into these primitives. This is a task which is not practical for typical natural scenes.

b) The requirement for the satisfaction of the implicit assumption that the number of variables needed to describe a scene is relatively small. Symbolic techniques do not lend themselves to effective procedures in large number-of-variables problems. There is no reason to believe that natural scenes (e.g., terrain scenes) can be encoded into messages containing relatively small numbers of variables without significant loss of information.

c) Our lack of knowledge, or inability to describe, the psychological correlates of a pictorial object. E.G., we are often surprised or amused by optical illusions, impossible objects, etc. Any representational form which is insensitive to such information will prove defective in applications where human response to pictorial data is a consideration.

Thus, if it is indeed the case that we cannot completely replace pictures with strings of abstract symbols (and this is the approach taken in almost all current research on computer based picture languages), we must see what can be done to use some combination of symbols and pictures, to communicate about pictures. A combined approach is probably necessary, since pictures (or picture segments) are limited in their ability to imply scene content which is not explicitly visible, while as noted above, symbolic description cannot cope with the undirected complexity and psychological implications characteristic of natural scenes.

Conclusions

In conclusion, I believe that our current state of knowledge about how to characterize natural scenes is inadequate to anticipate near term standardization of methods for communication about such scenes. However, I do believe that it may be possible, at this time, to specify minimal criteria for documenting IPR work employing such scenes. To the extent that we restrict our attention to artificial scenes, special applications, or line type drawings, standardization of communication using a symbolic PDL may be currently possible; but even here, the value of such standardization to the IPR community as a whole is open to serious question.

SYNTACTIC APPROACH TO THE DESCRIPTION OF IMAGE STRUCTURE AND CONTENT

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Syntactic approach to the description of image content and structure is discussed. Image structures can be described in terms of trees and graphs with nodes representing pattern primitives and subpatterns; and branches representing relations between subpatterns and primitives. Image content can be described in terms of the features or attributes (geometric and/or texture measurements) of the primitives and subpatterns. These feature measurements could be interpreted as the semantic information of primitives and subpatterns. The information of structure and content can also be used for image data management (storage and retrieval). The correctness and/or classification of such image content and structure description can be verified from the grammar generating the tree or graph structures with the associated semantic conditions. Examples are given to illustrate this approach.

LANGUAGES FOR IMAGE CONTENT AND STRUCTURE

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The following statements outline my position:

1. Research in picture interpretation and graphics has developed various languages and representations for images (e.g. tree, array, plex, web grammars). Such representations are predicated on structural frameworks of objects, their parts, relations and attributes. An image may be described by presenting the representation at a certain level of detail or by relating one representation to another.
2. Most research efforts have been confined to restricted classes of line drawings, using well-defined geometrical relations. It has proved difficult to computationally define descriptions which are meaningful for humans and which account for 'real-world' data. One problem is the ambiguous nature of the data amongst different observers.
3. Attempts to automatically extract (or synthesize) descriptions for given images have largely failed. A major reason has been the problem-solving nature of the extraction process, requiring information not usually supplied with structural representations.
4. Given the status of research, descriptions of images for interchange must be considered within restricted domains and purposes (e.g. chest x-rays for demonstration of lung cancer), where a context for term definitions could be unambiguously established. It would not be possible in general to automatically extract descriptions of content and structure from image data. However, it is conceivable that such descriptions could be transported and interrogated as a data base in a restricted dialogue.

Constructive Descriptions of Images

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A common method for documenting the structure of an object is to document the process of constructing it from a small set of primitive ingredients. Such structural synthesis of images is common in computer graphics, which has concentrated since inception on generation rather than analysis of images. This note recounts computer graphics techniques applicable to describing images but does not offer any new solutions.

The constructive descriptions used in graphics are often *abstract models* of a real situation: images generated from the models are intended to communicate information to a human who interprets the abstraction. For example, a computer model of an electronic circuit is often displayed using conventional abstract symbology of electrical engineering. The model may also contain additional information adequate for calculating the physical placement of components, the circuit response, or the manufacturing cost. The design of the descriptive model is governed by the information it must represent, that is, by the questions that are asked of the model.

We will survey two specific sorts of models that may be suggestive of ways to model the structure of some images. First, we can attempt to model physical objects and the processes by which images of these objects are made on the retina. The model, or information derived from it, yields information about the structure of the image. Second, we can use abstract graphics models to describe the image itself, independent of the processes that generated it.

Three-Dimensional Geometric Models

Techniques have emerged from computer graphics research for modeling certain three-dimensional objects and for producing somewhat realistic images of scenes composed of these objects. The geometric models of objects commonly use polyhedra, parametric polynomial surfaces and conic surfaces as primitive elements [11, 1]. Increasingly, computational geometric techniques seek to model complex objects or complex assemblies of objects by sequences of simple operations applied to primitive objects [2, 4, 8].

Current methods for synthesizing images from such models are compromises between efficiency and proper simulations of imaging [12]. Although some hidden-surface elimination techniques correctly solve the geometric problem of determining which surfaces are visible, only crude illumination models are used to calculate intensities on the surface. These methods are adequate for creating images intelligible to humans, but fall far short of simulations of reality.

To decide whether a model captures the structure of a *natural* image, we can compare the image with one synthesized from the model. The comparison can be done on the sampled image directly, or perhaps after some processing such as feature extraction [6, 3]. Errors detected by the comparison need to be related to an error in the model, which may represent a structural fault (e.g., omission of an object), or a less serious difficulty (e.g., improper illumination of an object). See Figure 1.

The practical application of these techniques is severely limited to a small class of scenes. However, the class increases as humans increasingly construct physical artifacts that have geometrical models: the number of bits used to describe the shape of a General Motors automobile descends as more of its parts are designed by a computer-aided-design system.

The class of images susceptible to synthesis from models can doubtless be increased by more research. For example, why is it not possible to build models of X-ray imaging processes and of chest cavities to describe a patient's chest and the corresponding chest X-ray? The benefits of a physical analog, the phantom patient, are evident in training radiographers.

Two-Dimensional Image Descriptions

If synthesis from a model of the scene is not feasible, it may be possible to describe the structure of the image as a synthesis of *regions*, each of which plays a structurally relevant role. We can describe a region by a description of the region boundaries, together with annotations which identify and describe the region and may relate it to other regions in the image. Boundary descriptions can be simple closed geometric figures (eg, polygons, conic sections) or sequences of primitive boundary elements (eg, lines parametric curves, or even points) [10]. It is a simple matter to determine from any of these descriptions which pixels lie within a region. The relations among regions contain valuable information about the structure of the image. See [8] for an example of two-dimensional region descriptions and of relations among the regions.

The region descriptions can be viewed as a set of "overlays," each of which describes a region of structural interest in the image. The spatial descriptions and annotations can also be viewed as a recipe for constructing the image from its structural components.

Representations

Straightforward representations of regions that are readable by both humans and computers are feasible. Perhaps the basic element of description is the *relation*; although the examples use the notation of Leap [7], the methods of relational data bases [5] are equally applicable. Relations are expressed as *triples* that relate three *items*: A ⊗ O ≡ V. This can be read as "A of O is V." An item may have a *datum*, consisting of numerical or string data to be associated with the item. For example, an item that represents a boundary might have as datum a string that gives the chain encoding of the boundary.

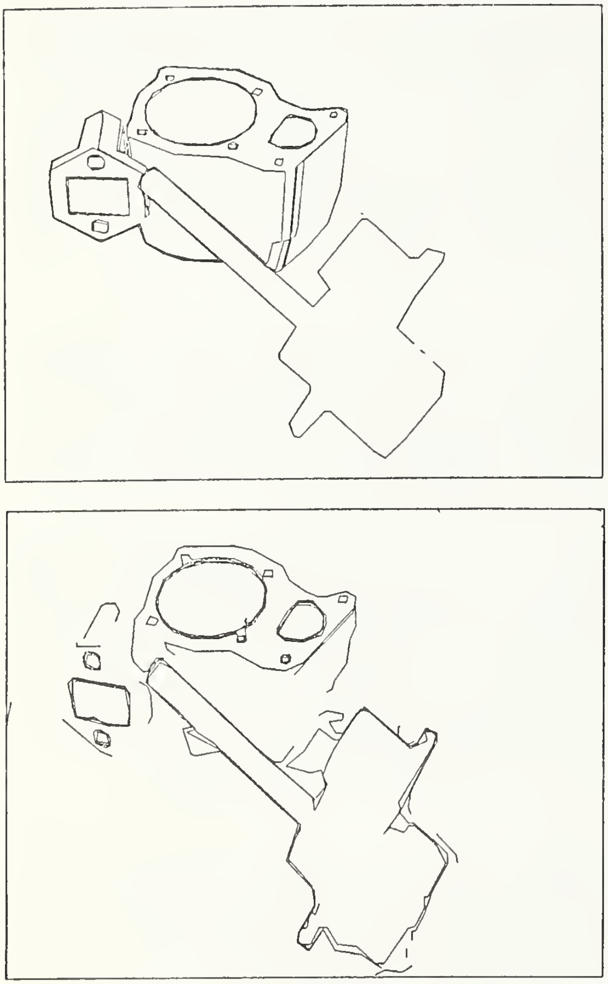

Figure 1. An example of comparing a synthetic image and an image derived from a natural scene. The top image is synthesized from a geometric model of a water pump and impeller; the bottom image is derived from a natural image of the scene. Taken from [3].

The simplified example below shows how one might describe an image consisting of a single cell. The boundary descriptions for the cell and nucleus have presumably been traced by an expert. Appropriate medical findings are also recorded:

; Description of the parts of the image.
PartOf ⊗ Image ≡ Cell1

; Description of the cell, and enumeration of its parts.
PartOf ⊗ Cell1 ≡ Membrane1
PartOf ⊗ Cell1 ≡ Nucleus1
Type ⊗ Cell1 ≡ RedBloodCell
Pathology ⊗ Cell1 ≡ Normal

; Relations between regions and structural parts (nucleus, cell)
Region ⊗ Cell1 ≡ Region1
Region ⊗ Nucleus1 ≡ Region2
Within ⊗ Region1 ≡ Region2

; Properties of regions
Boundary ⊗ Region1 ≡ Boundary1
Boundary ⊗ Region2 ≡ Boundary2

; Coding information for the boundaries of the regions
CodingType ⊗ Boundary1 ≡ Chain
CodingType ⊗ Boundary2 ≡ Chain

; A chain coding (taken from Freeman)
datum(Boundary1) = "042600001042700003
22111070067655445442240400"
datum(Boundary2) = "042600003042700003
2210765530400"

This example shows but one of many possible ways to record information about the structure and relationships among regions of an image. For example, we could give a computer program that will synthesize a similar image, provided the program itself conveys structural information.

The appeal of descriptions such as these is that they can be reasonably understood by humans, and, if properly designed, can be read and processed by computer. An image can thus carry with it a data base to which important questions can be addressed: it can record the analysis of expert observers of the original image. It should be feasible with present understanding to design a standard representation for this data base.

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DOCUMENTATION OF THE RECORDING ENVIRONMENT

Chairpersons: Judith M. S. Prewitt, National Institutes of Health
John M. Evans, Jr., Office of Developmental Automation
and Control Technology, NBS

Panelists: Wayne Huelskoetter, Dicomed Corp.
Kendall M. Preston, Jr., Carnegie Mellon University
James Greenleaf, Mayo Clinic
Werner Frei, University of S. California
J. K. Zieniur, Bureau of Radiological Health
Marvin Maxwell, National Aeronautics and Space Administration
Brent Baxter, University of Utah
Joseph Boccia, M.D., U. S. Army

Documentation of the Recording Environment

Chairpersons: Judith M.S. Prewitt and John M. Evans, Jr.

The objective of this session was to identify the common problems associated with the transformation from a physical object to a digitized image. Optics, electronics, analog-to-digital converters all influence the resulting data and their effects must be calibrated and documented to insure correct and successful subsequent processing in image pattern recognition work.

The session was organized as a series of eight presentations by speakers experienced in and expert in selected diverse and complementary aspects of this set of problems. The speakers discussed both the generic problems associated with image digitization and those specific problems associated with medical and satellite imagery applications.

The questions and answers for each topic follow the respective papers of the speakers. This format was adopted to keep the flow and relevance of the discussion in the context of the papers of each speaker.

CONCLUSIONS: Whereas the problems of geometric distortion, resolution, vignetting, amplifier and sensor non-linearities, and A/D converter errors are generally understood and recognized, there are, in general, no commonly used universal calibration test patterns or techniques to remove these effects from the final digitized image data. Every investigator makes the attempt to remove the effects of the recording environment, but there is a need for test patterns and calibration techniques, and for associated documentation, to provide better uniformity and higher quality in digitized imagery.

Universal test patterns for automatic image pattern recognition would fall into two classes:

First, for digitizing systems working from film: a checkerboard pattern with sharply defined grid edges, with stepped and continuous gray scale portions, and with a uniform gray border to detect vignetting.

Second, for microscopy: a similar pattern deposited on a microscope slide.

There was, in addition, discussion of calibration of ultrasonic pulse and imagery systems, but no clear consensus appeared on calibration techniques or test objects or images.

INSTRUMENT PARAMETERS IN IMAGE DIGITIZATION

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INTRODUCTION

Defining an image in digital form is a relatively straight forward process--or so it seems on the surface. The image or picture is simply subdivided into a number of points commonly referred to as picture elements or "pixels"; each pixel has a numerical number assigned to it representing the brightness of the image at the pixel point.

However, to extract useful information from the digitized image, it might be helpful to know a few parameters associated with the digitization process.

DIGITIZING PARAMETERS

Resolution

The first question usually asked relative to a digitized image is "what's the resolution?" The typical answer is "1024 x 1024" or "25 microns". Neither answer, of course, defines the resolution of the digitized image. In fact, the term "resolution" is one of the most confusing, misused and misrepresented parameters in digital image processing. Because of the large number of disciplines involved in the manufacturing and use of digitizing equipment, the variety of terminology of these disciplines compounds the confusion. The photographic expert feels comfortable with line pairs/mm or microns, while the computer scientist prefers a nice binary number. The electronic engineer may prefer TV lines/inch, and the optical engineer prefers MTF. Different equipment technologies make it more convenient to use one term as opposed to another. For example, the resolution of a microdensitometer is easier to describe in terms of aperture width, while with an electronic scanner using a TV tube, image dissector tube or CRT, it is more convenient to speak in terms of TV lines/inch.

Rather than launching into a lengthy discussion of the merits and problems associated with the various terms currently used to define resolution, let's take a look at a set of parameters to be used to define the resolution characteristics of a digitized image which can be applied regardless of the scanning or digitizing device employed.

1. Scanning matrix:	The number of pixels per line and number of lines per image (i.e., 1024 x 1024, 480 x 1240, etc.)
2. Pixel size and shape:	The actual size referenced to the film plane specified in microns. The shape (circular, square or rectangular) and the intensity distribution should be specified.
3. Pixel spacing:	The distance between adjacent pixel and adjacent lines as measured between centers and specified in microns or millimeters.
4. Scan area:	The dimensions of the area scanned in millimeters.

Photometrics

The most common way of specifying the photometric characteristic of a pixel, and hence the digitized image, is the number of gray levels; i.e. 64 (6-bit) or 256 (8-bit). While these numbers are meaningful, they tell only part of the story. It is also necessary to know if the levels are transmittance or density levels, or some other function of input codes. Signal to noise (S/N) ratio of the digitizing equipment is also an important consideration. For example, one could hardly expect 256 accurate levels with a signal to noise ratio of 100 to 1.

If an electronic scanner is used, it may also be necessary to know the uniformity of the scanning system. This is usually expressed as a percentage. Therefore, to adequately describe the photometric characteristics of an image, the following information should be provided.

1. Transmittance or density levels: i.e. 64 or 256
2. Signal to noise ratio (S/N): db
3. Density range of image: i.e. 0.02 - 1.5D
4. Digitizing system uniformity (if applicable)

The digitization of a color image adds another parameter to be concerned about--spectral response of the sensor, the color filters, light source, etc. In other words, it takes more than simply digitizing the image three times through red, blue and green filters. Unless the spectral response of the digitizing system is reasonably equal, relative to the red, blue and green components, the resulting digitized image will not be an accurate representation of the image.

Geometrics

For many applications of digital image processing, particularly those involving measurements, the geometric accuracy of the scanning system is important. Geometric parameters of importance include:

1. Orthogonality between X and Y axis: specified in degrees.
2. Rotation of scan lines to film.
3. Scan line curvature: percentage deviation from a straight line.
4. Scan line linearity: percentage deviation from an ideal pixel to pixel spacing.

It is also important to understand how the various parameters are defined and measured for a particular device. Numbers without definitions are meaningless.

Other Considerations

The parameters of resolution, photometrics and geometrics as described above will adequately describe an image in most cases. However, some applications may require knowledge of the stability, repeatability and drift of the digitizing device used. These characteristics become very important when digitizing color images since usually three scans of the image are required. Any drifting in the spatial positioning or scan position due to color shift through the filter can be significant.

The speed of the digitizing device is, or course, an important throughput parameter for the person doing the scanning. However, once the data has been recorded on tape and sent to another person, the speed has little significance. Therefore, except to the extent that the scanning speed has a direct effect on S/N (in that case the S/N ratio pertaining to the scan speed should be referenced), it is not a parameter needed to define the digitized image.

SUMMARY

As we all know, no digitizing device is perfect. Each has advantages and disadvantages, and trade-offs must be made based on the needs of the application. The resultant digitized image will be distorted to some degree. Therefore, it is important to understand characteristics of the digitized image in terms understandable by all of the recipients of that digitized image. The parameters discussed above and summarized below should, in the majority of cases, define the image independent of the scanning techniques.

1. Resolution
   a. Scan matrix
   b. Pixel size and shape
   c. Pixel spacing
   d. Scan area
2. Photometrics
   a. Transmittance or density levels
   b. Signal to noise ratio
   c. Density range of image
   d. System uniformity
   e. Spectral response (color)
3. Geometrics
   a. Orthogonality
   b. Rotation
   c. Scan line curvature
   d. Scan line linearity

Just as in the evaluation of music where the quality is determined by the pleasure of the listener, the quality of the digitized image will be determined by how well it fits the needs of the user.

Discussion

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Diecomed Corp.

Instrument Effects in Digitizing an Image

Question: These effects are difficult to measure. Is a universal test image possible?

Answer: Ronchi rulings are now often used. A universal test image may be possible.

Comment: In digitizing photographs using a drum scanner, sudden intensity changes lead to transient distortions because of inevitable instrument response time constants. This implies a variable signal to noise ratio.

Question: How accurately can you return to the original pixel?

Answer: In electronic systems, after warm up, you can get back pretty well (±1 pixel.)

Question: What do you mean by 25 micron spot size?

Answer: This is a convolution of the instrument function with the source function, which is a smoothly peaked function. Spot size obviously depends on where you make your measurements, for example, half width at half maximum.

Question: What about modulation transfer function (MTF)?

Answer: Can use MTF but it doesn't always mean anything. We have tried to use it.

Comment: Resolution and grey scale interact.

Answer: Yes.

Question: One must distinguish between resolution elements and pixels. S/N ratios are defined only in a resolution element. This is particularly a problem for opaque material because you can't get opaque scanners. How do you define total resolution?

Answer: You can use a test image.

Question: How much resolution do you need in the test image?

Answer: That depends on your need. You don't want to overdo it. People don't analyze their requirements. The best resolution may not imply the best instrument for a given application. For example, a system with given resolution may have to run much slower than another to get the same S/N ratio.

CALIBRATION OF TELEVISION MICROSCOPES

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1. INTRODUCTION

With the commercialization of clinical television microscopy as regards automatic cell analysis and hematology, about 1 billion cell images are digitized and processed each year in the United States. Proper calibration is necessary in order to assure the reliability and repeatability necessary to produce valid cell identifications in these machines. In these microscopes image information is transferred from the object (a cell) on the microscope slide via the imaging optics into image space using electromagnetic radiation in the visible portion of the spectrum. Calibration of this process must include data on colorimetry, resolution, linearity, and dynamic range. It is the purpose of this paper to outline certain calibration techniques which are used for this purpose.

2. SCANNERS

There are two primary types of television microscope scanners. One is the image plane scanner; the other, the flying-spot scanner. In the image plane scanner, the light detector lies in the plane which is conjugate to the eyes of the viewer. Such a configuration is easily instrumented using standard commercial microscopes and taking advantage of the trinocular tube which is ordinarily used for photomicrography.

The flying-spot scanner differs from the image plane scanner in that the illumination source is placed in what is usually the image plane of the microscope. The microscope optics form an image of this plane onto the specimen. The size of the source is kept small (equal to 1 picture element in diameter) which leads to the name "flying-spot". Light transmitted through the specimen on the microscope slide is collected by the microscope condenser optics, which, in turn, cause it to impinge on the light detector. Flying-spot scanners are easily implemented using cathode ray tubes placed in the image plane with the illumination directed down the trinocular to the specimen. An excellent survey paper describing such scanners is provided by Mansberg and Ohringer, An. N.Y. Acad. Sci. 157, 5-37 (1969).

Modern scanners (especially commercial scanners for cytology automation) operate under control of a digital processor. Also included is automatic transport of the microscope slide which, of course, includes both automatic focusing and the automatic location of cells on the surface of the slide itself. The systems use closed-loop focusing mechanisms which maximize the high video frequencies in the television signal. Some systems are capable of maintaining focus within a few microinches.

3. CALIBRATION OF IMAGE QUALITY

There are four methods of documenting the recording environment as far as the performance of the scanning mechanisms is concerned: (1) Resolution calibration, (2) Color calibration, (3) Calibration of linearity, (4) Calibration of dynamic range.

Resolution may be calibrated quantitatively by measuring the modulation transfer function of the system using either bar or sinewave targets or by producing images of fine structures such as diatoms. Unfortunately, the modulation transfer function varies across the field of view and mechanisms such as the contourgraph must be used to determine system performance across the entire field of view.

Colorimetric calibration is usually performed in a global fashion using a prism or grating monochromator. This device measures the overall spectral response including the spectral output of the light source and the spectral sensitivity of the photodetector. Such calibration is necessary in order to compensate for varying levels of photon flux as the illumination wavelength is changed or as the color of the specimen changes.

Linearity and dynamic range are usually calibrated simultaneously by varying the photon flux through the optical system at fixed colors or over the entire spectrum. In order to simplify the calibration the entire spectrum white light is frequently used and the mechanism for varying level is the so-called "neutral density filter". The output of the detector is measured as a function of photon flux. At the same time noise measurements are performed in order to determine the calibration uncertainty. This latter measurement must be accompanied by a measurement of the bandwidth of the associated video amplifier.

4. CONCLUSIONS

In order that images digitized either by flying-spot or image plane television microscope scanners may be validated for use in experiments in image enhancement, image bandwidth reduction, image transmission, and in image mensuration for the purpose of pattern recognition, a set of standardized tests should be established which will define the recording environment in as quantitative a manner as possible. The spectral response of the system should be determined in a relative manner either using standard color filters or a monochromater of a standard slit width (expressed in equivalent nanometers). This will permit a correction of the stored image for the spectral sensitivity of the scanning detector as well as the spectral emissivity of the associated light source.

In addition it is necessary to calibrate resolution and modulation transfer function, both of which can be done by the simple expedient of scanning a knife edge at different parts of the field or by producing a contourgraph. The Laplace transform or a Fourier analysis of this step-function response is all that is required to determine the MTF. Lastly, dynamic range and linearity may be determined using an appropriate set of neutral density filters.

Periodic calibration is necessary (ideally before and after image digitization) so that the images archived may be standardized. Furthermore it might be opportune to use standard color images over standard fields of view in order to check noise on the picture element by picture element value. This, however, is difficult in that it presents severe alignment problems.

It is hoped that this short description of calibration problems and some of their solutions will be found useful in establishing a television microscope image data base for use in picture processing and pattern recognition not only for cell images but also for use in other types of imaging via the television microscope scanner.

Discussion

Ken Preston
Carnegie Mellon University

Calibration in TV Microscopy

Question: What can be done to achieve selective collection of data?

Answer: That depends on the example, For SEOS only 1% of the data is analyzed. This is an excellent example of the problem. However, no one feels burdened by this unused data. On the other hand, blood cell analysis is good: the microscope looks at millions of cells and outputs just five lines of print.

Comment: You need to know a priori what you're looking for to select out desired data.

Question: In measuring linearity, do you want geometric or gray scale pattern?

Answer: Gray scale. A checkerboard can do both.

Question: In calibrating these instruments, there is a need for protecting the public. Should the National Bureau of Standards do this?

Answer: The Federal Drug Administration has this responsibility under the Medical Instruments Act.

Question: Do you need color in the checkerboard test image?

Answer: No, a gray scale can be used with color filters.

Comment: A physical object is needed as a test pattern, not just a specification of line pairs/mm.

DIGITIZATION OF ULTRASONIC SIGNALS FOR BIOMEDICAL INVESTIGATION

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Transmission images obtained using x-ray energy are analogous to shooting particles through a mass of tissue and measuring the number of particles emerging on the other side. Acoustic energy, on the other hand, can be considered to be a mechanical disturbance of the material itself propagating through the entire body under investigation. Since the mode of propagation is the material itself, acoustic energy interacts very intimately with the material properties of the tissue being imaged. Such strong interactions can sometimes reveal subtle alterations in tissue characteristics (1,2).

We have recently developed new techniques of imaging with acoustic energy which when applied under highly controlled conditions can obtain images representing the two-dimensional distribution of specific acoustic material properties within tissue. These methods are especially applicable to imaging of the material properties within breasts. Acquisition, analysis, image display, and processing of resulting images from such data requires standardization of the entire sequence of processes.

My remarks here will concern only the environment within which the data are collected and not object descriptions or classification. Acoustic images obtained from digitized signals consist of values derived from analysis of, or operations on, digitized signals obtained from acoustic transducers scanned spatially over known positions on a boundary around some portion of the object of interest. Elements of the set of activities required to obtain data necessary for acoustic imaging are: 1) acquisition of the fundamental acoustic signals, 2) digitization of the signal, 3) measurement of information concerning the transducer characteristics, motion, and associated lenses, and 4) performance of the analysis techniques utilized to map the raw data into the final image or images.

Acoustic signals received from transducers represent pressure amplitude as a function of time. Very often, in addition to the amplitude of the received signal, one must also know the time at which the transmitter was pulsed. Transmission systems require, in general, arrival time information and are usually range gated so that only a portion of the signal time is utilized for subsequent analysis. On the other hand, echo systems can require digitization of the acoustic amplitude signal for a longer duration of time which will include all of the echoes returning from the region of interest.

The stored data are the digitized version of the raw signal or some other function of the received amplitude signal which can represent actual amplitude digitized at a sample rate high enough to include all of the expected frequencies in the signal or it can include rectified, clipped or thresholded versions of the received signal. The digitized value can also represent simply the time of arrival of the pulse or the amplitude of the first pulse received. An example of a system for acquisition of acoustic signals from tissue within a sample holder is shown in Figure 1.

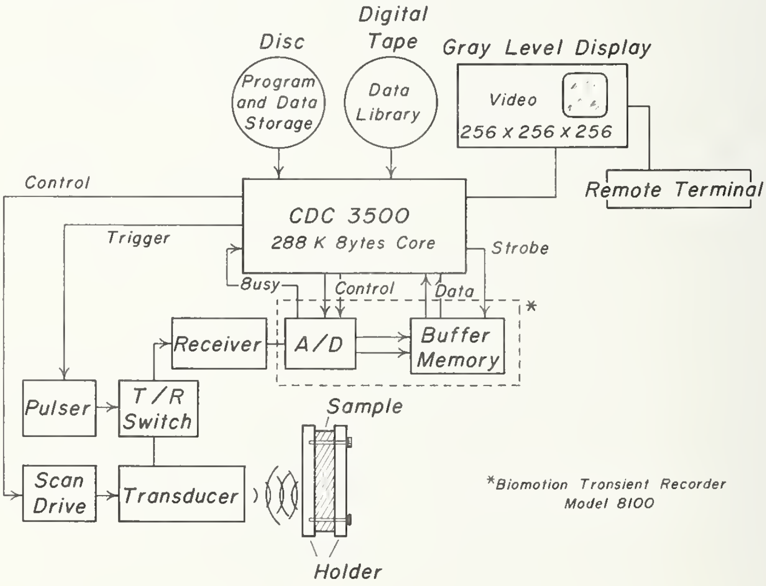

Figure 1 Computer-based system for acquisition, analysis, and display of ultrasound signals. Tissue samples, held between lucite plates are scanned with a computer-controlled scanner. Computer triggers transmit pulse and controls parameters of A/D conversion of

received signal (i.e., voltage range, sample rate, number of samples, etc). Digitized pulses from each position on 120 x 100 point grid are stored on digital magnetic tape for later display in B-, C-, or A-scan modes on gray level video display. System is controlled through remote terminal.

In addition to the digitized version of the signal, one must also record, or understand by convention, information concerning the transducer position and characteristics. Acoustic signals to be utilized for obtaining multi-dimensional images very often require extensive information concerning coordinates of the transducers which were extant during the transmitted pulse. Not only the three-dimensional position of the transducer but perhaps its orientation in space also may be required. Scaler calibration of the coordinate system can be included externally, that is, units of millimeters per pulse or internally with the use of ticks or internal fiducial marks within the image. Included in the required information are the transducer size, frequency response and whatever lenses may be utilized. Under certain circumstances, calibration of the voltage-to-pressure conversion parameters of the transducer may also be required.

The generation of quantitative images from digitized acoustic signals requires some form of calibration, either external or internal to the data, in order to convert the resultant pixel value used within the image to actual values of material properties within the imaged tissue. External calibrations may be included on the tape header such as the period of delay between the transmitter pulse and the digitizing window. Calibrations internal to the image, scanned at the same time as the tissue under study, may include acoustic data obtained from materials of known acoustic property which could then be utilized for obtaining conversion tables to relate the digitized samples to the corresponding tissue properties. An example of a device for obtaining both spatial calibration and material property calibration is shown in Figure 2.

Figure 2 Example of tissue holder used for acoustic evaluation of tissue. Circular chambers can be filled with materials of known characteristics and scanned along with the tissue (transverse section through canine heart shown). Subsequent analysis can utilize signals from known materials for calibration of parameters of acquisition system. Physical dimensions can be determined by using edges of lucite block for fiducial marks.

ACKNOWLEDGEMENT

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Discussion

James Greenleaf

Mayo Clinic

Images from Digitized Acoustic Signals

Question: What is the quality of calibration in your data library (for excised breasts)?

Answer: Very low. We are just getting data for developing pattern recognition techniques. Will eventually do in live breasts.

Question: What is your test object for a chromogram?

Answer: Hard saline, blood samples. These give you 0.1% on velocity. Attenuation is qualitative, not quantitative. Defining resolution is also hard because of lens geometry, etc. We want to see 1-2 mm objects with $v>v_{min}$.

Question: Do you do any in vivo measurements yet?

Answer: No.

Question: How does the reconstruction effect noise?

Answer: You have a convolution kernel, so you can unscramble the data. Jitter in arrival time results in noise in the velocity data.

A Suggestion for the Calibration of Digitized Imagery

by

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In recent years, advanced digital image processing and pattern recognition techniques have attained a high degree of sophistication. At the same time, a growing family of electro-optical image digitizers have appeared on the market, supplementing the experimental devices familiar to the researcheres in that field. Such devices have been naturally adapted to the particular applications considered, and their characteristics are just as varied as the particular designs and technologies employed.

Thus, it is an obvious and legitimate question to ask what a given image data set precisely represents, especially if that data set is to become a standard for a certain research community. Ideally, one would desire a noise-free measure of some physical aspect of an object or scene, as a function of geometric coordinates. The measure could reflect for example the radiant light intensity, the reflection coefficient or perhaps the x-ray absorbtion factor, depending upon the application. In addition, the physical quantity would ideally be band-limited to the Nyquist rate, e.g., contain no spatial frequencies above one-half the sampling frequency. Finally, the sampling pattern would approximate a two-dimensional array of Dirac pulses.

Clearly, such an ideal case is far from reality, as a number of distortions and violations of the sampling theorem are most likely to occur in the image acquisition and digitization process. The major factors obviously depend upon the particular devices used and can be any combination of the following physical limitations:

a) Optical degradations caused by the front-end imaging system, which can introduce geometric distorsions, aberrations and vignetting, as well as limit the spatial frequency content of the image.

b) Photographic non-linearities and film grain noise when a photograph serves as an intermediate information storage.

c) Aliasing, which occurs when the image being scanned is insufficiently band-limited.

d) Other spatial frequency degradations depending upon non-ideal scanning apertures.

e) Inhomogeneous target areas when the image is converted by television-type or image dissector analysers.

f) Non-linear electro-optical transfer functions and noise.

g) Incorrect spectral sensitivities in the case of color.

h) Inaccuracies of the A/D converters.

Unfortunately, the above factors are not easily tractable, even with the help of manufacturer specifications, perhaps because they pertain to a variety of fields and technologies, but also because some factors depend upon sometimes critical operator adjustments.

It is felt that a complete specification of such parameters would require exacting standards which may not be practical in view of the widely diverse systems and domains of application. Not only is it questionable whether all measurements can be done on systems in the field but it also appears that complete specifications, if available could be just as confusing as certain manufacturer's descriptions.

The alternative proposed here is that a series of images scanned on a given system at one time be accompanied by one or two test images of well-defined targets. Such targets can be easily designed to evidence possible geometric and other spatial degradations (aliasing, resolution, for example), in addition to a provision for grey-scale verification. It is perfectly conceivable that such test images can be used not only to check the data but also to restore the digital imagery by well-known image processing techniques.

An excellent example of this practice is offered by television engineering, which has been faced with similar concerns for several decades. It is believed that the concept could be adopted easily in the present field, because it provides an objective frame of reference at a very small cost and without the prerequisite of a very detailed knowledge of the physics and technologies relevant to the hardware configurations involved.

Discussion

Werner Frei
University of Southern California

A Suggestion for Calibration of Digital Imagery

Question: How about direct digitization of video tape or radio or TV signals?

Answer: You can start at the amplifier. There are electronic test signals for calibration from this point.

Question: Would you clarify the requirement for 4 extra bits for 10% accuracy?

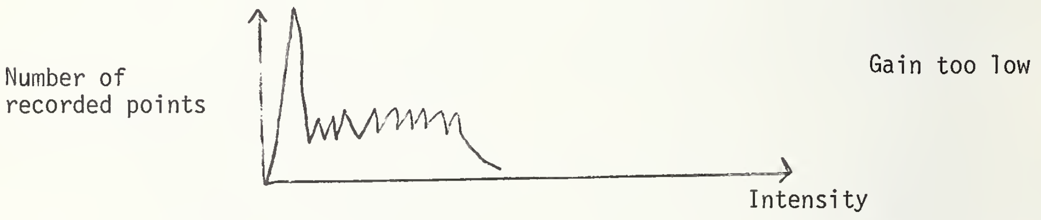
Answer: I can send you the reference.

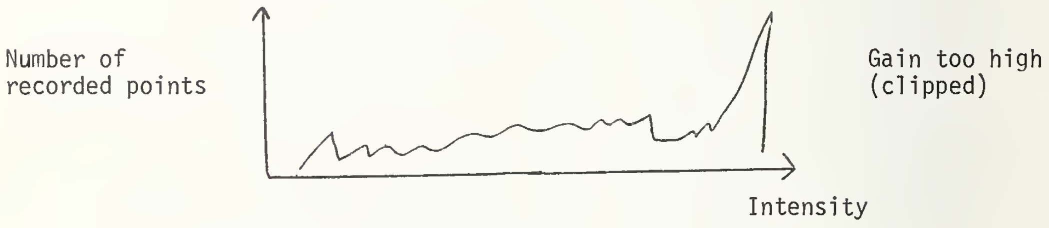
Comment: You need at least 2 extra bits.

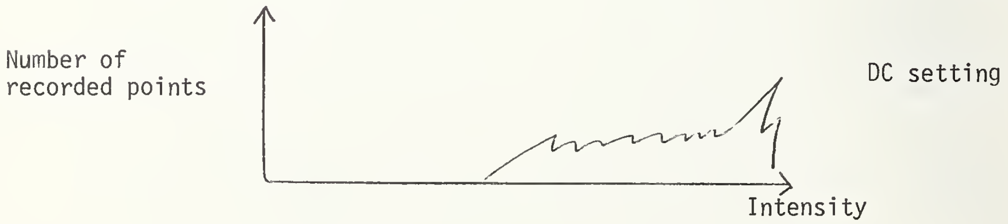
Question: Why can't you make the DC knob disappear by setting the zero level?

Answer: You can. You can avoid all of these problems if you are careful. It is careless operators that make problems.

For example, consider these problems as histograms:







Factors Which Influence Acoustic Images of Medical Objects

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The ultimate goal of ultrasonic imaging is to obtain a two dimensional representation of the anatomical region of interest containing as much information as possible. Many factors influence this image. Because this is a very broad and complicated topic, I will confine the discussion mainly to the physical factors.

Obviously any means of storing or manipulating the ultrasonic image should minimize the loss of pertinent information. I shall try to suggest factors relevant to this.

It is these factors that will be important in documentation of an imaging system. Any ultrasonic visualization system uses a transducer which emits a highly coherent beam of ultrasonic energy. Because of this high degree of coherence any discussion of such a system should adopt a Fourier optics approach. One should keep in mind however, the important differences i.e., in the acoustics case because of the longer wave lengths we encounter a different ratio of object dimensions to wave lengths.

In the case of a coherent system using acoustics optic, the limit of resolution is a function of the F-number of a lens and wavelength, λ, of the ultrasound wave. It usually is defined as $0.61\lambda F$, where F is the ratio of focal length to the lens diameter. This value depends on the phase difference of the two waves emitted by two point sources which are to be distinguished. But in any case the value given here is the smallest one. In the case of a scanning system using a single transducer or an array without any focusing devices the dimensions of an elementary spot depends mainly on the directional characteristics of the transducer(s) and the distance between the transducer and the receiver. Because of diffraction effects which in the case of the coherent wave plays a major role the dimensions of the elementary spot will always be bigger than that obtained with the focusing device.

The amount of information contained in the image depends on the spatial frequency range of the image. The cutoff frequency is equal to $L/2\lambda d$ where L is the diameter of the aperture (square or circle), λ is the ultrasonic wavelength and d is the distance between the aperture and the image plane.

During the storage process the image area has to be divided into elementary areas over which the amplitude is averaged. The sampling theory gives us information as to how large an elementary area may be and still preserve all information contained in the image. This theory states that if f_{max} is the highest spatial frequency encountered and L is the linear dimension of the image, the image should be sampled $4(f_{max}L)^2$ times. This forces the linear dimension of the elementary area to be no larger than $1/2f_{max}$.

Therefore the optimum storage of an ultrasonic image will occur if we have $4(f_{max}L)^2$ sample points. Since the dynamic range of the amplitudes in the case of medical applications can extend over a 100 dB range, it is important that the mode of display, storage or sampling device have as large a dynamic range as possible to avoid losing the information. In our discussion we have not yet taken into consideration the measurement time. For medical uses it is important to be able to perform investigations under dynamic conditions. Some existing devices are capable of forming images in 1/100 seconds. Storage devices should be able to store the above mentioned information in less than 1/100 seconds.

In the preceding discussion we have made the assumption that we wish to store a previously formed image, i.e., that formed on a cathode ray tube. The quality of this stored image is influenced by characteristics of the receiver as well as the storage devices. In some cases the receiver may degrade the image more than the storage device. In this situation it is desirable to feed the electronic signals to the receiver in the storage system in parallel mode.

The number and choice of the parameters which should be stored along with the image depends upon many factors. In routine work with one particular system it would be enough to record the intensity of the emitted wave, pulse length and repetition rate as well as electronic parameters which could be changed during clinical investigations. Also medical parameters should be recorded. In the case of research and development work many more system characteristics should be recorded. These should include all parameters influencing spatial frequency band, and amplitude or intensity distribution over the image surface.

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Discussion

Jersy Zieniuk
Bureau of Radiological Health

Factors which Influence Acoustic Imagery of Medical Objects

Question: What kind of a test object is used for ultrasonics?

Answer: Tried a test with wires. This worked O.K.

Question: How about velocity calibration?

Answer: We are not looking at a volume, only at a pellicle, so we only have relative amplitudes to consider.

Question: What kind of range, that is, distance from the object to the lens, do you have?

Answer: 2 cm.

Comment: Range depends on frequency. 30cm at 3MHZ and, for reflection, can go up to 10MHZ.

Documentation of the Recording Environment

by

M. Ritter and M. S. Maxwell

The panel's topic, "Documentation of the Recording Environment," covers the range of sources that, in remote sensing from satellites, distort and degrade the informational content of the original scene. These sources are numerous and highly variable in their effects, and are distributed through all phases of remote sensing from the initial generation of scene radiances with problem areas such as scene "noise" due to variable canopy cover and bireflectance properties in the case of agricultural products to data digitization, detector linearity and noise.

In a rough way, we may distribute the elements of satellite remote sensing into several general areas:

- Physical (Phenomenology)
  - Scene generation
  - Atmospheric propagation
- Acquisition
  - Sensor/scanning
- Signal Processing
  - Prefiltering
  - Sampling
  - A/D Conversion
  - Digitization
- Data Storage and Handling
  - Communication Links
  - Tape Characteristics
  - Reformatting
  - Interpolation Processes
  - Information Extraction

I shall discuss briefly two areas that impact strongly on the remote sensing chain. The first is compensation for the sensor system response, which is relatively easy to obtain, and to document. The second is the impact of the atmosphere on remote sensing, which is a more intractable problem.

Any sensor degrades the radiance pattern (and hence, the information content) of the scene under observation in many ways. Diffraction and aberrations of the optical train spread the energy from each point of the scene into areas in the image plane. The size of the detector elements and the smear that results from scanning the scene across the detectors further spreads the image. This situation is depicted in figure 1. The scene radiance pattern, for simplicity is taken as a vertical square wave bar pattern, (a). The discrete distribution of points in the image plane, (b), is the result of the finite number of ray tracings from a single point in the field. Counting the number of points per unit interval in a given direction yields a point spread function for that direction, (c). The interaction of the spread function with the scene radiance readily (in this case of a repetitive pattern) exhibits its dependence on the spatial frequency of the radiance distribution, (d), (e). A graph of the modulation function with spatial frequency is shown in (f). Representative modulation curves for the detector and scanning smear factor are also shown on this graph. The composite system modulation transfer function (MTF) for these three factors is the product of their individual MTF's and is shown in (g). In practice, the system modulation transfer function is a measured curve and includes the composite effect of all system factors. An equivalent measure is the composite system point spread function, (h).

The system point spread function is of direct interest to us for this discussion. It represents the fractional radiance "poisoning" each pixel gives and receives from its neighbors. With this detailed knowledge, the sensor data output can be reprocessed or restored to undue some or much of the radiance poisoning that resulted from the spread function. The degree of restoration is obviously signal to noise level dependent. This type of work is currently being carried out by Bendix for NASA on Landsat imagery in an effort to improve crop classification accuracy.

So much for the easy case. Let us turn to the impact of the atmosphere on the propagation of the scene radiance pattern. We had tacitly implied that there was no atmosphere in the first case, that is, that the scene radiance reached the sensor collector without alteration of spatial and spectral radiometric distributions. In actuality, the situation is complex, highly variable, and under certain conditions of significant magnitude in its effect on the information content of the scene. Elements of atmospheric scattering are shown in figure 2 . Absorptive processes, clouds, and cloud shadowing are not addressed. The specific intensity of the light at the sensor depends not only on the reflectivity of the object under view in the scene but also the solar illumination at the top of the sensible atmosphere, the scatter attenuation of this illumination as a function of the incident and emergent optical path lengths in the atmosphere, the path radiance due to atmospheric scatter, the albedo of the background and its scatter into the sensor's field of view. Further, the scatter function depends upon the aerosol content of the atmosphere.

To a first approximation, ignoring inhomogeneity and anisotropy, two known landmarks or training sites in a total scene would be sufficient to rectify the alterations due to the atmosphere, viz.

The irradiance at the sensor may be expressed as:

$$H_{\Delta\lambda} = \frac{\bar{\rho}_{\Delta\lambda} F_{\Delta\lambda} e^{-\bar{\tau}_{\Delta\lambda} \sec\theta}}{\pi} + \wp_{\Delta\lambda}$$

where $\bar{\rho}_{\Delta\lambda}$ is the average reflectivity in band

$F_{\Delta\lambda}$ is the impingent solar illumination

$\bar{\tau}_{\Delta\lambda}$ is the effective optical path length for band

θ is the sensor zenith angle

$\wp_{\Delta\lambda}$ is the path radiance

It thus follows that:

$$\frac{H_{\Delta\lambda_1} - \wp_{\Delta\lambda}}{H_{\Delta\lambda_2} - \wp_{\Delta\lambda}} = \frac{\bar{\rho}_{\Delta\lambda_1}}{\bar{\rho}_{\Delta\lambda_2}}$$

and,

$$\wp_{\Delta\lambda} = \bar{\rho}_{\Delta\lambda_1} H_{\Delta\lambda_2} - H_{\Delta\lambda_1} \bar{\rho}_{\Delta\lambda_2} \Big/ \bar{\rho}_{\Delta\lambda_1} - \bar{\rho}_{\Delta\lambda_2}$$

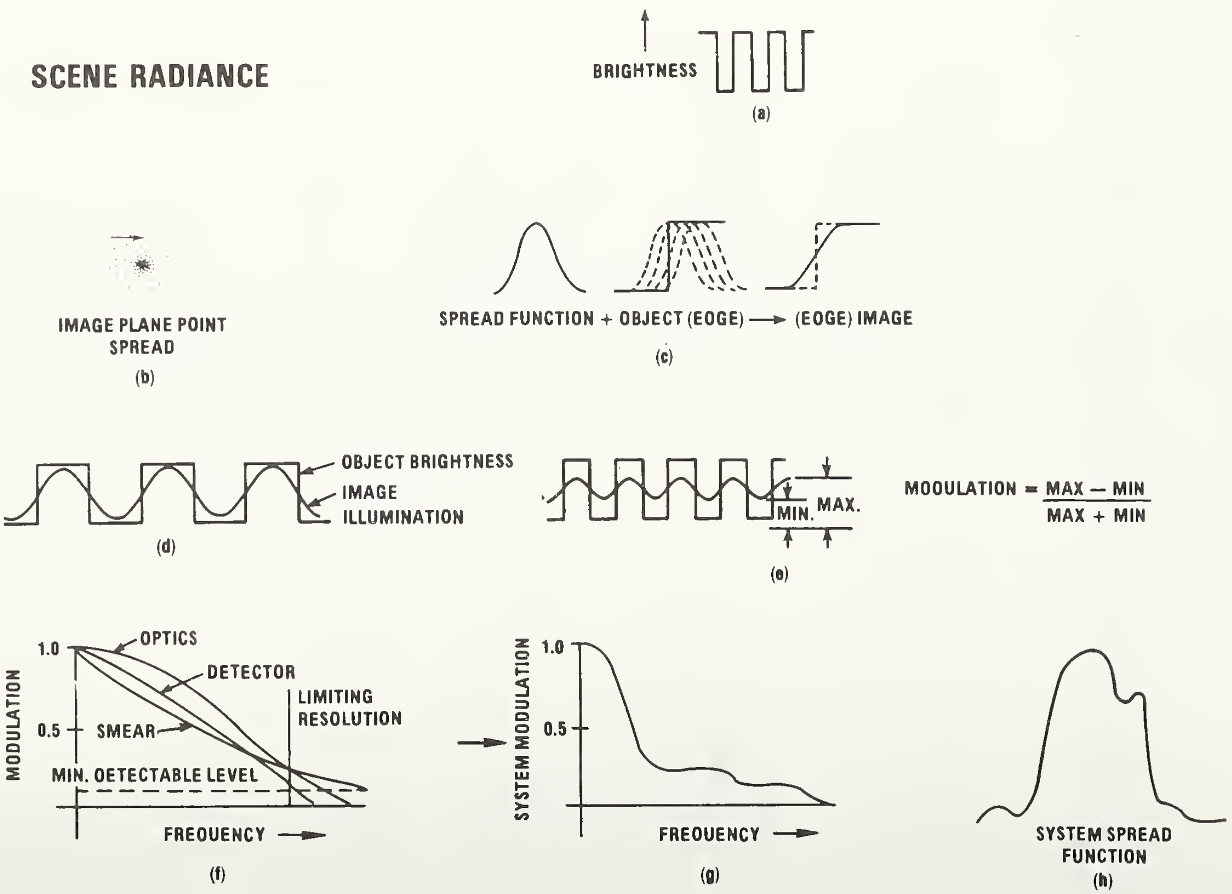
The $H_{\Delta\lambda}$ are measured quantities, hence, if the $\bar{\rho}_{\Delta\lambda_{1,2}}$ are somehow known, then $\rho_{\Delta\lambda}$ is determinable.

The unknown $\bar{\rho}_{\Delta\lambda}$ can thus be inferred by:

$$\bar{\rho}_{\Delta\lambda} = \bar{\rho}_{\Delta\lambda_{1,2}} \left(\frac{H_{\Delta\lambda} - \rho_{\Delta\lambda}}{H_{\Delta\lambda_{1,2}} - \rho_{\Delta\lambda}} \right)$$

As of now, no atmospheric corrections are being applied in an operational mode to satellite imagery. Research in this area is being conducted presently at the NASA/Johnson Space Center.

SENSOR RESPONSE



(a)

IMAGE PLANE POINT SPREAD

(b)

SPREAD FUNCTION + OBJECT (EDGE) ⟶ (EDGE) IMAGE

(c)

(d)

(e)

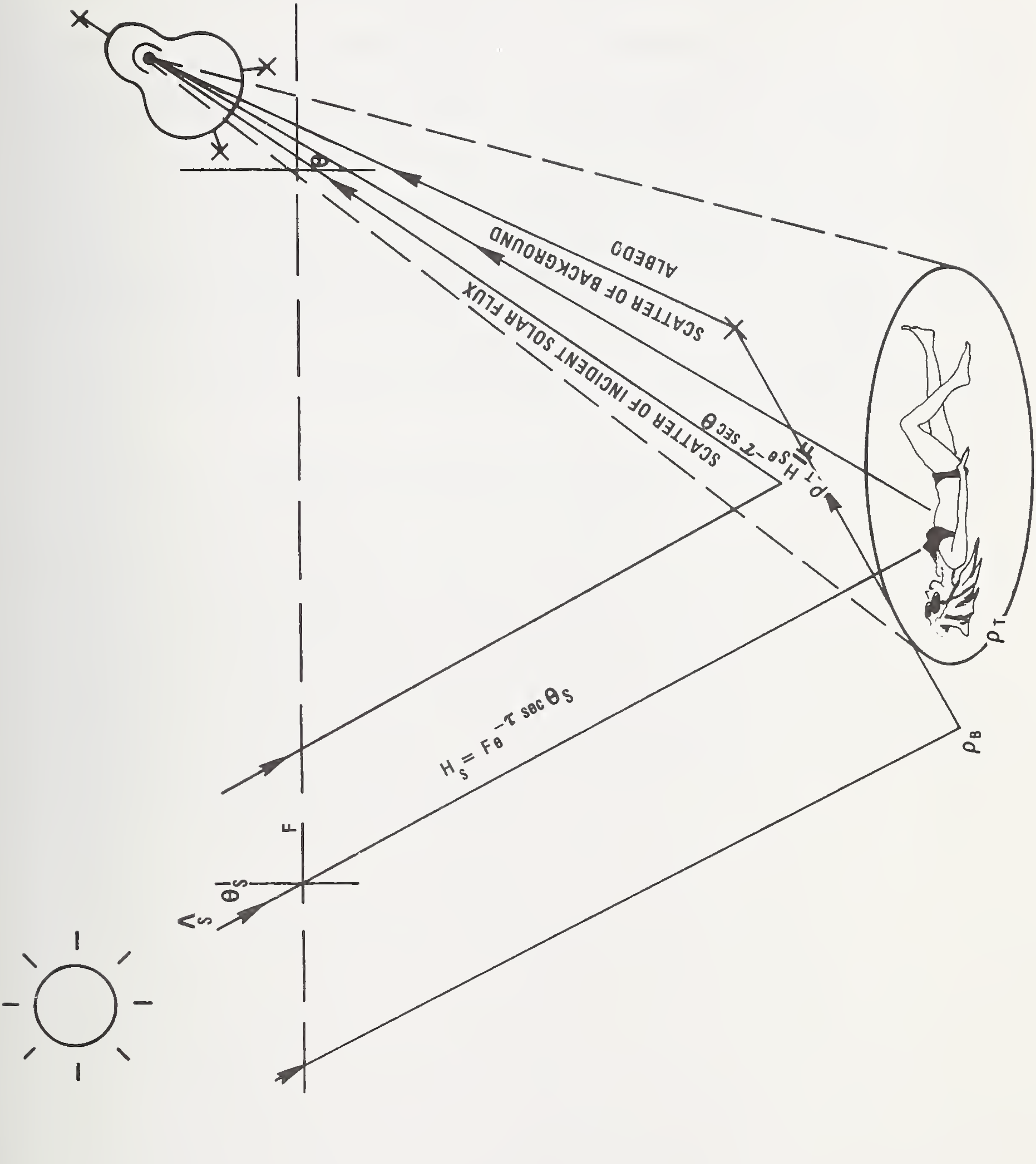
$$\text{MODULATION} = \frac{\text{MAX} - \text{MIN}}{\text{MAX} + \text{MIN}}$$

(f)

(g)

SYSTEM SPREAD FUNCTION

(h)


ALBEDO
SCATTER OF BACKGROUND
SCATTER OF INCIDENT SOLAR FLUX
$\rho_T H_S e^{-\tau \sec\theta} / \pi$
θ
ρ_T
ρ_B
$H_S = F e^{-\tau \sec\theta_S}$
F
θ_S
Λ_S

Discussion

Milton Ritter
NASA Goddard Space Flight Center

Sensor and Atmospheric Effects on Satellite Imagery

Question: In inverse filtering, you have a point spread f(T) which isn't constant.

Answer: You need at least *nominal* degradation and can do better. T is a second order effect.

Question: Do you know the spread function?

Answer: You know the *design* spread function.

Comment: This has been done for space images and second order corrections really are second order.

Comment: You can do second order corrections "on the fly".

Question How about S/N?

Answer: You can improve by correlation with neighboring points.

Correcting Gray Scale Distortions in Photographic Images

by

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The objective in digitizing an image is to obtain a numeric representation having some known relation to the spatial distribution of light energy incident on some optical surface such as a camera film plane or the retina of the eye. One common relationship (and indeed a very useful one) is simply to require that the numeric data be proportional to light intensity. Simple as this seems, the introduction of a photographic process between the original scene and final numeric data requires a carefully applied calibration and correction step to correct for gray scale nonlinearities introduced by the film.

To measure and correct for these distortions, a sample of film, identical to the one used in the camera, is exposed to carefully measured amounts of light in a sensitometer or other suitable instrument. Figure 1 illustrates this situation schematically. Both films are processed together in the same chemistry and the density of the test film is measured as shown in Figure 2. Note that the photographic density* is an approximately logarithmic function of exposure. Note also that substantial modifications to this function are possible by changing the development process. This is the reason both films should be processed simultaneously.

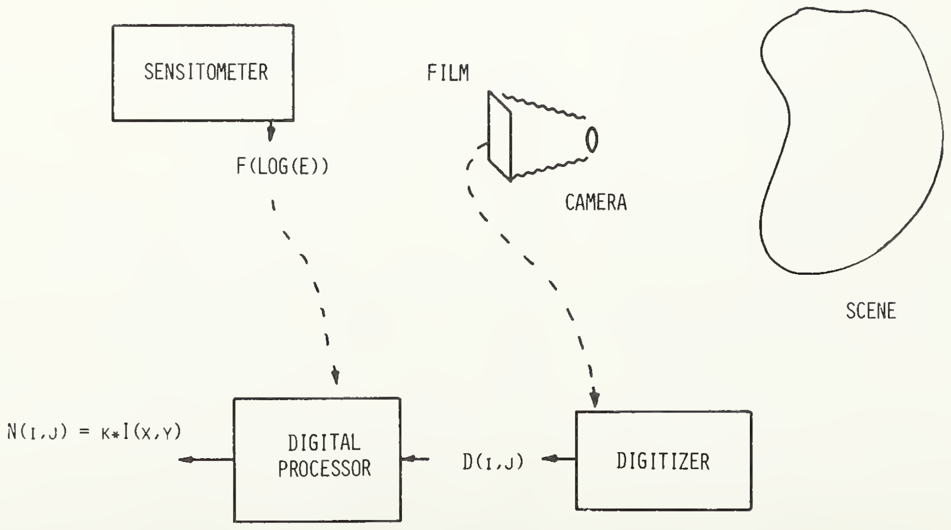
SENSITOMETER
FILM
CAMERA
SCENE
F(LOG(E))
N(I,J) = K*I(X,Y)
DIGITAL PROCESSOR
D(I,J)
DIGITIZER

FIGURE 1

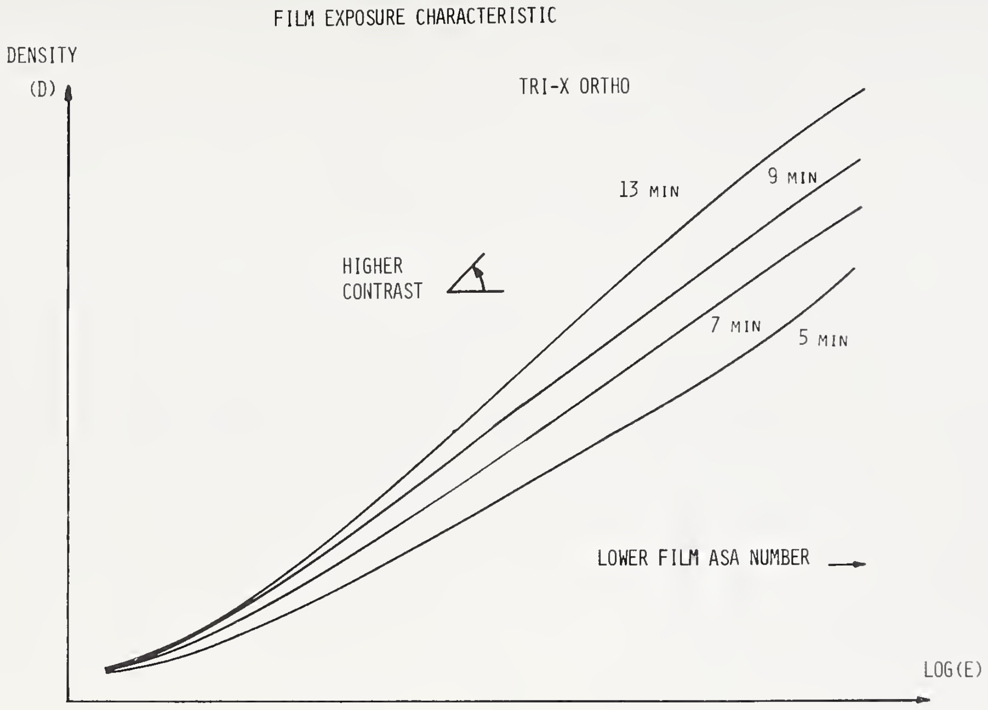
FILM EXPOSURE CHARACTERISTIC
DENSITY
(D)
TRI-X ORTHO
13 MIN
9 MIN
HIGHER
CONTRAST
7 MIN
5 MIN
LOWER FILM ASA NUMBER
LOG(E)

FIGURE 2

Discussion

Brent Baxter
University of Utah

Correcting Gray Scale Distortions in Digitizing Photographs

Question: There is a problem of getting an invertable F.

Answer: If image has very dark or very light regions, you want a low contrast film to be able to encompass the entire range. You can increase range by cutting down development time.

Question: What about resolution at high silver regions?

Answer: You must be able to measure I_0 accurately.

Comment: Put a wedge on known substance. (Gives known density on film to automatically calibrate the densitometer during read out).

Discussion

Lt. Boccia
Armed Forces Institute for Pathology

The Recording Environment in Pathology

Question: Would you comment on the data bank of images?

Answer: This is proposed. We are just beginning. We have the instrument: the scanner, 1/2μ stepping stage, and a small minicomputer (16 bit, 32K core, 20M bytes disc). It takes 2 minutes to scan a cell, but this is very flexible. The system looks for a nucleus, can edit data, and can get skeleton overlay.

Question: How do you do calibration?

Answer: We will need test patterns. Dr. Bahr and electronics staff will do it.

Question: Would you be willing to reblock your data to another standard format?

Answer: Yes.

PROTOTYPE IMAGES

Chairpersons: Theo. Pavlidis, Princeton University
Roger N. Nagel, National Institutes of Health

Panelists: Jack Sklansky, University of California, Irvine
Sam Dwyer, University of Missouri
Fred Billingsley, Jet Propulsion Lab

Panel on Prototype Images: Overview

by

Roger Nagel

The panel on prototype images was formed to consider the goals and selection criterion for a centralized data base of prototype images. The panel addressed the topic from several points of view including the philosophy, practicality, and utility of such an endeavor.

In the first three of the panelists' presentations, the design goals, practical problems, and technical problems attended with the formulation of an image data base were discussed. These talks as summarized by the panelists themselves are presented in the text. The remaining two panelists described their experiences in the actual preparation and use of data bases designed for specific application areas. Again these presentations are presented in this report.

After the individual talks and at the conclusion of the presentation audience participation was solicited. While no consensus can be claimed there was agreement on several issues as summarized below:

On the topic of should a data base of limited size be solicited and distributed by a central facility, the general sentiment was yes, and the suggestion that NTIS or NBS spearhead the effort was made.

Two competing goals for such a data base seemed to divide the audience. Some see the goal as facilitating the comparison of algorithmic techniques, i.e., texture measures, while other feel that specific application areas such as radiography should be the main selection goal. It was apparent to all that no single data base would suffice, and that the creation of several data bases by parties with similar goals should be encouraged. It was pointed out that several such data bases currently exist. Equally obvious is the desire that all such data bases be in some "universal" format hopefully agreed on or specified by this conference.

No matter what the goal of a candidate data base, there seemed to be agreement that selection criterion and screening of data base entries were important. It was suggested that in formulating a candidate data base a committee be appointed to screen and solicit images. Criteria should include but not be limited to images with varying degree of difficulty, prior results on published algorithms, reasonable sample sizes, and precise documentation on the source and recording environment of the imagery.

It was further pointed out that the availability of prototype imagery is often complicated by legal problems as in the case of medical data, and classification problems as in the case of intelligence data. In addition it is frequently difficult to document the "ground truth" of the image as human photointerpreters, experts in the various fields, often disagree.

Finally, the problems of differing image size, bits per pixel and pixel data types represent an additional source of problems in a centralized data base. Images as small as 256 pixels to those with millions of pixels are used while individual pixels can be binary or complex valued.

In summary, it was felt that the problems to be faced in a centralized image data base are formidable, but that practical data bases related to specific goals could be solicited, selected, and distributed if well defined goals and selection criteria are employed.

PROTOTYPE IMAGES - GENERAL REMARKS

by

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The major motivation for the creation of a data base of <u>Prototype Images</u> is that it will allow the direct comparison and evaluation of various methods in image processing, pattern recognition, automated diagnosis etc. Although pictorial data bases should meet certain standards of documentation and portability, Prototype Images must satisfy a number of additional constraints. The purpose of this session is to make suggestions and recommendations in this context. I believe that a number of considerations must be taken into account.

<u>I. Purpose</u>: There are two major types of work where such a data base will be used, each type having different requirements:

(1) Testing of Picture Processing Algorithms (Segmentation, Boundary Tracing etc.).

(2) Testing of Classification Algorithms.

In the second case one will deal with specific applications (e.g. tumor detection in chest radiographs). In the former there is no such restriction and a mixture of subjects is desirable in order to test the generality of a proposed algorithm. In order to offer statistically valid results the data bases used for the second purpose must be quite large.

<u>II. Major Features</u>: (1) It is important that the test images have an appropriate degree of difficulty in order to make comparisons meaningful. (2) The images should have no bias in favor of any given methodology. For example some edge detectors do quite well along vertical or horizontal directions but not along others. Thus a proper test-picture should not show directional preference. (3) Precise documentation about the recording environment, tape format and description of the contents must be provided.

The first two features are of special relevance for the selection of pictures for the testing of processing algorithms. This fact suggests that the use of surrogate images should be given serious consideration. The third feature is of particular relevance for the testing of classification algorithms and a number of very challenging problems are faced there.

The size of the data base for picture processing tests will probably be rather small. However the opposite is true for the other type. Not only must each set of prototype images be quite large but a large number of them will be necessary in order to take care of the ever increasing applications where the methodology of pattern recognition is applied.

A preliminary effort in establishing guidelines for data bases of prototype images has been made by a task force (chaired by this speaker) within the framework of the Biomedical Pattern recognition Subcommittee (chaired by Professor J. Sklansky) of the IEEE Computer Society Machine Intelligence and Pattern Analysis Technical Committee (chaired by Professor K. S. Fu). The task force concluded that it would be very difficult to establish precise guidelines for acceptability of prototype images. Instead it suggested that a review of a proposed data base by three independent referees be performed. The referees would evaluate whether it is appropriate to serve as a set of prototype images. Thus standards of quality would be maintained in a similar manner as for published papers.

However a number of questions remain open: the choice of one or more facilities where data bases would be submitted or which would solicit data bases of prototype images ; the selection of referees; the financing of the reviewing procedure, which can be quite expensive; and the distribution mechanism. It should be noted that these questions are also in the domain of the IEEE - MIPA Subcommittee on Data Bases (chaired by Dr. J. B. McFerran).

Prototype Images - Selection Problems

by

Roger Nagel

The formulation of an image data base raises several important <u>content</u> and <u>procedural</u> questions. At this juncture it is not at all clear how the procedural questions of format and documentation can be settled. However, given that such questions can be reasonably answered (by other groups at the meeting) we are left with the problems of data base collection and distribution.

Implicit in a data base is some notion of content. Yet here again a question of scope arises. For example, to what audience will the data base be addressed? If it is assumed that the data base is intended for a comparison of algorithms in the technique-oriented sense then the ability to cover many application areas is compromised, and vice versa. This question is essential because of the expected limit to the size of any data base in order to make distribution feasible.

In Table 1 a representative list of application areas is presented and in Table 2 a sample listing of techniques is presented. Both the size and incompleteness of these tables brings home the point that an exhaustive inclusion of sample imagery is not practical. Thus the selection of prototype images presents a difficult problem simply in terms of content criteria.

Due to the limited size of a realistic data base, and the obvious fact that it is impractical to cover all possible areas, the task for which the data base is intended becomes a critical factor in the selection of prototype images. If we direct the data base to the research and development community, it implies a technique orientation. Whereas if it is directed at the industrial users, application areas are the guiding criteria for content selection. My own bias would be toward research and development, and I would choose those techniques which are currently in the literature for criteria in sample image selection.

A reasonable rationale for such a choice is the flow of techniques from the R&D community to industry. Thus we provide the test bed for algorithm development and comparison, while the general utility in particular application areas is not yet tested.

Even when the content selection criteria are known, we are still left with the question of mechanism for collection, and distribution. That is, how much screening of candidate images should be done for documentation, format, prior results, and utility? Can or should such a data base be updated to grow in number of samples? Furthermore, should results of new algorithms be added to the documentation, as the data base is used?

In closing I put forward the proposal that a limited data base can be selected and distributed. In the beginning, a modest set of techniques should be selected as the basis for content selection. This proposal assumes that some form of universal format will be developed by the other workshops, as well as a minimum documentation standard. The distribution of such a data base with no updating facility is now possibly at NTIS, and other sources.

While such a proposal is only a first step, it is within the realm of possibility and can be spearheaded by the National Bureau of Standards.

TABLE I: APPLICATION AREAS

SATELLITE

- RESOURCE MONITORING
- WEATHER FORECASTING
- MILITARY - TARGET RECOGNITION
- INTELLIGENCE RECONAISSENCE

MEDICAL

- RADIOGRAPH
- RECONSTRUCTION
- CYTOLOGY

FORENSIC

- FINGERPRINT
- HANDWRITING
- FACE IDENTIFICATION

INDUSTRIAL

- NON DESTRUCTIVE TESTING
- CHARACTER & PRINT READING
- ASSEMBLY LINE MONITORING

ROBOTICS

CARTOGRAPHY

TABLE 2: TECHNIQUE AREAS

- POINT OPERATIONS
- NEIGHBORHOOD OPERATIONS
- TEXTURE
- EDGE & LINE
- TRANSFORMATIONS
- REGISTRATION & SIMPLE COMBINATION
- GEOMETRICAL
- SEGMENTATION, TRACKING
- QUANTITATIVE MEASUREMENTS
- CLASSIFICATION

Prototype Radiographs

by

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I. INTRODUCTION

A technology of computer-aided image analysis currently is being developed for two major areas: a) remotely sensed terrestial images, and b) biomedical images. Within biomedical images, radiographs are receiving special attention. This can perhaps be explained by the following observations:

1) In the United States, approximately 700,000,000 medical radiographs are analyzed annually by a population of about 9000 board-certified radiologists.
2) Of these radiographs, about 230,000,000 are chest radiographs.
3) Perhaps a thirty percent increase in the number of radiographs will take place in response to the concern over the increased costs imposed by malpractice suits.
4) There is a trend toward more precise and careful documentation of diagnoses of radiographs also in response to the threat of malpractice suits.
5) The incidence of false negatives in the detection of being tumors is about thirty percent. Comparable error rates for other lesions seem likely.
6) Among the various forms of images that reveal a patient's internal structures (e.g., X-radiographs (including xero-grams), thermograms, ultrasonic scans, and nuclear images), X-radiographs provide the greatest resolution and consequently has the greatest information content per image.

The following are a few of the potential applications for a technology of computer-aided analysis of radiographs:

a) routine diagnosis of radiographs, including report-writing,
b) therapy (e.g., radiation therapy; surgery),
c) mass screening
d) public health (e.g., correlating radiographically determined structures with certain populations,

e) basic medical science (e.g., relating computer-detected pictorial textures to diseases),

f) training of radiologists.

The development of an image-analysis technology needs standard or prototype images. In this paper we discuss several of the basic issues involved in the construction of a data base of prototype radiographs as a means to accelerate the development of an effective technology of computer-aided radiography.

II. WHY DO WE NEED PROTOTYPE RADIOGRAPHS

The following are a few of the benefits that would be provided by a readily available set of prototype radiographs.

1) An objective comparison of computer algorithms developed by different research groups would be greatly facilitated by a set of prototype radiographs.

2) The acceptance by the medical profession of a computer algorithm for aiding the diagnosis of radiographs usually implies a change in the routines by which diagnoses are reached. If a convincing case for such a change can be obtained at all, it will have to be based in part on a test of the algorithm properly selected on a set of prototype radiographs whose diagnoses are accepted by the medical profession as valid.

3) Occasionally a computer algorithm may reveal a relation between computed pictorial features and otherwise undiscernable physiological or diagnostic phenomena in the radiograph. To establish the validity and/or reliability of such a relation will require a set of prototype images illustrating the phenomenon of interest.

4) For many research groups, a representative set of prototypes will eliminate or postpone the purchase, operation, and maintenance of expensive scanning and digitizing equipment.

One cannot hope to build a set of prototype radiographs in anticipation of all algorithms that will need to be tested. The domain of possible disease states and possible physiological phenomena is too large. Hence we must a) construct a small representative set of radiographs, and b) establish a set of guidelines and criteria for the selection and solicitation of prototype radiographs.

III. EVALUATION CRITERIA

Below we suggest a) the forms that prototype radiographs may take, and b) possible criteria for determining the acceptability of candidate radiograph for the file of radiographs.

We suggest that a prototype radiograph may take one or any combination of the following forms.

a) A "raw" radiograph -- i.e., the most direct highest quality means of storing the image. X-radiographs are usually recorded on film or xerographic paper. In cases where an image intensifier tube is coupled to a television display, the raw radiograph would be a video tape recording. In the cases of computerized tomography and isotope scans, the most accurate storage technique is a digital memory -- usually digital magnetic tape.

b) An unfiltered digitized radiograph. This is usually obtained from the raw radiograph by means of a scanning or reading device and an analog-to-digital converter, and stored on digital magnetic tape. Computerized tomography and isotope scans are conveniently stored directly in this form of memory.

c) A filtered digital radiograph. This may be obtained by compressing the spatial and gray level digitizations of the unfiltered radiograph into a form (e.g., eight bits per pixel, 256 x 256 pixels per radiograph) that can be accepted by most minicomputer systems.

IV. DOCUMENTATION OF PROTOTYPE RADIOGRAPHS

Regardless of which of these forms is used, each prototype radiograph will need to be accompanied by substantial documentation: the raw radiograph requiring the least documentation, and the digitized filtered radiograph the most.

We suggest that ideally the documentation include the following:

1) Imaging system

   Anode voltage
   Subject-to-film distance
   Anode-to-film distance
   Angle of the anode
   Anode current
   Exposure time

Frequency spectrum of emitted X-rays

Dimensions of the Potter-Bucky diaphragm, if used

Types and thicknesses of film, emulsion, and fluorescent screen

Point spread function as a function of position in the image plane

Film processing parameters: especially development time, chemical ingredients, and temperature.

2) Patient

Weight, height, sex, age, occupation, medical history, genetic factors, geographic habitat, disease (if known). If a panel of experts established the disease, the members of the panel should be identified and the distribution of votes for each polled opinion should be described, without necessarily revealing how each member voted.

If surgical confirmation of the diagnosis is available, the basis for this confirmation (i.e., the observation or the pathological test) should be described.

Portion of patient viewed (e.g., chest, lumbar region, breast)

Projection (e.g., posterior-anterior, lateral)

Geometric parameters (film-to-object distance, size of object, etc.)

3) Phantom of human structures.

A precise identification or description of the phantom should be given. A full description of the procedure for replicating the phantom should be available.

4) Test pattern.

Two types of test patterns for prototype radiographs are desirable: a <u>step wedge</u>, held at a known distance from the film, superimposed on the raw radiograph; and a three dimensional test object, exposed onto a separate film without the patient, with exposure and other imaging conditions identical to that for the raw radiograph.

5) An additional documentation for unfiltered digitized radiograph.

If the digitization was obtained from a scanning device, the basic physical parameters of the scanner must be documented in addition to the documentation required for raw radiographs. These parameters include the aperture, the signal-to-noise level, the range of linearity of the scanner pixels, and the number of bits per pixel. If the digitization is obtained from computerized tomography, the basic physical parameters of the tomographic system (such as the diameter of the ray, the distance between adjacent ray positions, and the angle between adjacent projections) as well as the reconstruction algorithm must be specified.

6) Additional documentation for a filtered digitized radiograph.

In this form, the parameters of the digital filter must be documented, in addition to the documentation needed for the raw radiograph and unfiltered digitized radiograph. For example, if the filter operates on a histogram, the histogram transformation must be described. The number of bits per pixel and the number of pixels per unit length must be specified for both the unfiltered and the filtered digitized radiographs.

In addition, of course, the recording parameters must be specified. For details on this subject see report of session on "Standard Tape Formats."

IV. SOLICITATION FOR A CENTRAL FILE

The prototyper to be solicited depends on the types of algorithms under development. Currently we are aware of research on computerized analysis of radiographs of the following structures.

1) Chest
    a) ribs
    b) lung tissue (especially pneumoconiosis)
    c) lung tumors
    d) calcifications
    e) heart
    f) pulmonary blood vessels

2) Breast
    a) cysts
    b) ducts
    c) chest walls
    d) skin profile
    e) carcinomas
3) Bone
    a) trabeculae
    b) slight fractures
    c) spine
    d) knee
4) Stomach
5) Head

In addition to prototype radiographs of human subjects (e.g., chest radiographs, xeromammograms, etc.), it will also be useful to have access to prototype radiographs of excised tissue. Examples of such tissue are cancerous breast tumors, benign breast tumors, diseased bone, and diseased lung tissue. Radiographs of these excised tissues will provide data that is not obscured by images of tissue outside the concern of the algorithm developer.

In addition to prototype radiographs of human subjects and of excised tissue, it will be useful to have access to prototype radiographs of well designed phantoms. These phantoms fall in two classes: test patterns and realistic simulations of human physiology.

The test patterns are needed in order to provide a precise means of modelling the X-ray imaging system and the effects of the film and Bucky grid. Since the imaging process depends on the distribution of the density of the subject in 3-space, as well as on the distribution of the focal spot, it is likely that a wide variety of three-dimensional test patterns will be designed and constructed. Evaluating the ability of various algorithms to model or reconstruct these test patterns may be a useful early step in the development of these algorithms.

A good example of a phantom that simulates human physiology has been constructed at the University of California at Irvine under the supervision of Dr. E. N. C. Milne and the technical assistance of W. Roecke.

The phantom simulates the chest: including the ribs, the lung, the heart, pulmonary vessels, lung tumors, and calcifications. This phantom yields exceedingly accurate simulations of chest radiographs, and provides a means for accurate control of size and placement of simulated tumors, blood vessels, etc. Radiographs of such a phantom can be much more accurately documented than radiographs of a human subject, because a) the relative positions of all the objects in the phantom are known with great accuracy, b) the phantom doesn't move during the exposure, c) the phantom permits the use of small-focal-spot tubes, with the concomitant high quality images at the expense of long exposures, and d) the phantom permits repeated exposures to provide original radiographs for the file of prototypes. (Original radiographs of human subjects usually must be kept at the originating clinic.)

V. CONCLUDING REMARK

Although the needs for prototypes and the associated documentation are quite complex, modest beginnings in these directions can be made that would be very helpful to researchers on computer-aided radiography. Examples of these beginnings are:

1) a set of normal chest radiographs
2) a set of radiographs of chest phantoms
3) a specification for a three-dimensional test pattern.

ACKNOWLEDGEMENTS

The author is indebted to Carolyn Kimme for her suggestions and comments.

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Thoughts on Standardization of Parameters for Image Evaluation

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NASA Headquarters

It may be anticipated that images will be received for image processing and analysis from a wide variety of sources and with a wide variety of sensors. Since it is desirable to have image processing algorithms be as universally applicable as possible, they should be designed, where possible, to be insensitive to the parametric variations of the source material. Where this is not possible, these variations must be taken into account. We therefore need to consider what parameters may be defined in common across a suite of image types.

CONSIDERATIONS OF SOURCE TYPE

Consider for example the four images in Figure 1, derived from a radiograph, the Landsat satellite, normal film photography, and a scanning electron microscope. The image producing characteristic of these sources are quite different, yet similar pattern recognition or other image analysis questions may be asked of each.

We need first to consider the difference between image connotations and image content. Image connotation, in this sense, is that set of external knowledge, culture, education, or other situationally dependent information which is used in conjunction with the data of the image itself. This total set of information is, in effect, a model of the real world of which the image is a replica, and the problem is to answer questions about the real world using data from the image as one source. Connotation, like beauty, is in the eye of the beholder. Therefore, if standard images are used as surrogates, a wide variety must be available so that a suitable one for a given problem may be selected.

To avoid these connotation problems, we need to consider whether it is possible to define objective parameters or measurements of images which, in the proper combinations, may serve as surrogates for "real images." These parameters may be pixel-specific, location dependent, or combinations thereof. Parameters which have proven useful in defining the characteristics of images include such as the gray scale linearity, granularity of the quantization, spectral content, geometrical fidelity, resolution of the system expressed as either the point spread function or the modulation transfer function, and the spatial frequency content and characteristics of the data itself (which in turn may contain various amplitudes and bandwidth of noise) or the statistics of the spatial variations of local areas. In addition, we must recognize the difference between intra-pixel (for example, the pixel resolution) and inter-pixel (for example, the recognition of multi-pixel objects) effects.

We will consider here only digital images which are used as fodder for digital processing and will avoid entirely the question of eyeball analysis of visible images, a subject which has had considerable treatment in the literature, although not primarily from the point of view of selecting standard images. This question of eyeball analysis, however, cannot be completely avoided since it serves as one interface between the digital analysis per se' and the human verification of the analysis results.

PARAMETERS

We now need to consider parameters which have some relation to the real world. Although photographic film is quite non-linear certain analyses are only tractable if the brightness/digital number transfer curve is assumed linear. In addition, the response of the human eye is approximately logarithmic and therefore comparison of linear digital analysis with eyeball analysis must be carefully scrutinized. This raises the first question which must be considered in the design of a surrogate image so that the analysis may relate to the real world image for which the problem is being solved:

> Will the true data be recorded on film originally over such a wide range of film densities that parts of the image will be recorded on the toe and shoulder of the recording characteristic curve where the local contrast is low? If so, this must be taken into account when generating the surrogate image.

There seems to be no reason to include gray scales of the standard type in the surrogate images to be used for digital analysis; however, if included, they will provide some measure of control of the eventual reproducing process used to display the processed image.

Also, at least for "first order" reference images we will ignore the possibilities of coma, penumbra effects and the like, thus again opening the possibility of non-surrogate analysis. We will assume that the system of interest is spatially stationary. In the same sense, we will define that the system is geometrically stationary, i.e., rubber sheet distortions internal to the image will be ignored (again, unless specific situations require the reintroduction of this factor).

These assumptions will allow us to generate surrogate images with known and predefined properties instead of requiring (or allowing) us to select images from an external library and being required to analyze them to determine the properties. Other properties which cannot so easily be dismissed now need to be considered in some detail.

QUANTIZATION GRANULARITY

The number of gray levels used for quantizing a continuum image into discrete levels will have definite visible effects even at the five or six bit quantization accuracy point, and may affect the processing even when more levels are used. This leads us to questions of the following type:

> What is the sensitivity of the processing to a various number of digital levels? What about truncation in the digital processing? Is there an implicit level of quantization in the data or the sensor itself? What are the noise characteristics being simulated? How close a separation of different gray levels must be detected? Suppose they are adjacent or not adjacent?

NOISE

In the absence of noise, a clean signal will be recorded as the same digital number every time it is quantized. In the presence of noise, however, there is a finite probability that the digital number assigned to the signal will be different than that which would have been assigned to the clean signal. This effect is illustrated in Figure 2 and curves pertaining to two commonly asked questions are shown in Figure 3.

Noise will also perturb other types of processing, especially that which needs uniform areas or clean edges. This leads to:

> In the true scene, what is the variability in nominally uniform areas (in magnitude and in the special frequency content of the variation)? What is the sensor noise and its bandwidth? What data questions (see Figure 3) are being asked? Does noise vary with brightness?

SPECTRAL CONTENT

The spectral content may have as few as one dimension (radiographs, monochrome pictures) to three dimensions (typical color film) to four (Landsat) to 24 (the NASA multispectral aircraft scanner). In addition, correlated multitemporal images may effectively have even more. Pattern recognition and processing in the multispectral domain is very effective where available. However, in setting up surrogates for this situation, the covariance between spectral bands which tends to occur, the tendency for the same material to usually have the same spectral content (in the visible sense, color) and the degree to which given materials aggregate into more or less uniform areas in the picture must be taken into account. Pattern recognition techniques for use in this situation (e.g., Landsat analyses) will optimally consider both the tendency of a given material to aggregate in patches in the image and also to aggregate statistically in multi-dimensional spectral space. Thus typical questions to be answered might be:

> What is the typical multispectral distribution expected? Are the clusters spherical or elliptical? i.e., what is the interband correlation? What is the cluster spread, especially as compared to the typical intercluster distance? What is the typical aggregation size distribution to be expected in the image for materials of nominally uniform spectral content? Can any nonspectral data be mapped congruent to the real image and be treated as another "spectral band" in a multivariant analysis?

POINT SPREAD (IMPULSE RESPONSE) FUNCTION

Any system upon viewing a delta-function object (for example, a star) will reproduce that object, not as a delta function, but rather that point spread out in image space around the ideal delta function location. Since object space may be considered as composed of a tightly packed array of delta functions each with its own amplitude, the reproduced image may be considered to be composed of the summation of the corresponding series of point spread functions (psf) each at its appropriate location and amplitude. This situation is sketched in Figure 4a.

The basis function used to sample the image at each of the digital locations, combined with the basis function used to reproduce it at each of those locations, will have a filtering effect on the high spatial frequency content of the image as sketched in Figure 4b. Indeed, the Nyquist criterion requires that this filtering function occur before the digitization can properly be made. This effect is shown in the spatial frequency domain in Figure 4d; the upper limit of spatial frequency content after filtering will determine the appropriate digitization spacing. The effect of this filtering upon a sharp edge is shown in Figure 4c. It can be shown that the edge softening caused by the filtering, when combined with the digitization spacing appropriate to that same filtering function, will result in maximumly obtainable edge transition, from 10% to 90%, of approximately 1.5 pixels.

Thus, any generated images representing edge sampling must consider this effect. In particular, those processing algorithms which require sharp transitions for their success will be particularly affected.

Thus, the type question which we are led to are:

What is the spatial frequency response (or related to that, the point spread function) of the imaging system simulated? How does the quantization spacing compare with that required by the Nyquist criterion? What is the distribution of energy as a function of spatial frequency of the base band data itself? What reproducing basis function will be used to produce a visible image upon the completion of the processing?

GEOMETRICAL (AREAL RELATIONSHIPS)

Binary Images

These include that set of images in which only two values of brightness are available, namely black and white. These images typically take the form of line drawings of specific objects, of maps (which display the location of objects, but do not represent the objects themselves), text, including written music (in which written characters of some language are used to indicate sounds of concepts), homograms (from gram, a display, and homo, uniform, a display in which norminally uniform or homogeneous subject areas are displayed as uniform or uniformly textured areas in the image), as half-tone images (in which gray scales are represented by a spatially varying binary pattern). Figure 5 illustrates some of these.

Here we get to the guts of the pattern recognition problem, and must consider the questions of the following type in defining our surrogates:

Is the information to be simulated characterized by the properties (e.g., shapes and sizes) of areas as defined by lines (the edges of the areas)? Or is it in the areal extent (again, size and shape) of uniform or uniformly textured areas in a homogram? Or is it the lines themselves as in text or in map? How much culture (as opposed to information actually in the data itself) is required for the analysis? Is this apparent in the image or introduced in the subsequent analysis? Is the analysis of a given area dependent on or independent of the analysis of and/or interrelationship with its neighbors? Is orientation, size, or scale critical? Will analysis be by statistics or by template matching? If the former, what are the statistics required for the size and shape of the subelements; if the latter, what are the tolerances allowed in the template? Is the analysis dependent on texture (this includes not only the visible texture, but perhaps the impression of gray scale evidenced as texture in the half-tone image)? If the half-tone image, do we handle it binary-wise or do we reduce resolution and average out the dots and treat it as a gray scale image? Is edge sharpness important? How about affine transformations, such as rubber sheet stretching?

With Gray Scale

Again we need to differentiate between information directly within the image and interpretations based on the image used as a data source to allow us to solve an external model (i.e., the culture factor again). Analysis of information completely contained in the image might be characterized by (but obviously not limited to) automated clustering, which reduces the incoming image to homograms. For the gray scale case we must answer questions of the same type as proposed for the binary case, but in addition, must ask such questions as:

How shall we handle gradually shaded areas such as produced in images of cylinders? How do we define or "know" what is represented?

Again we are faced with a culture problem since the "know" is not information in an image. For machine analysis, this culture (i.e., the model being solved using the image as a data source) must be defined to the computer in all its painstaking details. Then for proper simulation the algorithm must exercise all of the expected combinations and must therefore, include examples of each.

CONCLUSION

Thus, although surrogate images may be generated in terms of quantifiable and definable parameters such as has been outlined above, the set of parameters actually considered, and the ranges over which they must be varied, must be defined in terms of the model being solved. In order to properly exercise and test the analysis, the right questions must be asked, answered and simulated. Simulation by generated images as outlined here, allows the control of various parameters which are important and allows the generation of surrogate images which can be designed to exercise the algorithms to their utmost.

However, just as a hammer will not turn screws (it is the wrong tool/problem combination), the wrong surrogate/analysis combination will be unproductive at best, or perhaps downright misleading. In this sense, although the factors outlined above are considered to be important (but not necessarily exhaustive) in the understanding and definition of the problem, careful consideration must be given to the entire problem situation to assure that all factors have been considered.

Fig. 1. Examples of images from widely divergent sources, a) Radiograph, b) Landsat Multispectral Scanner, c) Film Photography, d) Scanning Electron Microscope.

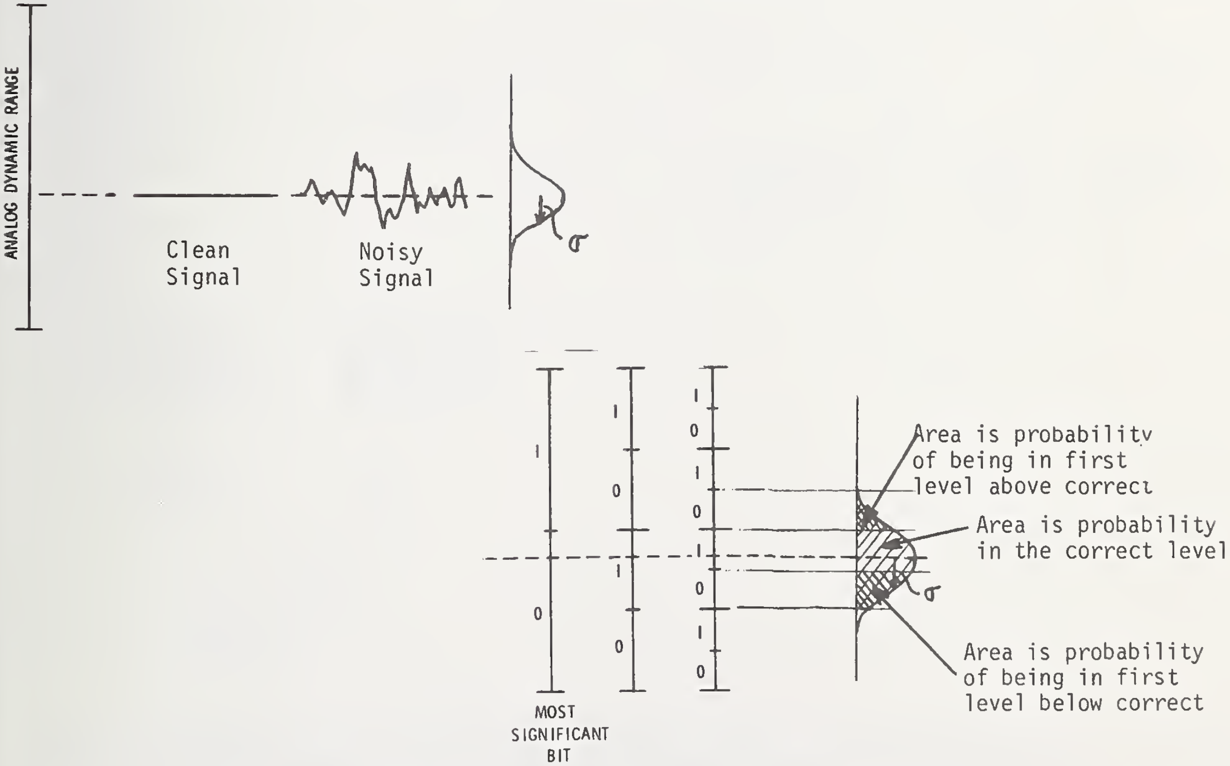
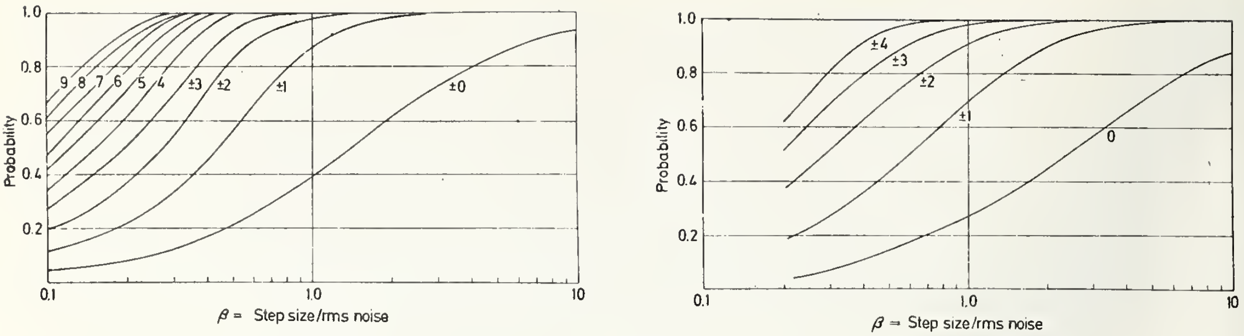


Fig 2. Effects of noise on quantization accuracy (sketch).



Given a signal uniformly distributed over the quantization intervals. Given a Gaussian noise of value =σ. The curves show probability of correctly assigning a digital value corresponding to the noise-free signal within ±0, ±1, ...±9 DN (inclusive) as a function of the ratio β = step size/σ.

Given two signals which have been perturbed by Gaussian noise of value equal to σ. Each is quantized to the same number of bits. The curves given the probability of correctly determining the true difference in the two levels within ±0, ±1, ...±4 (inclusive) DN as function of the ratio β = step size/σ.

Fig. 3. Effects of noise on quantization and on ability to differentiate two areas of different brightness.

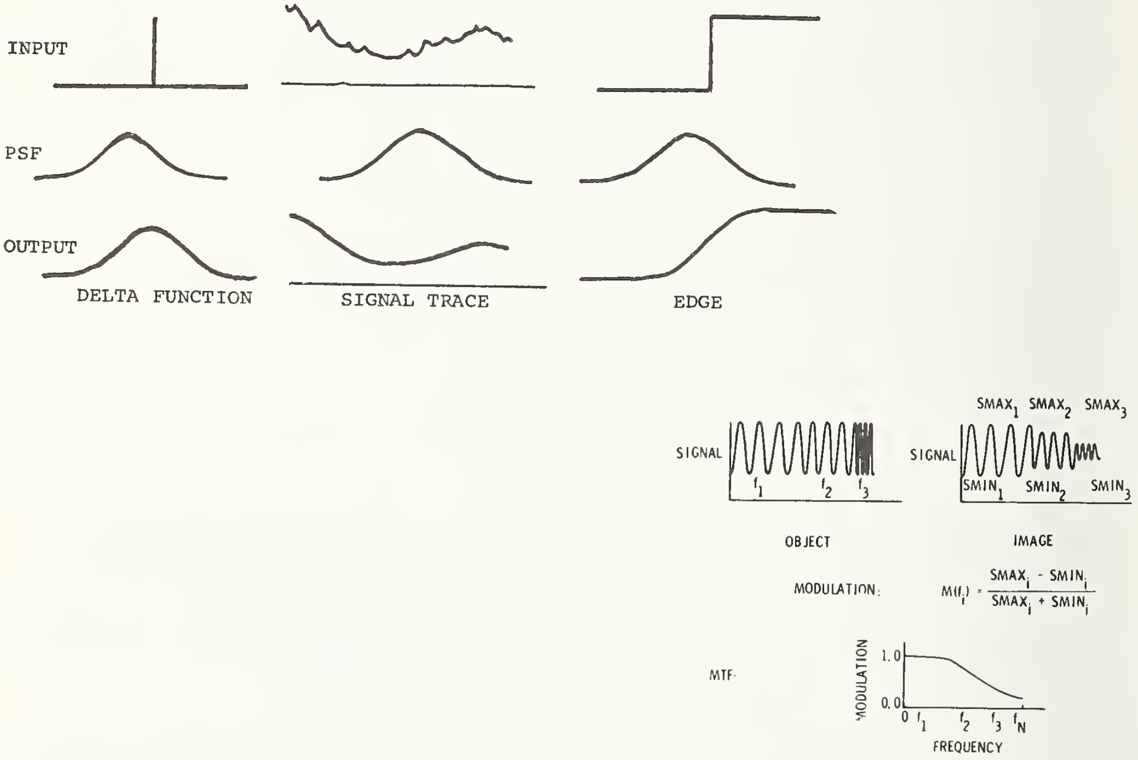
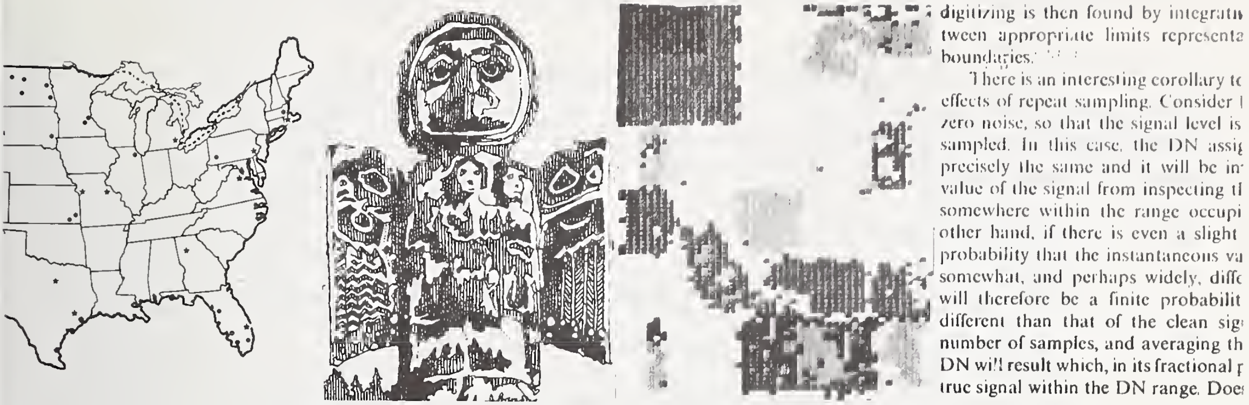


Fig. 4. Filtering effect of the psf a) Effect of finite psf on delta function, b) Effect on a data trace, c) Effect on edge softening, d) Effect shown in spatial frequency domain.



digitizing is then found by integrati
tween appropriate limits representa
boundaries.

There is an interesting corollary tc
effects of repeat sampling. Consider t
zero noise, so that the signal level is
sampled. In this case, the DN assig
precisely the same and it will be im
value of the signal from inspecting tl
somewhere within the range occupi
other hand, if there is even a slight
probability that the instantaneous va
somewhat, and perhaps widely, diffe
will therefore be a finite probabilit
different than that of the clean sig
number of samples, and averaging th
DN will result which, in its fractional p
true signal within the DN range. Doe

Fig. 5. Illustrations of types of images a) Map, b) Line Drawing, c) Homogram, d) Text.

WORKSHOP ON STANDARDS FOR IMAGE PATTERN RECOGNITION

June 3-4, 1976

PROGRAM

THURSDAY, JUNE 3, 1976

8:30 AM REGISTRATION

9:15 AM WELCOME TO NBS
Ruth M. Davis, Director
Institute for Computer Sciences and Technology, NBS

9:30 AM INTRODUCTION, HISTORY AND OBJECTIVES OF THE WORKSHOP
John M. Evans, Jr.
Office of Developmental Automation and Control Technology, NBS

Russell A. Kirsch
Applied Mathematics Division, NBS

Roger N. Nagel
National Institutes of Health

10:15 AM COFFEE

10:30 AM STANDARD TAPE FORMATS
Chairpersons:
John Dehne, Army Night
Army Night Vision Lab

William Alford
Goddard Space Flight Center

Prototype data formats will be presented and dicussed by a multi-disciplinary panel. A questionnaire will be distributed for completion by Workshop participants.

Panelists:
Theo. Pavlidis
Princeton University

John Sos
National Aeronautics and Space Administration

Sandra Hawley
ESL Incorporated

12:30 PM LUNCH

1:30 PM IMAGE CONTENT AND STRUCTURE
Chairpersons:
Azriel Rosenfeld
University of Maryland

Russell A. Kirsch
Applied Mathematics Division, NBS

To make images maximally useful for interchange, it is necessary for the provider of the data to furnish descriptions of the image content. At the simplest level, such descriptions refer to the image as a whole. But most interesting and important image sources require articulated descriptions of the image structure giving the relations of the parts of the image as well as their names. Such image descriptions are useful not only for image data base management, but also as standards for evaluating the success of pattern recognition algorithms.

A research problem that currently exists is the development of suitable languages in which to embed descriptions of image content and structure. This session of the Workshop will be devoted to a discussion of the status of research and related work in graphic languages to provide the needed basis for image content and structure description.

Panelists:
M. A. Fischler
Lockheed Research Lab

K. S. Fu
Purdue University

J. O'Callaghan
CSIRO, Australia

R. F. Sproull
Xerox Corp.

3:30 PM COFFEE

3:45 PM IMAGE CONTENT AND STRUCTURE (CONT.)

5:30 PM RECEPTION AND DINNER

FRIDAY, JUNE 4, 1976

9:00 AM DOCUMENTATION OF THE RECORDING ENVIRONMENT
Chairpersons:
Judith M. S. Prewitt
National Institute of Health

John M. Evans, Jr.
Office of Developmental Automation and Control Technology, NBS

The content of the original image may be significantly altered in reducing it to data on a magnetic tape. Optical system response, sensor response, electronic processing and digitization and all will affect the data recorded. This session will identify the major problems and discuss the documentation needed to describe the relation of the original object to the data recorded on tape.

Panelists:
Wayne Huelskoetter
Dicomed Corp.

Kendall M. Preston, Jr.
Carnegie Mellon University

James Greenleaf
Mayo Clinic

Werner Frei
University of Southern California

J. K. Zieniuk
Bureau of Radiological Health

Marvin Maxwell
National Aeronautics and Space Administration

Brent Baxter
University of Utah

Joseph Boccia, M.D.
U. S. Army

10:30 AM COFFEE

10:45 AM RECORDING ENVIRONMENT (CONT.)

12:00 PROTOTYPE IMAGES
Chairpersons:
Theodosius Pavlidis
Princeton University

Roger N. Nagel
National Institute of Health

The selection and distribution of prototype images would assist researchers and lead to better intercomparison of alternative approaches. The panel will address the following two issues: (1) the selection of criteria for the evaluation of prototype images and (2) the solicitation of data bases for a centrally maintained file of prototype images.

Panelists:
Jack Sklansky
University of California, Irvine

Sam Dwyer
University of Missouri

Fred Billingsley
Jet Propulsion Lab

12:30 PM LUNCH

1:30 PM PROTOTYPE IMAGES (CONT.)

3:30 PM ADJOURN

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WORKSHOP ON STANDARDS FOR IMAGE PATTERN RECOGNITION

June 3-4, 1976

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Automatic image pattern recognition techniques have been successfully applied to improving productivity and quality in both manufacturing and service applications.

Automatic Image Pattern Recognition Algorithms are often developed and tested using unique data bases for each specific application. Quantitative comparison of different approaches and extrapolation of existing techniques to new applications is difficult or impossible.

To facilitate data interchange in this area a two day workshop was held at the National Bureau of Standards in Gaithersburg, Maryland on June 3 and 4, 1976.

The workshop considered the issues involved with interchange of images as data in standard formats on magnetic tape. Specifically, the workshop addressed the following objectives:

1. To define mechanisms for achieving a standard format for magnetic tape interchange.
2. To define requirements for documentation of the recording environment of an image.
3. To recommend mechanisms for selecting and distributing prototype images.
4. To consider the requirements and to explore the prospect for a language to describe image content and structure.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Automation; calibration; data formats; documentation; image content language; image processing; pattern recognition; prototype images; standards.

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