Image Information Processing for Photo-Interpretation Operations

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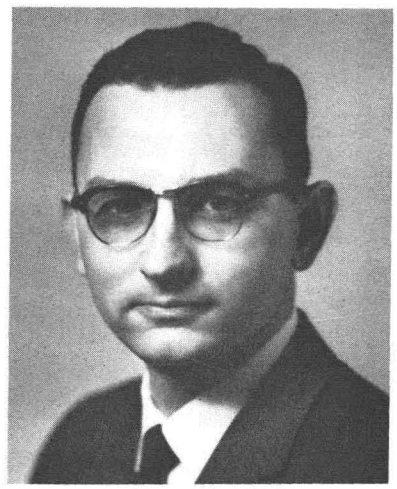
Introduction

THE rapidly evolving technology of computers accompanied by the increasingly sophisticated and imaginative application of these devices is beginning to have an impact on the operations performed by photogrammetrists and photo interpreters.

For many years, the development and application of a number of automatic type devices to a variety of photo-related operations (such as the viewing and mensuration of images and determination of land contour data) has provided both new and improved methods for performing such operations. Conversely, many other, equally important photo-related operations have been virtually unaffected by technological advances. This is clearly evident for those activities of the photogrammetrist and photo interpreter which can be classed as information processing operations.



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Of particular interest has been the degree to which a variety of information processing techniques can be applied to significantly aid photogrammetrists and photo interpreters in the extraction and utilization of information. Therefore, IBM's objective has been to investigate and seek solutions, both immediate and long range, to a variety of information processing problems associated with the handling of image-derived and image-contained data. An example is aerial photography which is viewed by photo interpreters to prepare a variety of products. Other related image type data include maps, charts, ground photographs, graphics and drawings.

During this past year, IBM has conducted, under the auspices of its Independent Research and Development Program, an investigation and analysis of photo interpretation operations to identify and develop techniques by which the technology of computers and information processing methods could be applied to such operations. This paper describes several techniques which were developed or initiated.

Image Information Processing

Basic to the study was the premise that the advances made during the past decade in the methods for collecting aerial photographic information have exceeded parallel developments in the handling of this information by photo interpreters. It is clear that technological advances in photographic emulsions and in the design of collection vehicles and camera lenses have had a significant effect on the amount of information that can be imaged in both a single photograph and a single photo-collection flight. Various viewing devices accompanied, in some cases, by specific mensuration capabilities have improved the interpreter's ability to view and measure the resultant images. But application is required in other areas. A study of the entire spectrum of

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operations performed by an interpreter or in support of photo interpretation, reveals that the bulk of the information handling techniques has not advanced in a commensurate fashion. More specifically, the methods of extracting, storing and retrieving data derived from photography have remained basically the same as those methods developed during World War II.

This study revealed that large numbers of routine photo interpretation tasks performed by human operators do not require skilled observation and judgment. Examples include the recording and filing of data, search for and retrieval of reference materials, and preparation of reports. These tasks were selected for initial investigation.

A series of image information processing concepts were postulated to integrate the technology of information processing with those operations which utilize photographs as a basic input to derive information. Based on these concepts, needed system techniques were identified for application. Several recently developed techniques were found to be applicable for handling alpha-numeric data. These techniques were supplemented by developing methods oriented particularly to image information processing activities. Included were a group of applications requiring:

a) Indexing and retrieval methods to be employed as part of a Photo and Graphic Storage and Retrieval System that could be implemented with a medium size computer in support of photo interpretation and photo library operations.
b) Retrieval query and presentation techniques for quickly obtaining information from formatted files in support of the interpreter.
c) Correlation techniques enabling a computer to assist the interpreter in the production of information relative to the identification and significance of imaged objects.

These system techniques, as they might be applied to a photo interpreter operation are depicted in Figure 1. Here, the data base and information processing capabilities of the system (on the left side of the diagram) are utilized in the photo-interpretation process (as shown on the right) through an interface of computer programs, as shown in the center of the diagram.

These concepts and techniques were subsequently developed to demonstrate their validity. The balance of this paper is devoted to describing two such techniques which are immediately applicable while a third is believed to embody a significant application potential. These are:

a) Photo and Graphic Indexing and Retrieval
b) Retrieval of Data from Formatted Files
c) Image Identification through Signature Correlation.

Technique for Photo and Graphic Indexing and Retrieval

Application Areas

Automatic means have been developed for indexing and retrieving photography and a variety of graphic materials responsive to the requirements for:

- Extraction of new information, by photo interpreters, in organizations having photographs as their basic input.
- Internal photographic input dissemination, routing, and control.
- Integration and correlation of new photo-derived information with data extracted from both previous photographs and collateral sources.

The *techniques developed* are capable of handling:

- Aerial photographs in a variety of formats and types including frame vertical or oblique, strip, and trimetrogon.
- Recording Photographs including Radar, Infrared, and Video.
- Ground Photographs
- Maps and Charts of all types
- Graphics including drawings
- Photo Interpretation Keys and other collateral reference materials.

Present Systems

Most of the present indexing and retrieval systems are based on the Standard Indexing System (SIS) plots which evolved from World War II and Korean experiences. These plots are contained in binders based on a permission indication of photographs available in a degree square. This plot provides a visual indication of coverage and is accompanied by auxiliary mission data including date, scale, quality, and taking organization.

Retrieval requests upon the present systems are for photo coverage over a particular geographic area or point on the earth's surface or for photographs containing specific images. A request may be qualified by scale, date of exposure, percentage of cloud coverage, type of photography, and other secondary

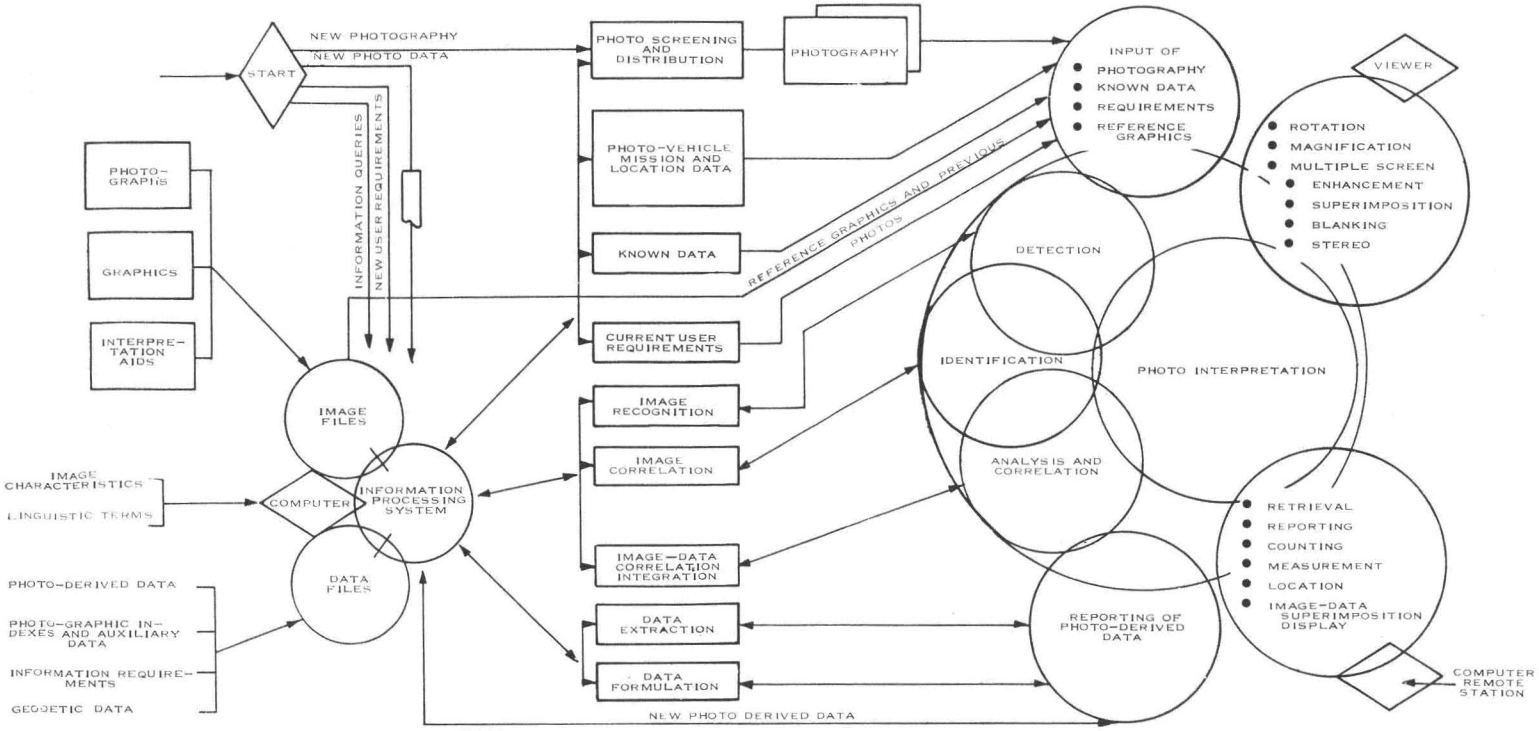


FIG. 1. System concept of image information processing for photo interpretation operation.

criteria. However, the basic retrieval is generally that of geographic location. The analyst, placing a typical retrieval request upon the present system, as depicted in Figure 2, must determine first the degree square or squares in which his request falls. Once determined, the relevant plots are pulled from file and the analyst begins his photo-coverage search. The search is accomplished by placing a map or area plot at the standard scale under the photo-plot. Acceptance or rejection is based on a visual match or no match comparison of the plot with the area of interest. The visual search and comparison is repeated for all plots that fall within the degree square. If a match occurs the analyst will review the title block at the top of the plot for date, scale, quality and type of photography. This is an arduous task and may take from several hours to several weeks of human effort.

The analyst will note the mission and exposure number for all photography that satisfies his requirement. In addition, he may prepare a composite plot of the relevant missions and exposures for subsequent use. Once the analyst has determined the required exposures, he may either request prints directly or he may request laboratory reproductions from negatives in file.

CONCEPT AND RATIONALE

The technique of indexing and retrieval developed by IBM maintains the spatial relation of photographs and graphics by geocoordinates, retains the mission data and adds additional information important to an analyst but not possible under the manual system. This information is stored in digital form and all retrieval parameters are handled simultaneously by a computer to provide quick response to an analyst.

Three concepts of this technique are shown in Figure 3 and are summarized below:

a) The *indexing criteria* provides a basis for handling photographs based on:
   1) Data *about* the photography which will be called "*source* data,"
   2) Data *in* the photograph which will be called "*content* data,"
   3) Data *related* to data in the photograph which will be called "*context* data."

b) The *storage criteria* must provide a means for handling photographs and index data within the parameters of two separate but related information files. These files consist of:
   1) A Photo-Image file containing the

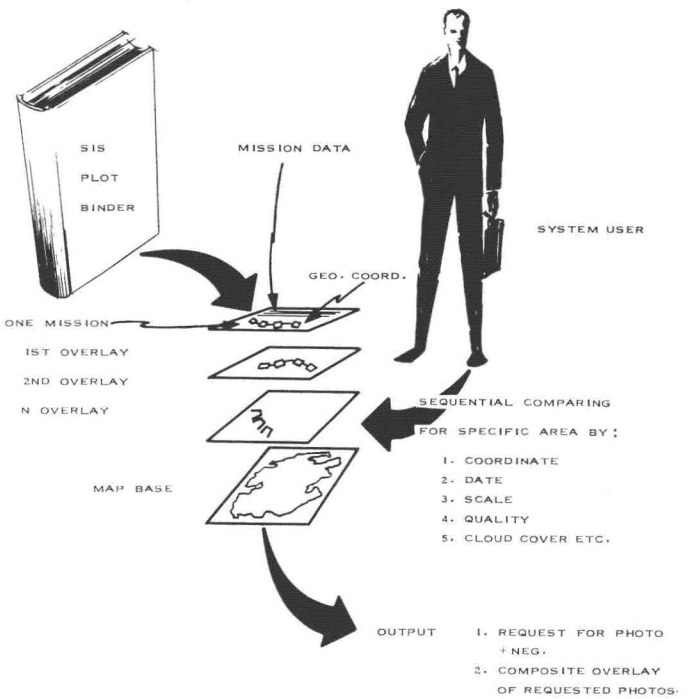


FIG. 2. Present retrieval systems.

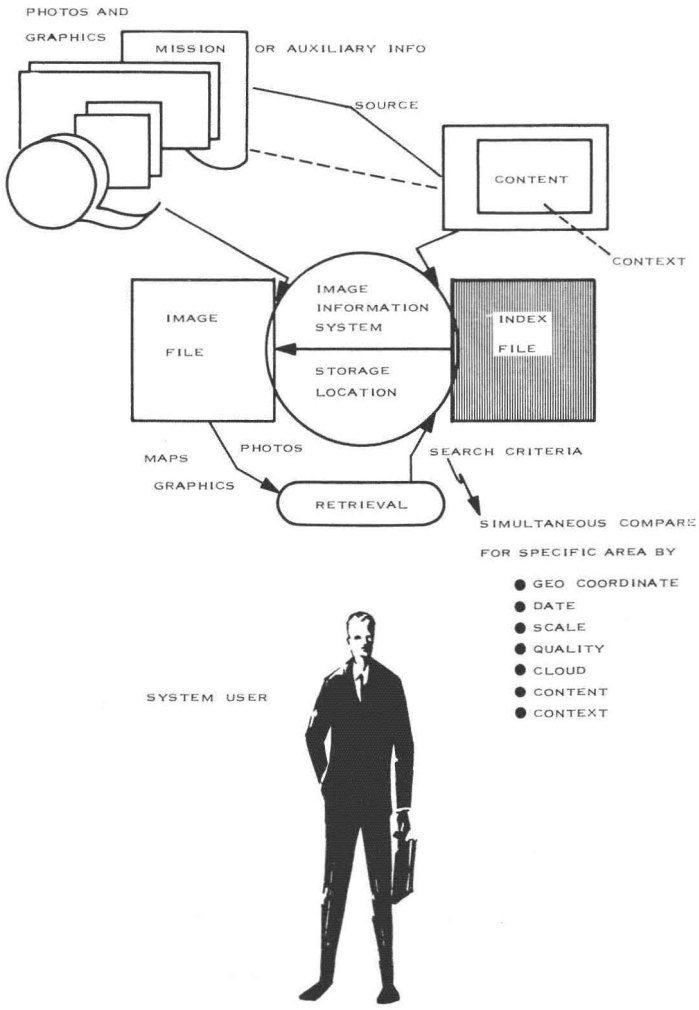


FIG. 3. Photographic indexing and retrieval system concept and rationale.

pictorial representation of information, and,

2) A Data file containing the information indices produced from or about a photograph.

c) The *retrieval criteria* must provide a means for obtaining the photograph and/or the related information index. Such retrieval will be based on:

1) The source-index with a major criteria of location and minor criteria consisting of mission, e.g., time, place, and camera-vehicle parameters,
2) Content-index with a major criteria of image descriptors which will be called keywords, and,
3) Context-index with a major criteria of keywords related to the pictorial content.
4) Any combination of above.

INDEX FORMATS

The information contained in the indices for photographic material includes:

- Location Data
- Time Data
- Mission Data
- Camera Data
- Vehicle Data
- Photo Data
- Content Data

Each of these items is arbitrarily assigned a unique Line Number, (400–600). These are presented in more detail in Figures 4 and 5.

- ACCESSION NO.
- STORAGE LOCATION
- TYPE MATERIAL
- WAC NUMBER
- SCALE
- DATE
- QUALITY
- PERCENT CLOUD COVER
- SNOW COVER
- SECURITY CLASS/GROUP/DATE
- GEO. COORDINATES (1-8)
- ORIGINATOR
- MISSION/SORTIE NO.
- PHOTO VEHICLE
- CAMERA (I.D SERIAL, POSITION, F/L, TILT)
- FILM (TYPE, FORMAT, ROLL, FRAMIN NO.)
- ALTITUDE
- HEADING
- KEYWORDS

FIG. 4. Index file format, photo.

RETRIEVAL SEARCH METHODS

It is anticipated that a major criteria of geo-location (contained in the source-index) will fulfill approximately 85 per cent of retrieval requests for comparative cover, distribution requests, and analysis requirements. The remaining 15 per cent will use a major criteria of content or context keywords, possibly combined with geo-coordinates to retrieve photos and data. For those photo interpretation operations concerned with the characteristics of images, the major retrieval criteria used will be keywords on content and context. The major features of the retrieval technique are depicted in Figure 6. Figure 7 shows the computer organization, program operation, and a typical request. The computer design logic is presented in Figure 8. These three figures provide the method by which a computer is used to search the indices to a file of photographs and other graphic materials, in support of photo interpretation and photo-graphic library operations. It should be noted that three types of programmed logic and computations are utilized in comparing search criteria with the photographic indices. They are:

a) *Equal logic (or direct match)*—which is used to match such descriptors as types of material, e.g., photo, map, vertical, oblique, camera used and images of interest.
b) *Boundary logic*—which is used to obtain matches against desired scale, date, quality, values, or range of values.
c) *Geo-Coordinate computation*—which allows an analyst to describe his area of interest in any irregular (or regular) shaped area (with 3 to 8 sides in the experimental program) and of any size. The program uses a mathematical technique based on the overlap of two convex polygons. This technique provides a more rapid and precise means of performing geo-coordinate calculations in contrast to previous techniques using greater or less-than logic.

Thus, the analyst will retrieve all photo and graphic material which not only satisfies his request parameters relative to such items as type, camera, keywords, scale, date, quality, but, in addition, all such material which also intersects, lies within, encompasses, or is tangent to his geographic area of interest. This search method was performed in the experimental program at the rate of approximately five (5) indices each second on a IBM 709.

Special attention should be called to the system potential for the retrieval of photographs for identification aid. In present systems, the "PI key" represents only the auxiliary information used by and designed

- ACCESSION NO.
- STORAGE LOCATION
- TYPE MATERIAL
- WAC NUMBER
- SCALE
- DATE
- SECURITY CLASS/GROUP/DATE
- GEO. COORDINATE (1-4)
- PRIMARY I. D.
- AUXILIARY I. D.
- ORIGINATOR
- KEYWORDS

FIG. 5. Index file format, graphic.

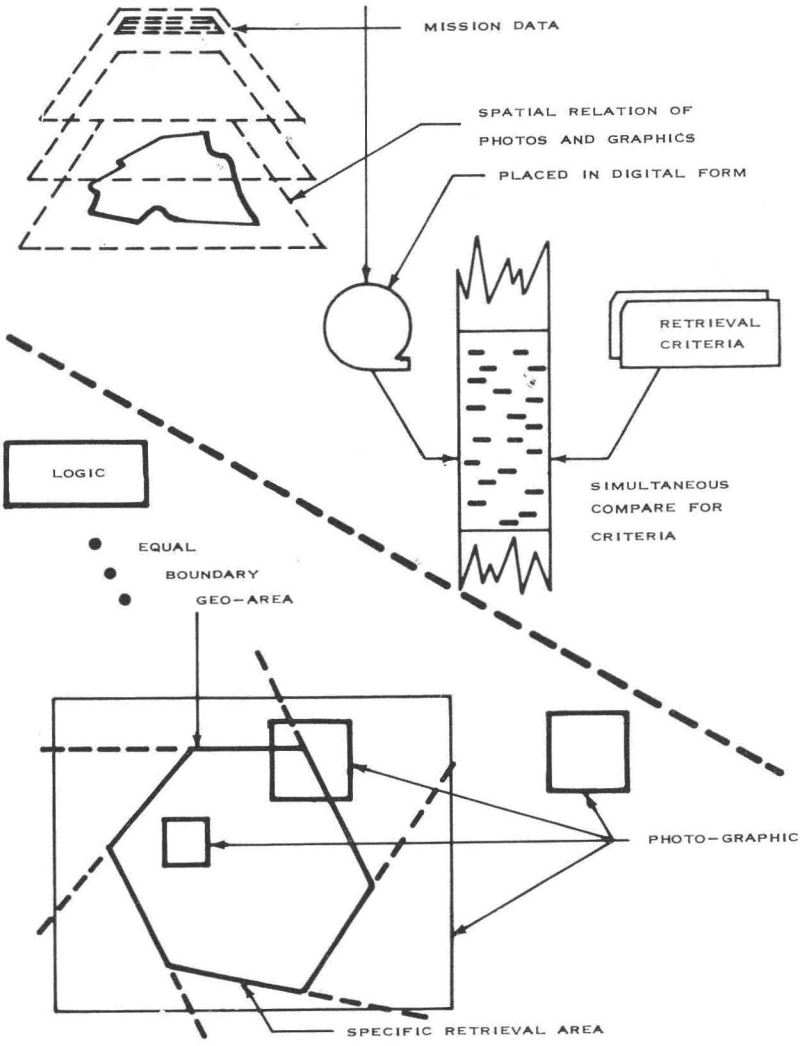


FIG. 6. Retrieval search method.

for the use of the photo interpreter. The PI keys consist of a collection of "typical" photographs assembled under various major subjects and designed to help him:

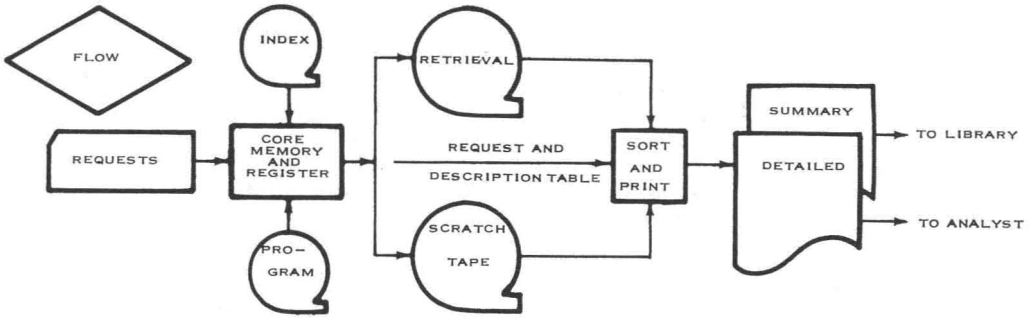
a) identify objects,
b) deduce the function of objects, and,
c) recognize the significance of activity.

By establishing a keyword concept as part of the index, the entire photo file becomes an up-to-date PI key and represents an important feature of the system.

TECHNIQUE FOR RETRIEVAL OF DATA FROM FORMATTED FILES

Automatic techniques have been developed for querying files of formatted data for retrieval and presentation in support of a photo interpreter. These formatted files can contain, for a given installation, a variety of data including previously acquired photo-derived data, geodetic data, information reporting requirements, and other collateral information. These diverse files can be accessed in a variety of ways using a general purpose program. In this application, there can be provided a more automatic means of screening new photography and of assigning viewing priorities in support of the photo interpreters.

For *screening*, the location parameters of all newly received photo missions can be superimposed over a matrix of "known" images of interest and a retrieval program similar to that already described can identify photog-



REQUIRE VERTICAL OR OBLIQUE PHOTOGRAPHS OF SCALES BETWEEN 1:10,000 AND 1:20,000 TAKEN BETWEEN NOV 1, 1960 AND SEPT 25, 1961 SHOWING ICBM OR IRBM SITES WITH QUALITY OF EXCELLENT AND LOCATED BETWEEN 39–45 N AND 40–00N AND 127–25 E AND 127–30 E

REQUEST 1 JOHN Q RESEARCHER

AND	497	AERIAL PHOTO
AND	498	VERTICAL
OR	498	OBLIQUE
AND	499	0380
AND	500	10,000–20,000
OR	500	000–00000

AND	501	110160–092561
AND	502	1–1
AND	600	40–00 N 127–30E
AND	601	40–00 N 127–25E
AND	602	39–45 N 127–25E
AND	603	39–45 N 127–30E
AND	8$$	ICBM SITE
OR	8$$	IRBM SITE

FIG. 7. Retrieval system, simplified diagram.

raphy containing or not containing items of interest. An additional sophistication could weight each image and thus provide a priority listing of photography to be viewed.

For *designating viewing priorities*, the keywords which describe significant objects and activities could be assessed for "rate-of-change" and a viewing frequency code applied to each desired keyword. This could produce a printout which would identify, by priority, those images requiring viewing with location and photo number designated. An additional sophistication could include the retrieval of previous photo coverage of such images and previously acquired data.

TECHNIQUE FOR IMAGE IDENTIFICATION THROUGH SIGNATURE CORRELATION

It is postulated that techniques of information correlation can be developed for producing information relative to the identification of significant objects imaged in photographs using the memory and association logic of computers. Implicit to this statement is the premise that images, both singly and in association, have unique, definable signatures.

The need for these techniques is based on the premise that the extraction of information from photographs will be accurate and significant to a degree dependent on the identification of images. Further, the large numbers and variety of objects and object groupings imaged in a photograph in combination with the different linguistic descriptors which convey significance exceeds the ability of a human mind to consistently provide accurate association and recall.

The computer memory and association logic abilities can provide a significant improvement by storing the unique descriptions of objects and object groupings and then, using a pre-defined set of descriptive parameters supplied by a photo-interpreter relative to a specific object or object groupings, perform a logical association search to identify such object or object groupings. (See Figure 9.)

There is also a requirement to correlate object descriptors to deduce their cumulative significance. This is considered to be a more complex correlation problem and one for which the criteria are imperfectly understood. In addition, the more sophisticated correlation-techniques would be dependent on the successful and accurate identification of objects.

Therefore, a computer program was written to support the development of techniques of correlation to provide the accurate identification of objects imaged in a photograph. This

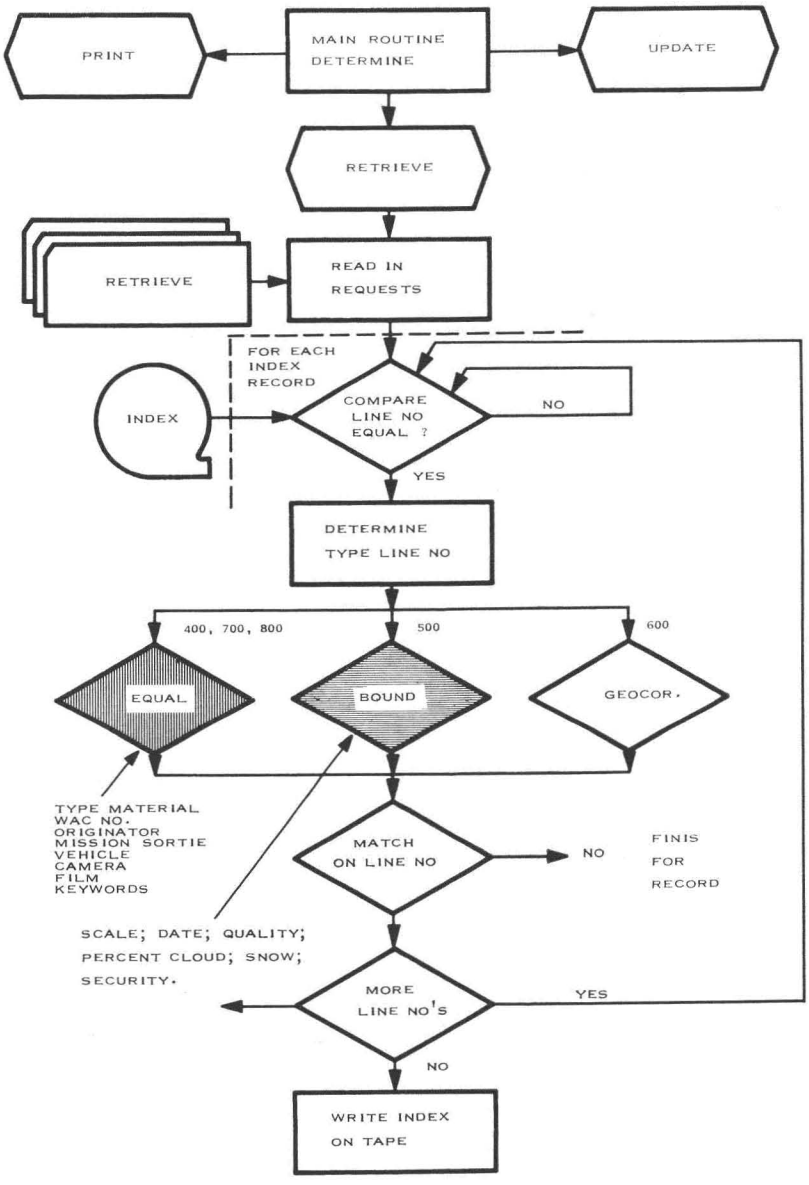


FIG. 8. Photographic retrieval program logic.

program provides an initial, but important, step toward providing more sophisticated correlation-techniques. This is accomplished by the selection of representative forms of object and object groupings and the development of computer correlation-techniques for identifying such objects.

The photo interpreter working in the present operational environment uses one of two procedures to establish image identification and to determine the nature and status of an image group. One technique is to perform a time-consuming, detailed, component by component, analysis. Once the analysis is completed, the interpreter assembles all his facts and makes a judgment as to the identification and significance of the image(s).

Another technique is to search for certain unique object signatures that will enable the interpreter to make a rapid and valid judgment as to the identification and significance of the images.

An object-signature may be defined as those apparent, unique characteristics that singly

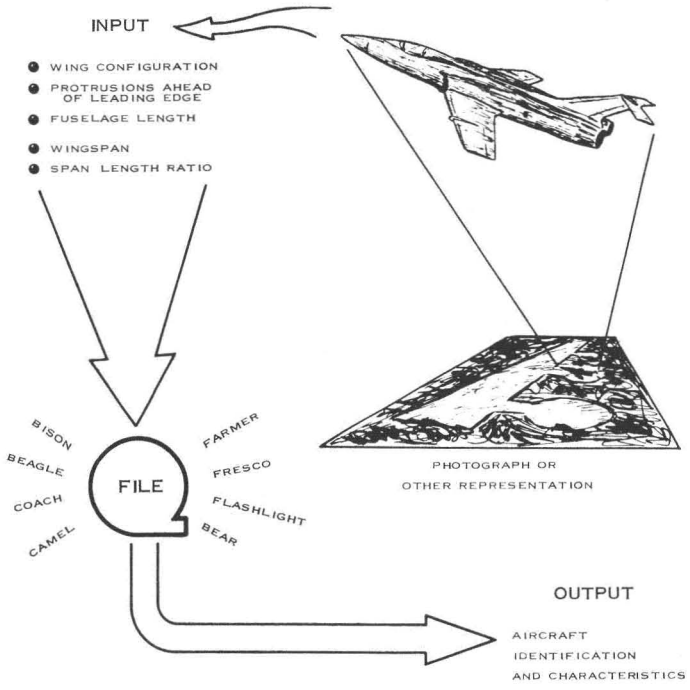


FIG. 9. Target signature (aircraft).

or in combination identify a specific object. The unique characteristics can be classified as those of component association, patterns, shape and configuration, size, tone, texture, site or position, and mensuration. Specific signatures may consist of one or the interaction of several of the above characteristics. The selection of representative problems of image-identification includes the following object groupings:

a) Single Object-Identification—Given an object identified as an aircraft, what is the type and name of aircraft?
b) Multiple Object-Identification—Given a complex grouping of objects identified as an airfield facility, what is the type and function of the airfield?

Two programming techniques are, at present, recognized as potentially applicable to the above stated problems:

a) Program 1 uses a table look up and equal matching logic to identify single objects. Only 100 per cent matching is utilized.
b) Program 2 uses a control table and a combination of equal and boundary object groups. In addition, each object group parameter will have a weighting factor assigned to it so that a correlation coefficient can be calculated based on the number and identity of the reported object parameters in conjunction with the number and identity of the control tables identifying parameters. This provides an identification probability factor.

The output of Program 1 is an on-line printout of a single object-descriptor identified by the program. The output of Program 2 will also be an on-line printout, but will be an ordered listing ranked on the identification probability factors showing the types of object groups identified along with the detail of identification parameters accompanied by their calculated factors.

The experimental program developed last year took the single object-identification problem and used the design logic of Program 1, to obtain initial experience with these techniques on an IBM 709.

As a result of its research and experimentation, IBM believes that the programs and techniques described in the preceding pages have direct and immediate application. It is intended that the program will be the basis for further experimentation and the development of improved techniques that will assist the image interpreter.