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A 'DIGITAL' TECHNIQUE FOR MANUAL EXTRACTION OF DATA FROM AERIAL PHOTOGRAPHY

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ABSTRACT

There is a growing need among local and regional planning and resource management agencies for accurate land use/land cover data. Usually, these data must be to a stringent level of detail and precision, and in a format compatible with simple computer storage or existing models. In addition, the data have to be provided within budgetary and time constraints. This paper describes an interpretation technique developed to meet these requirements.

ERIM's experience in the interpretation of remote sensing data has established that a cell or point format is a highly efficient method of interpretation when a fine spatial resolution is required and/or the number of classes to be interpreted is large. Applying this 'digital' format to the manual interpretation of aerial photography allows full utilization of the superior capabilities of a human interpreter to discriminate and identify the detailed surface and cultural features necessary for many planning and management activities.

The interpretation procedure described uses a grid cell approach. In addition, a random point is located in each cell. The procedure required that the cell/point grid be established on a base map, and identical grids be made to precisely match the scale of the photographic frames. The grid is then positioned on the photography by visual alignment to obvious features. Several alignments on one frame are sometimes required to make a precise match of all points to be interpreted. This system inherently corrects for distortions in the photography, which are often a major source of error in photographic data extraction. Interpretation is then done cell by cell. In order to meet the time constraints, first order interpretation should be maintained. The data is put onto coding forms, along with other appropriate data, if desired.

This 'digital' manual interpretation technique has proven to be efficient, and time and cost effective, while meeting strict requirements for data format and accuracy. The technique is applicable to many situations where extraction of detailed information from remote sensing imagery is required.

1. BACKGROUND

The Environmental Research Institute of Michigan was asked to prepare accurate land use/cover data from remote sensing imagery as input to the

Toledo Metropolitan Area Council of Government's section 208 area-wide water management program. Within time and budget constraints, data was needed in a format and level of precision required to input an existing water quality model. This model requires information on a specific point basis, that is, the land cover/use at a set of specific locations throughout a given watershed. Information on other pertinent factors, such as soils and topography, is also collected for these points, which are addressed using a readily determinable earth coordinate system,in this case, the Universal Transverse Mercator grid. The result constitutes a Systematic Unaligned Sample (one point randomly placed within each cell of a uniform grid), which has been shown to be a preferred system for sampling heterogeneous features with unknown, but uneven areal distribution (1,2).

The technique described here was developed and applied to medium scale color infrared aerial photography whose date of acquisition coincided with water quality sampling data. Thirty-five categories of land use/cover, and 12 associated features, were included in the classification scheme. The data was recorded on pre-printed sheets, which were also used for recording other information such as soils, topography, watersheds, etc. It was then punched directly into disc storage, where it was available for statistical analysis, manipulation, and mapping. Field checking showed that the data exceeded 90% overall classification accuracy.

2. INFORMATION EXTRACTION PROCESS

The information extraction process covers the interpretation of the aerial photography to obtain land cover/use information for each cell/point. It includes preliminary set-up of maps and photographs, grid alignment and retrieval, interpretation and coding of data.

A. Preliminary Set-Up

The first order of business after receipt of the aerial photography is determination of scale, so that the appropriate cell/point grids can be produced. The scale of the first and last frames of each flight line is determined, using the base maps. Up to 6 frames within each flight line are also scaled, depending on the flight line length. The measurements are recorded separately for east/west and north/south directions, and then plotted sequentially along the flight line.

A plot of the frequency of the various scale factors indicates the scale range of the grids to be produced. For instance, for nominally 1:50,000 scale imagery, a grouping may be found around 1:51,000, with clusters toward the tails of the entire range, 1:49,000 and 1:53,000. Accordingly, a series of different grid scales are produced, spaced over this range. A representative example is shown below:

TABLE 1

52,632	51,020	49,603
52,137	50,556	49,020
51,600	50,000	

Multiple copies of the grids for the base maps must also be prepared, at the proper scale. The USGS 1:24,000 or 1:62,500 topographic quadrangles are one of the more appropriate base map series.

B. Grid Alignment

The first step in actual interpretation is alignment of grids on the photography. This is a time consuming and at times tedious job, but it is critical to the success of the interpretation effort. Two major procedures have been used, but each interpreter will develop his own technique for making an optimum fit as rapidly as possible.

Grid alignment consists of positioning a properly scaled cell/point grid over a photographic frame, or part of a frame, so that it corresponds precisely with the positioning of the cell/points as indicated on the base map. This correspondence is determined visually by examination of the same features on both the map and photography, and their relation to the cell/point grid. Such features as roads and road intersections, buildings, streams, and railroads are commonly used. In some cases, more indefinite features such as forest/field boundaries and lake shores can be used, but great care has to be exercised to be sure that changes in these have not occurred between the date of the map and the collection of the photography.

Since scale is seldom, if ever, constant across an entire frame of aerial photography, it is usually necessary to make several alignments, or grid sets, in order to completely cover an entire frame, with only a small area being "matched" and thus interpreted for each. This variation can be caused by topographic changes on the ground, changes in plane altitude and tilt, or a combination of these. In some cases, it can be necessary to use two or more different scale grids on the same frame, and to match only a very small area at a time. Topographic differences, because they are localized, can also cause only one or two points to be mislocated, while the surrounding area matches the map. This distortion, which is a function of the geometry of aerial photography, cannot be avoided. In varied terrain it can be a severe hindrance.

One way to avoid the distortion problem would be to use orthophotography. However, the time and expense required to produce the orthophotos from the original imagery negates one of the major benefits of the technique described in this paper -- being able to use standard, uncorrected aerial photos to gather precise land resource data in a real-time manner.

The general technique of alignment is as follows:

1. Select a grid or grids at an appropriate scale, based upon the scale determinations, or the scale of a previous frame in the flight line.

2. Try to match the grid over a large area, using two east/west running roads, then two north/south roads. This will quickly indicate which grid approximates the actual scale most closely, and will show scale distortions over affected parts of the photograph.

3. Using features which are readily identified, line up the grid in one direction, and then the other, by setting the features in their proper place. Try to include as great an area as possible, but without sacrificing precise alignment.

4. When the grid seems aligned for major features, rapidly scan each row and column for correspondence between the map and photograph. If the match is good, tape the grid on the photograph, and delineate with a grease pencil the limits to be interpreted (that area over which the grid is precisely aligned) for that grid set.

5. Prepare the retrieval sheets.

An alternative technique preferred by some interpreters is to identify a number of points which fell on identifiable features on the map, circle these on the grid overlay, and then position the grid until all these points corresponded with the proper features on the photograph. All of the rows and columns still need to be checked for precise positioning.

Using these techniques, the grids can be fairly rapidly aligned on a photograph, even when the scale changes across it. A quality criterion is required such that no point on the photographs is more than one of its diameters away from its location on the map, or a realignment or new grid set is required. Still, the decision of how well the grid "fits" any section of a frame is a subjective one made by the interpreter, and great care must be exercised to avoid sloppiness. In order to reduce some of this subjectiveness, it is recommended that every alignment made be reviewed by at least one other interpreter. This interaction between interpreters brings about more precise alignments, and will catch some obvious misalignments before interpretation begins.

Since the magnitude of scale distortions increases geometrically away from the center of a photograph, alignment and interpretation of areas near the edges of the frames should be avoided. Standard 60% forward overlap (along the flight line) between frames, and 20% sidelap (between adjacent flight lines), facilitates this. In addition, the overlap enables the interpreters to make minimal use of badly tilted frames, or to avoid using them altogether. It also enables them to interpret areas covered by clouds on one frame, since in most cases the area will not be covered on the next or an adjacent photograph.

Two procedures with respect to alignment and interpretation may be followed. One is alignment of a single grid set, followed by immediate interpretation. This sequential mode is somewhat more inefficient than the second, however, especially where many grid sets, each covering a small area, are required. The second mode is to make all the alignments for a set of frames at one time, and then go back and do the interpretation. This system allows the interpreter to concentrate on one job at a time, either alignment or interpretation, and increased his proficiency and efficiency at each. It also eliminates waiting time by the coder since he is only needed during interpretation. Problems can arise, however, in that grids sometimes shift during the period between alignment and interpretation, necessitating realignment using the retrieval sheet. Also, photointerpreters should not spend much more than an hour consecutively doing the interpretation because of eye strain, and the alignment procedure affords a good break. A combination of the two modes of operation will afford a balance between the efficiency of aligning many areas at once, and the limitations imposed by sensible precautions for the welfare of the interpreters. It can also make allowances for personnel availability and external scheduling impacts.

In summary, some of the critical points to note concerning grid alignment are listed below.

1. Be sure the grid is properly positioned on the map, according to the geo-coordinates, with north up, and right reading.

2. Be sure the grid overlayed on the photograph is right reading, with north in the proper direction. Failure to do this can make alignment very frustrating.

3. Use the proper scale grid. Determination of the proper scale grid or grids, by alignment between east/west and north/south roads which are far apart, is critical (count the number of cells between roads, on the map and then the photograph). An improper scale grid can at times be forced into alignment over a small area. This should be avoided.

4. Try to cover as much area as possible with one grid set, but be aware of distortions and don't force the alignment. Stay away from the edges of the frame. Go to the adjacent frame instead.

5. Scan every row and column in the area being aligned, not just a few points or main features.

6. Don't worry about alignment outside of the area which will be interpreted for any one grid set.

7. Have another person review each alignment.

C. <u>Retrieval</u>

Because it may be important to be able to reexamine the land cover/use at a specific point, and if the use of future imagery to update the information is anticipated, it is necessary to document the precise positioning of the cell/point grids on the photography. This can be accomplished through a retrieval process performed by the photointerpreters after each grid alignment is made.

The retrieval documentation consists of two sheets attached to each frame of photography used. One is a clear mylar, on which the fiducial marks of the photograph, and the corners of a region for each alignment have been pricked with a pin. The other is a paper copy of the cell/point grids on which the area interpreted for each grid set is noted, along with the grid scale used, and the region number. Figures 1 and 2 show examples of these sheets. These two sheets should be considered as an integral part of the photographic record.

Preparation of these retrieval sheets is as follows.

1. After a grid is aligned for a given area, the clear acetate is overlayed and taped down. It is given a north arrow and marked with the photo frame number.

2. The fiducial marks of the photograph are pricked in the acetate and circled.

3. The corners of a fixed region on the grid are then pricked on the acetate, and identified with the grid set number.

4. On the paper grid, the actual area interpreted for the grid set is inclusively marked with cross-hatchings, and the grid set number and grid scale used are noted.

5. For subsequent alignments on the same frame, the fiducial pricks in the acetate are realigned with the fiducial marks on the photograph, and a new set of pricks made and numbered for the new grid set. The area interpreted is delineated on the paper sheet in the same manner.

A standard procedure should be established governing the retrieval system. The region corners pricked on the retrieval sheet should be the same for all grid sets. Standard notations should be used. The paper sheet and a map should also be consulted when using the retrieval sheets to be sure that the area of interest has been properly identified.

Use of the retrieval sheets to realign the cell/point grid is simple.

1. Identify from the paper retrieval sheet the grid set in which the area of interest lies and note the grid scale used.

2. On a cell/point grid of the proper scale, align the pin-pricks for the desired grid set with the corners of the region used and tape the mylar to the grid.

3. Put the photograph under the grid and align the fiducial pricks in the mylar with the fiducial marks of the image.

4. Tape the aligned grid to the photograph. The retrieval sheet can then be removed for easier viewing.

5. Delineate with a grease pencil the area interpreted for this grid set.

Mylar, or some other stable transparent film should be used for retrieval sheets. This will minimize the differential expansion between the sheet and the imagery, which can make re-alignment difficult, and less precise.

The paper retrieval sheets attached to the photographs will also serve as an index to the interpreted areas on each frame, and help save valuable time in determining which image was used to interpret a given area of interest.

D. Coding

Computer generated coding forms are a simple data recording medium for the photointerpretation effort, as well as other data such as soils, topography, watershed, etc. which may be gathered. These forms can be conveniently generated as listings by row and column of all the points in a region, with the geo-coordinates and I.D. numbers already assigned.

The coders need to be both thorough, in order to avoid errors, and able to write rapidly and neatly. The interpreters often can proceed much faster than a coder can write down the data, and it may take a while to get the two in synchronization and operating efficiently.

E. Interpretation

Interpretation should be done from the best available imagery with regard to clarity and contrast. Enlargements are not necessary. For many projects, the interpreters will need only a 10x hand magnifier to view the film. This magnification optimized the detail visible on an image, without bringing out the grain of most film. In some cases, especially urban areas, 8x magnifying stereo viewers will afford better interpretation through the added third dimension.

Decisions on the classification type for a cell are generally made based upon the dominant class within the cell. Thus, if 50% or more of a cell is one class, it is coded as that class. When one category does not cover 50% of the total area various decisions rules can apply. Determination of these rules, or other means of classifying a cell (percent types, weighted heirarchy, etc.) will be project specific. The decision rules should, however, try to retain the emphasis on speed of interpretation.

If a point system is also used, points will be classified according to the land category directly beneath them. Very small areas may be excluded, however. Again, these decision rules will be dependent on project requirements.

3. APPLICABILITY AND CONSTRAINTS

The technique described above is the way of extracting useful information from aerial photography. It is designed to be simple, inexpensive, and quick, and without the use of sophisticated equipment, highly skilled operators, or computer programs, it allows for extraction of geographically precise, accurate information. In addition, almost any type of aerial photography can be used. These attributes make it especially applicable for local and regional planning bodies with low budgets and large data needs, as well as for statewide or larger geographic areas where statistical information provided by point sampling can be very useful.

The method is dependent upon the availability of a base map series. The accuracy of the geographic alignment procedure is only as good as this map base. In order to maximize the efficient and speed of the operation, it is also necessary to maintain first order interpretation. first order interpretation requires that the classification of each feature on the imagery be immediately obvious to the interpreter, without recourse to measurements, keys or detailed examination of surrounding features. The level of detail obtainable from any given set of imagery is dependent upon the type and scale of photography and level of experience of the interpreters. However, the speed of the technique itself is basically independent of the number of categories to be identified so that, unlike most other data extraction methods, it costs little or no more to obtain information on 40 categories than it does on 10.

Finally, it should be noted that a general data extraction process has been described. It provides a technique which has been proven effective. Any user of the technique, however, can and should change it to meet his specific needs and resources.

Figure 1 Paper Retrieval Sheet

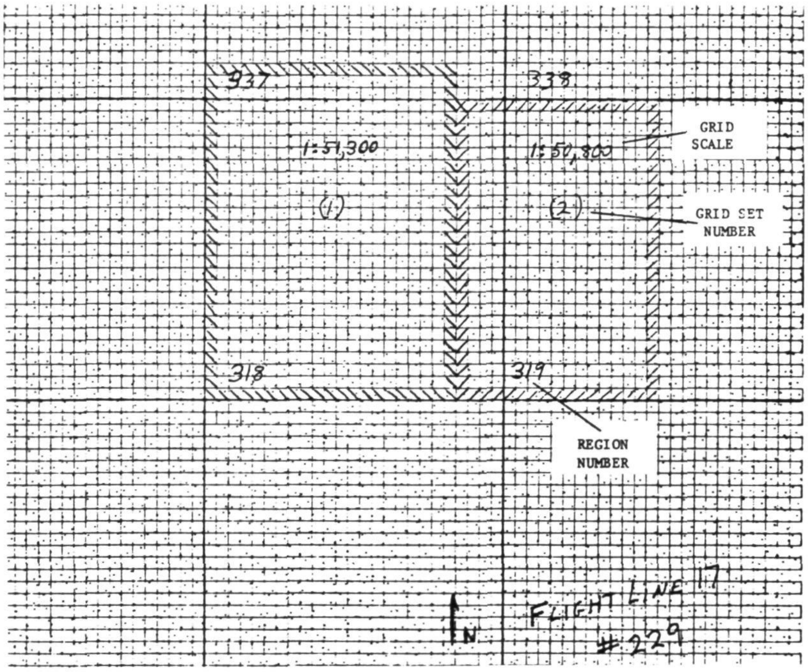
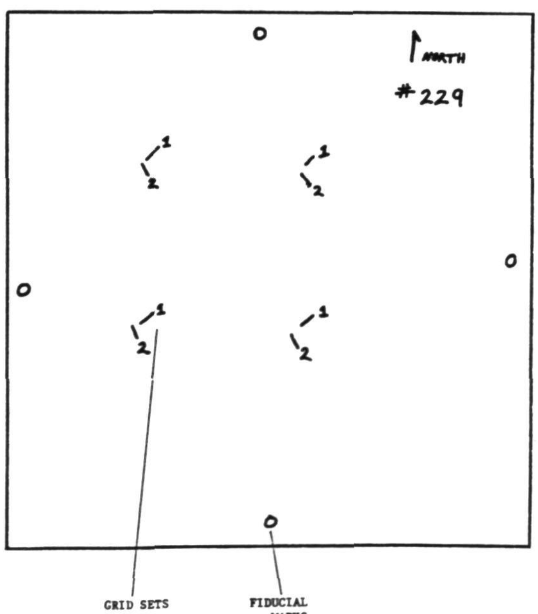


Figure 2 Mylar Retrieval Sheet



NOTES

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