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Computer Analysis of Photo Pattern Elements

Computer processing, employing the Photo Pattern Element concept, resulted in a reduction in interpretation time and in the skill level required of the interpreter.

Introduction

The world today is vitally concerned with ecology, sources of energy, and disarmament. A valuable tool in these areas is the science of remote sensing which has become a vigorously growing field. To date, most of the effort in remote sensing has been toward the means of data acquisition, as evidenced by the new films, multi-spectral scanners, new cameras, and the various space programs. These efforts have been very successful and data are now being collected at an unprecedented rate.

Without interpretation and analysis all of these data are useless; however, few advances have been made in the area of interpretation and analysis. That is not to say that efforts in that direction are not proceeding, some of the more notable being the work of R.M. Centner and E.D. Hietanen, who have shown the feasibility of an adaptive pattern recognition technique, wherein a decision logic network is "trained" to classify imagery.[1] Perhaps someday there will be a fully automated interpretation and analysis system, but that appears to be far off.

Interpretation is an essence a two-step process. The interpreter must first observe and recognize the objects and patterns appearing in the image and secondly he must compare and analyze what he sees and then record the results of his analysis.

The purpose of this study was to attempt to separate these two steps and to a certain extent, disregarding the first, attempt to model in the computer the second step. Initially, the two steps must be separated and the first made as elementary as possible. The simplification of the first step should be easily accomplished and presents no problem since most people have the ability to see stereoscopically with only a few hours of instruction and nearly everyone has a concept of what a plain, a plateau, a gully, etc. looks like. Thus, it should be possible to take an untrained person and, in a short period of time, train him to view photos stereoscopically, recognize pattern elements, and code the observed pattern elements for computer processing.

If this study were successful, two main benefits would result: One, a large pool of potential photo interpreters would become available because the need for extensive training would be reduced; and two, the time required to train a fully qualified photo

Abstract: *Much success has been achieved in collection techniques for remote sensing data, yet more investigation remains to be done in processing techniques. This paper describes an attempt to adopt the classical Photo Pattern Element techniques to computer processing. Two approaches were tried; the first had limited success but the second was successful. Interpretation time was reduced, as was the skill level required of the interpreter, and the Photo Pattern Element concept was shown to be highly flexible and adaptable to computer processing.*

interpreter would be reduced, as the student could observe and record the elements of the unknown patterns and then compare his own analysis with the computer output. In this way he could sharpen and refine his analytical skills and reduce the amount of individual supervision and instruction required.

In order to process any data on the computer, there must be some logical, orderly framework for the data (other than the mechanical arrangement necessary for the punch cards, tape, or other input medium). That is, from input to the final output, there must be some logical continuity to the flow of data. In a purely mathematical problem, the formula or equation serves this function; in this study the framework used was the pattern element concept.

The pattern element concept was used because it is at present the standard format used by photo interpreters in analyzing soil patterns. There are three basic principles which form the foundation of the pattern element concept as applied to photo interpretation.

(1.) The airphoto is a record of the earth's surface.
(2.) The earth's surface materials can be grouped into recognizable patterns.
(3.) Soil patterns are repetitive in nature. Where similar environmental, geological, topographical, and climatic conditions exist or have existed, similar ground patterns exist.[2]

The photo pattern concept, as applied to soils identification, evolved near the end of World War II, probably as the by-product of the impetus given to airphoto intelligence. Some of the early contributors were D.J. Belcher, D.S. Jenkins, R.E. Frost, and J.D. Mollard. Much of their work was done under the auspices of Purdue University and the National Research Council.[3]

The fact that the pattern element concept is the standard approach is not to say that it is without variations. The Civil Engineering Department at The Ohio State University has adopted a version with seven pattern elements. The seven pattern elements are—landform, drainage pattern, gully shape, special features, photo gray tones, land use, and vegetation. These seven pattern elements provide the framework within which the data were organized for computer processing. There are several possibilities within each element which are termed descriptors.

The development of a set or group of descriptors to be used by the photo reader in observing and coding the photo's data is a step that must be approached with care. This set of descriptors must be consistent with the version of the pattern element concept used in programming the computer, i.e., the version using seven pattern elements. The words used as descriptors must be consistent with the pattern element being described. In other words, the term that conjures up in the photo reader's mind a picture of a landform must be under the heading of landform and not under special features. The term that creates a mental image of a gully shape must be under that heading and not under drainage pattern.

In essence, what is of concern here is semantics. Does the word or phrase chosen as a descriptor create in the photo reader's mind a picture or image of something he sees on the photograph? If the answer is yes then the descriptor chosen is a valid one for that particular item. Conversely, if the desired image is not created in the observer's mind the descriptor is a poor one. Each descriptor chosen in each pattern element must pass this test.

Not only must the descriptor create the desired image in the reader's mind but the total set of descriptors for any one pattern element must cover all of the possible images that the observer might encounter. The list must cover all of the possibilities, but each individual term or phrase must not create an image that can be satisfied by more than one of the expected characteristics. In other words, each descriptor must create a unique image in the reader's mind. There is one other constraint that must apply to the list of descriptors that is developed for each pattern element, that is, that in addition to the above restrictions the list cannot be too long. The idea here is to eliminate the human decision-making requirements, not increase them.

Perhaps the idea can be clarified by drawing an analogy to a similar idea in set theory. The set of descriptors for each pattern element must be made up of a number of subsets, represented here by the terms or phrases that are mutually exclusive and exhaustive and not too numerous. The descriptors used in this study were developed by the author and may or may not require modification when used by other individuals.

Method

As previously mentioned, the primary thrust of this investigation was to model in the computer the analytical and decision-making processes that take place in the mind of the trained photo interpreter. Exactly what processes take place in the mind of the interpreter, after his visual mechanisms have transmitted the intelligence to his brain, has been and will continue to be the subject of long and continuing research. This research has, to date, not been able to identify the exact process and it was not the purpose of this investigation to attempt to do so, but to model those processes. No model can exactly duplicate the process. A model is satisfactory if it can produce as an end product the same or a reasonably similar output as the process being modelled.

The first attempt at modelling the analyst's mental processes was to assume that each pattern had associated with it a certain set of descriptors arranged in all their possible combinations. In other words, the analyst has mentally calculated and stored in his memory every possible combination that could represent a particular pattern. This we now call the model.

In attempting to write a computer program to use this model on the IBM 370/75, it was decided to exploit the fortuitous circumstance that there are seven pattern elements in our system and that the IBM 370/75 can use arrays of up to seven dimensions. If an array or matrix in seven dimensional Euclidian space is declared (dimensioned within the computer), each element in that array can be described or addressed in exactly the same fashion as an element in the more familiar two or three dimensional arrays, i.e., as a subscripted variable.[4] If we use the code number for a certain descriptor as one argument in the address of an array element, then by using the descriptor codes for all seven pattern elements we have the address for one specified element of the array. The element in the array, so identified, must contain a value that is correlated to one type of pattern. In this program, the array was filled with two byte integer words that identified a format code that was to be printed out.

The problem of placing the correct value in each element of the array was first approached by coding the possible combinations on cards and having these values read into the array. It soon became apparent that with four codes for landform, four for drainage patterns, three for gully shapes, five for erosional and special features, four for photo gray tones, five for land use, and five for vegetation, when considering residual sandstone patterns alone, the number of possible combinations would be very large. Therefore, a short computer program was written that worked out all of the possible combinations and punched a code on cards for subsequent read-in to the main program.

With this program computing all of the possible combinations, the hand labor was greatly reduced; however, when considering just the aforementioned residual sandstone patterns, nearly 4,000 computer cards were generated. This number of computer cards makes a heavy and bulky load and presents a problem in logistics when running the main program. Thus, it was decided to incorporate the combination program into the main program as a subroutine which would be called when necessary.

As the program was finally written, a seven dimensional array was dimensioned in the main program and filled with the values that cause the format to indicate an "undefined pattern" which would be printed out. The array was then passed to the subroutine where the elements that corresponded with all of the possible combinations indicating sandstone, shale, etc. were filled with the values that would cause the appropriate format to be written out.

The array was then passed back to the main program and the data cards containing the title of the photo set to be analyzed and the seven code numbers indicating the pattern elements were read. The seven code numbers comprised the address of a specific element in the array and the value in that element was then read out and used as a code to identify the specific format for sandstone, shale, etc. that correlated with the observed pattern elements. That format, along with the title of the photo set being analyzed, was then printed out as the computer output.

This approach was successful with the sandstone patterns, and it was then attempted to expand the program to include other patterns. It soon became apparent that this model could not be further expanded. A look at the mathematics involved will show why. By using the descriptors selected for sandstone patterns it is possible to obtain some 24,000 combinations. This is well within the capabilities of the computer facility at The Ohio State University; however, when the descriptors for shale are added the possible number of combinations increases to over 1,880,000. Since OSU's computer is limited to 630,000 bytes of storage, it is obvious that this approach is impractical.

After some reflection, it was decided to try a model where, instead of storing all of the possible combinations in the computer, the combinations would be worked out individually and compared with the unidentified pattern elements.

Where in the first model all possible combinations were read in and stored in the computer, the second model used the reverse approach. Since the number of photo sets being analyzed will always be several orders of magnitude less than the number of possible combinations, it is clear that much less computer memory will be used to store the data for the photo sets being analyzed than all of the possible combinations that can be worked out. As each combination is worked out it can be checked against the unknowns in the memory to see if a match occurs. This is the approach that was followed in programming the second model.

The program is really one main program which controls three subroutines which are called, as needed, in the overall scheme for the processing of the data. The main program (called PATEL) controls the subroutine DATRD (for data read), the subroutine CMBCK (for combination check), and the subroutine PRINT.

As stated before, the main program (PATEL) is the controlling section of the whole program. It declares certain variables to be common to all sections of the program, declares certain variables to be integer variables, and dimensions all the arrays used in the program. It should be noted here that the PATEL program limits the number of photo sets that can be analyzed at any one time to 100. This should not be an unbearable hardship for most organizations, and if a larger capacity is desired it can be obtained by increasing the dimensions of four arrays.

As the computer proceeds through the program, the number of photo sets to be analyzed is read and the subroutine DATRD is called to read in the data for the unknown photo sets. After the data have been read in and the control returns to the PATEL program, the heading for the output is printed and the list of possible descriptors for the first pattern is read in. The subroutine CMBCK is then called and the possible combinations are worked out and checked against the stored data for the photo sets. Upon return from the CMBCK subroutine the PRINT subroutine is called and any matches identified are printed out. The program then loops back to the read statement where the possible descriptors for the next pattern to be searched for are read in. The CMBCK subroutine is then called and the process repeats itself until the descriptors for all patterns to be considered have been read in and checked against the stored photo data. The program then proceeds to an alternate entry to the PRINT subroutine, which causes all of the undefined photo sets to be identified and printed out. When the program returns from the PRINT subroutine, the number of photos analyzed, the number uniquely identified, the number redundantly identified, and the number undefined are totaled. An appropriate heading is printed out and these numbers in both absolute and percentage forms are printed out. The program then proceeds to the STOP statement and is terminated.

The DATRD subroutine does exactly what its title implies; it reads in the data and stores them in the computer memory. It should be noted that this subroutine makes use of execution-time dimensioning.[4] Execution-time dimensioning, although adding somewhat to the complexity of the program, has the advantage of allowing the program to be completely flexible as to the number of photo sets being analyzed, from the obvious minimum of one to the maximum of 100.

The subroutine CMBCK works out all possible combinations of the descriptors for the pattern being considered and checks these combinations against the data stored in the computer memory to see if a match occurs with any of the unknown photo sets. As all photo sets are assumed to be undefined until proven otherwise, an array is first filled with the value one as that value indicates an undefined pattern to the PRINT subroutine. The method used here is to ask a series of true or false questions by means of an IF statement.[5] If and only if the answer is true for all seven of the elements is the photo set identified as being of that pattern. An array, initialized to all zeros corresponding to all false answers, is used to keep track of the answers.

Next is a series of seven DO loops, one for each pattern element. The first loop goes through all of the coded descriptors for landform and checks against the stored data in the computer's memory to see if a match occurs. If a match does occur, the value "one" corresponding to "true" is placed in the first storage position of the array in the row corresponding to the photo set matched, and this process continues until all photo sets have been checked against all of the possible landform patterns. After the photo sets have been checked against the landform patterns, the program moves on to check for matches in drainage patterns. If a match occurs the value "one" is stored in the second position of the array, in the proper row and in the same manner as when a match is found for the landform elements. This process is repeated for all of the remaining pattern elements, i.e., gully shape, erosional and special features, photo gray tones, land use, and vegetation.

After all photo sets have been checked against all possible pattern elements, the array is totaled up for each photo set. If the row total is seven, the logical equivalent to seven "true" answers, the photo set is identified as being that particular landform. Appropriate values are then passed to the PRINT subroutine which indicates which photo sets have been identified and their identification.

The PRINT subroutine controls the printing of the program output. It consists primarily of statements that cause the proper identifications to be written out when directed to do so by the CMBCK subroutine.

Since it is necessary not only to identify the photo sets identified by the program but also to identify the patterns for which there were no matches, provisions have been made to identify those photo sets which cannot be identified and those with redundant identifications.

It has not been stated explicitly, but perhaps inferred, that this program was written in the FORTRAN language for use on the IBM 370/75 installation at The Ohio State University. The FORTRAN G1 compiler was used and the one step procedure SUPER used. The procedure SUPER resulted in a simplified Job Control Language (JCL). The program in its current form requires less than 126K bytes of storage and runs in less than 10 seconds.

TABLE 1.

Analysis of the observed pattern elements yields the following results

Photo Set	Soil Class	Pattern
DZ23-29 & 30	Residual	Sandstone
BCT-76-57 & 58	Residual	Sandstone
BTB-3V-94 & 95	Residual	Sandstone
ABP-6K-74 & 75	Residual	Shale
BCT-7N-168 & 169	Residual	Shale
ALC-48-36 & 37	Residual	Limestone
BZE-3-109 & 110	Glacial	Till Plain
BCF-2G-101 & 102	Glacial	Till Plain
BVC-1G-198 & 199	Glacial	Lake Bed
BAG-29-26 & 27	Glacial	Kettle—Kame
CWJ-3K-200 & 201	Glacial	Kettle—Kame
BCP-1G-82 & 83	Glacial	Esker
DA-6-227 & 116	Glacial	Morain
AAB-6A-51 & 52	Aeolian	Sand Dune
BMC-47-121 & 122	Aeolian	Loess
CMT-2DD-93 & 94	Alluvial	Coastal Plain
CDV-5EF-67 & 68	Alluvial	Beach Ridge
BCT-5C-177 & 178	Alluvial	Flood Plain

TABLE 2.

Statistics	
Number of Photo Sets Analyzed	18
Number Uniquely Identified	18
Per cent Uniquely Identified	100.00
Number Redundantly Identified	0
Per cent Redundantly Identified	0.0
Number Undefined	0
Per cent Undefined	0.0

RESULTS

In this study U. S. Department of Agriculture (USDA) photography was used and the photographs were identified by their USDA number.Eighteen photo pairs were analyzed using the PATEL program. A stereo pair was observed for landform and the best description was chosen from the master list of landform descriptors; the corresponding numerical code for the best descriptor was then entered on the worksheet. The same procedure was used for drainage pattern, gully shape, and the other pattern elements. The data on the worksheet were then punched on cards for computer processing.

The program deck was processed, and the output from the PATEL program is shown in Tables 1 and 2. It can be seen that the program was able to uniquely identify all 18 photo sets analyzed. There were no redundant identifications, nor were there any photo sets that the program was unable to identify.

The photographs used in this study were from the files of the Photogrammetry Laboratory of the Civil Engineering Department, The Ohio State University. These photographs had been previously interpreted by several students and the instructor, and the soil patterns identified by the PATEL program agreed exactly with the identifications made by these interpreters.

The time required to analyze a set of photographs by the standard methods of photo interpretation varies considerably depending upon the interpreter's familiarity with the area, geological studies available, etc. The time required to observe and code any one photo pair did not exceed three minutes. No prior literature survey was required, nor was any other type of preliminary work required. Total processing time on the computer for all 18 photo sets was

6.14 seconds, and computer charges were $1.68. The minimum amount of time required to process a set of photographs is limited only by how fast the human observer can read and code the data.

Conclusions

One conclusion is immediately possible from the results of this study; not only is the pattern element approach to soil pattern identification a valuable tool in the standard methods of photo interpretation, but it is also readily adaptable to an automated approach.

A second conclusion is that the PATEL program will work with different sets of descriptors. During the course of this study several changes were made in the various sets of descriptors as the program was refined. Changes were made in order to achieve a more compact and precise set of descriptors to promote more efficient reading of the photos. The program ran consistently with 100 per cent correlation with the manual identifications, regardless of the particular set of descriptors used, as long as the set of descriptors met the previously mentioned criteria of exclusiveness and exhaustiveness.

One final conclusion is that the search and match approach is a valid approach to modelling the decision making proceesses of the skilled photo interpreter. This approach should be especially attractive to organizations having computer facilities with limited internal storage.

The results of this study generated considerable interest in both the Civil Engineering and Computer Science Departments at Ohio State. As a result of this interest, the PATEL program has been modified so that the list of pattern elements (descriptors) is displayed on a CRT and the correct one is selected by means of a light pencil. This modification is being used for instructional purposes and will be the subject of a report when research is complete.

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Articles for Next Month

V. D. Brandow, H. M. Karara, H. H. Damberger, and *H.-F. Krausse,* A Non-Metric Close-Range Photogrammetric System for Mapping Geologic Structures in Mines.

N. C. Gautam, M.A., D.L.Sc., Aerial Photo-Interpretation Techniques for Classifying Urban Land Use.

Dr. Sanjib K. Ghosh and *Dr. Hebbur Nagaraja,* Scanning Electron Micrography and Photogrammetry.

R. Michael Hord and *William Brooner,* Land-Use Map Accuracy Criteria.

Prof. Dr. J. Hothmer, Education for Users of Photogrammetry.

Kunwar K. Rampal, Least Squares Collocation in Photogrammetry.

A. J. Richardson, A. H. Gerbermann, H. W. Gausman, and *J. A. Cuellar,* Detection of Saline Soils with Skylab Multispectral Scanner Data.

E. Seeger, Orthophotography in Architectural Photogrammetry.

D. L. Wertz, W. T. Mealor, M. L. Steele, and *J. W. Pinson,* Correlation between Multispectral Photography and Near-Surface Turbidities.

Edgar A. Work, Jr. and *David S. Gilmer,* Utilization of Satellite Data for Inventorying Prairie Ponds and Lakes.