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INVESTIGATIONS OF AN URBAN AREA AND ITS LOCALE USING ERTS-1 DATA SUPPORTED BY U-"PHOTOGRAPHY"

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ABSTRACT

An urban area in central Pennsylvania and the surrounding locality were investigated separately at first by photointerpretation of ERTS-1 imagery and by computer processing of MSS tapes. Each of these independent approachs had shortcomings. Next the photointerpretation and processing were coordinated. The results of the cooperative effort of photointerpreters and computer processing analysts were much improved over independent efforts. It was found that single frames of U-2 photography could be projected onto printer output maps with little recognizable distortion in areas 10 to 25 cm square. In this way targets could be identified for use as training areas for computer processed signature identification. In addition, at any stage of category mapping, the level of success in correct classification could be assessed by this method. The results of the classification of the study area are discussed.

The state of the art of producing thematic land use maps by digital processing and analysis of multispectral scan data from ERTS-1 by the Office for Remote Sensing of Earth Resources at The Pennsylvania State University as of March 1, 1973, is the concern of this report. The geographic area of the study is a portion of East Pennsboro, Hampdon, and Lower Allen townships in Cumberland County just across the Susquehanna River from Harrisburg, Pennsylvania. The area is especially well suited for the study because it exhibits many terrain and cultural features most readily recognizable on ERTS imaging systems. The area is rapidly developing with a variety of targets including the Susquehanna River, Conodoguinet Creek, rail marshalling yards, urban and suburban areas, industrial developments, agricultural regions, forest, as well as a newly developed system of interstate highways. Such targets, properly identified, provide fixed points of reference between which items of lesser definition can be investigated and mapped. The rapid growth in the area provides an opportunity for evaluating the temporal dimension offered by ERTS data. Initial work at Penn State exposed the limitations of machine processing alone as well as the restrictions of visual photointerpretation alone from ERTS scenes. Hence, this paper emphasizes the development of a system combining the strengths of each method.

The maps shown in Figures 2, 3, and 4 were produced on a CalComp Drum Plotter.[1] MSS bulk ERTS-1 data tapes were processed on an IBM system 370/165 using a Remote Job Entry terminal. The programs used are described in a paper by Borden (1972). Supporting ground truth used for verification came from the 7-1/2 minute quadrangle map (1:24,000 scale) of Harrisburg-West prepared by the U. S. Geological Survey from aerial photographs taken in 1961 and field checked in 1963. Culture as of 1961 required supplemental data that was provided by infrared photography taken from U-2 aircraft on July 26, 1972. The photos are of 70 mm format with a scale of 1:445,000. As character maps were produced by the high-speed printer, they were verified for accuracy by projecting the U-2 photographic transparency onto the map using a 3-1/4" x 4-1/4" Model D American Optical Company slide projector. Scale distortions of the computer-generated, character map prevented proper registration of the projected photo over the entire area of the map. This required a distribution of positively identified targets throughout the area so that adjacent portions of the scene could be sequentially brought into proper registration.

Figures 2, 3, and 4 were produced from ERTS image number 1080-15185 of October 11, 1972. As bulk MSS tapes were received from NASA, they were subset to produce working tapes for selected portions of the image with guidance for the scan line and element numbers provided by an Ozalid print from any channel of the ERTS positive transparency. Two preliminary maps are produced for review of definable

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[1]These maps were presented in this form for the convenience of publication. The normal form of map presentation is a character map prepared on the high-speed printer.

boundaries. One shows variation in overall reflectance of the scene that is similar to gray scale maps in other systems. The second map is prepared to identify local areas of spectral uniformity. In some scenes the location of clouds and their shadows are noted to avoid misinterpretation as ground features. When these preliminary steps are completed, one is ready to proceed as indicated in the flow chart in Figure 1.

First level mapping is started by choosing training areas from the two preliminary maps. Select the most easily recognized targets from spectrally homogeneous areas with positive widely separated geographic locations. The Susquehanna River is an excellent example of such a target. Clusters of characters of lesser areal extent on the spectrally uniform map are next persued. Mean vectors are computed for the training areas using the four channels to establish spectral signatures. The euclidean distance of separation for pairs of mean vectors are computed and printed out as shown in Table 1 (to be referred later). As the character maps are produced, they are verified as described above by projecting the U-2 photos on the map. The maps may be produced in separate categories for ease of checking. Figure 2 shows such a map. Note first the easily recognized category of river in the upper right with the meandering creek entering from the left. This map shows the categories of open fields, forest, and golf course in addition to water. Areas verified by U-2 photo correlation are outlined with heavy lines. This process leads to the definition of lesser areas now geographically fixed and interpreted on the U-2 photograph. The number and variety of targets is expanded both with respect to type and extent of geographic separation. This is a cyclic operation, as indicated in the flow diagram, that continues until the mapper feels he is ready to advance to the next stage.

Second level mapping exploits a computer program using cluster analysis developed by Turner (1972). This program works where uniform training areas cannot be found because of spectral nonhomogeneity or small area. Figure 3 was greatly benefited by this technique. The signatures for some suburb, old suburb, confusion suburb, and industrial and for all parking lots and concrete were thus developed. This map was also verified by correlation with U-2 photographic projection and the targets successfully defined so marked. The category "confused suburb" comes about because of its lack of positive separation from agricultural fields. When one considers the mixed character of a suburb consisting of roofs, lawns, trees and shrubs, and streets, it is easy to see how some of these combinations might fortuitously compare to a mix of small fields or long, narrow fields related to contour stripping. Reference to Table 1 shows that the signatures for a category of "confused suburb" (the = symbol) and that for a field (the - symbol) does not have a wide separation. This separation is the euclidean distance of separation of the vectors representing the particular target.

Categories are separated for mapping on the basis of some minimum distance. When this distance is too small, confusion may result. For example, the distance between the "confused suburb" signature and the field signature is relatively small, 1.1, thus confusion between these categories could be anticipated. In contrast, the separability of river water (the W symbol) from every other category is quite large implying no problem in classifying river water correctly. If a mixture of characters is printed in an area, it may be desirable to keep the separate signatures, but lump the area. On the other hand, the signatures may be blended to produce one character, for example, in the two industrial signatures (the + symbols) that are quite separate, 17.7, but that occur together in a mixture for many industrial areas. These separate signatures must be preserved, but would be assigned the same mapping symbol. Judgment should be used here. More work is still required on the category called highways. It comes up well in areas of high subject-to-background contrast, but is weak in urban and suburban areas. Perhaps the mapper will have to produce highway networks by the judicious connection of scattered symbols. This is not a satisfactory procedure. Other spectrally nonhomogeneous targets definable by cluster analysis that are difficult but worthy of great effort are quarries and small streams. Note again the cyclic procedure through level two.

The third and final level of mapping is now approached. It may be that too many categories have been defined and the resulting map output is too refined or too confusing to the reader. Stray symbols can be suppressed. A careful review of the map objectives should serve as a guide to the final number of categories to be mapped. When a limiting goal is established, then the final cycle can be cut off. It should be noted that the mapping program includes a percent of the area mapped for each category. This makes it easy to express the area of each category when the total area bounded is known. Figure 4 is the final presentation. This is a combination of the first two. However, in order to make the map readable, the forest area was subdued so the blank areas are forest and unclassified. The hope of

Table 1. Distances of separation for categories.

	1 W	2 =	3 -	4 +	5 +
1 W	0.0	31.8	31.5	14.2	31.4
2 =	31.8	0.0	1.1	18.3	14.2
3 -	31.5	1.1	0.0	18.0	13.8
4 +	14.2	18.3	18.0	0.0	17.7
5 +	31.4	14.2	13.8	17.7	0.0

diminishing the unclassified group may rest on the merging of data from two scenes for different seasons of the year.

Conclusions that can be reached from the work on these maps are as follows: The categories of water, forest, high density suburbs, old suburbs, industrial, parking lots and concrete are reasonably well defined. The categories of agricultural fields, highway, and low density suburbs need more study. Some items highly desirable in land use mapping may not be obtained because of size or low subject-to-background contrast. The temporal aspect of the data has not yet had sufficient opportunity to be exploited. The combined efforts of interpretation of ERTS images, aircraft underflight photographs, and computer-generated, character maps has the potential to generate land use maps of high quality.

LITERATURE CITED

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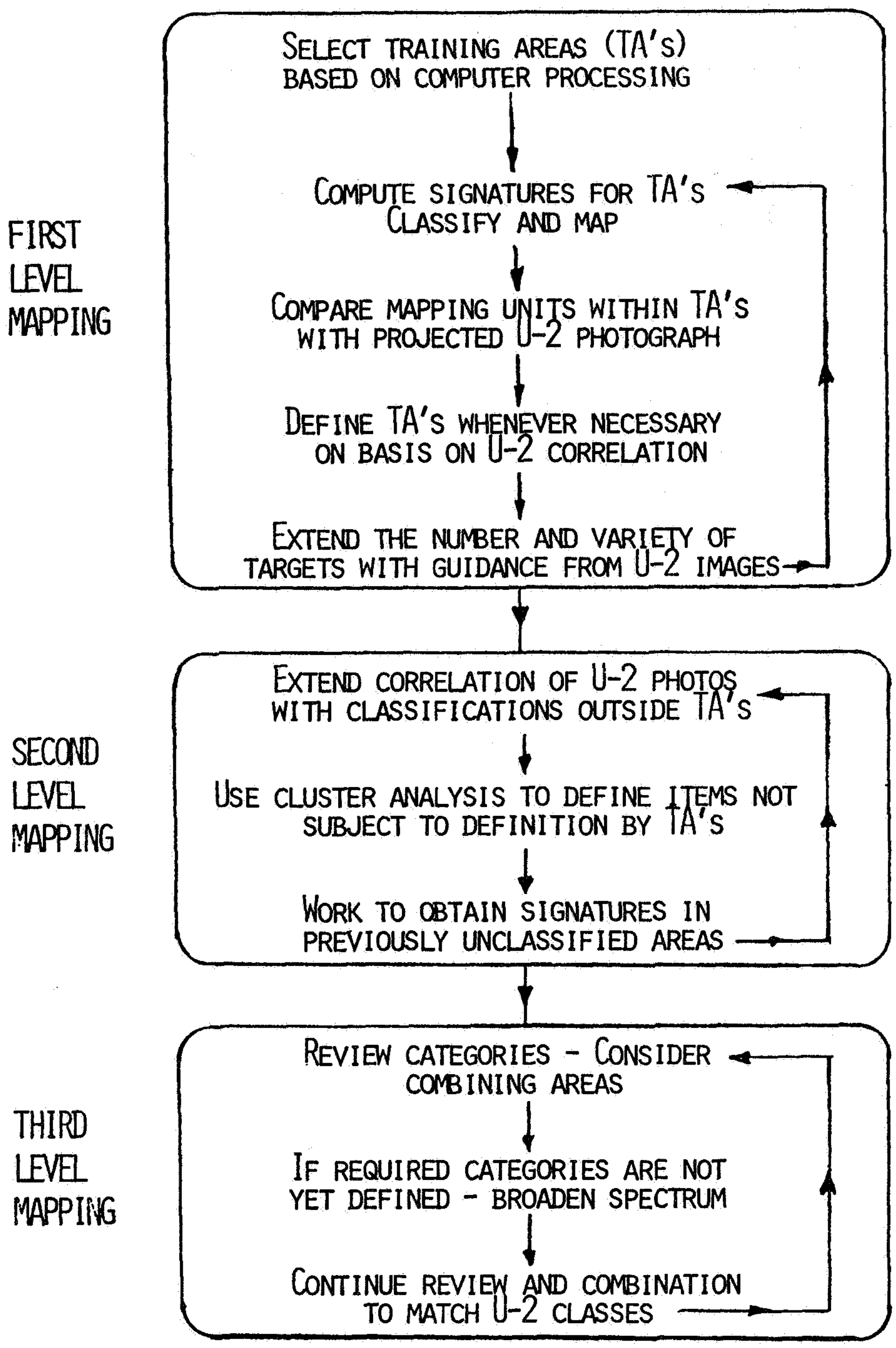


Figure 1
Mapping activity flow chart.

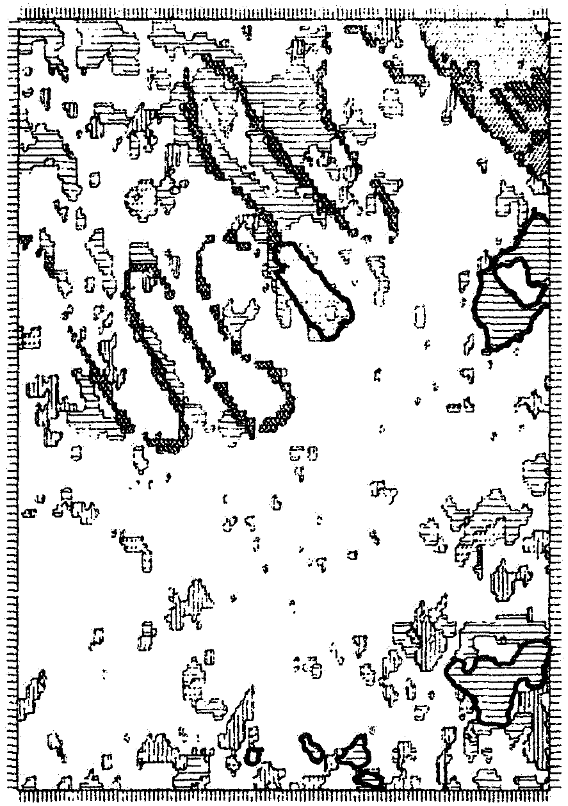


Figure 2

Classification map of agriculture and forest.

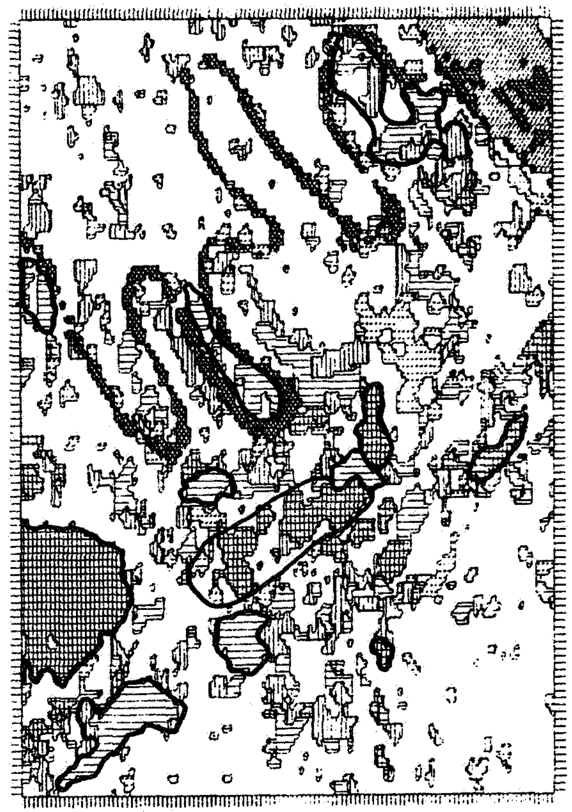
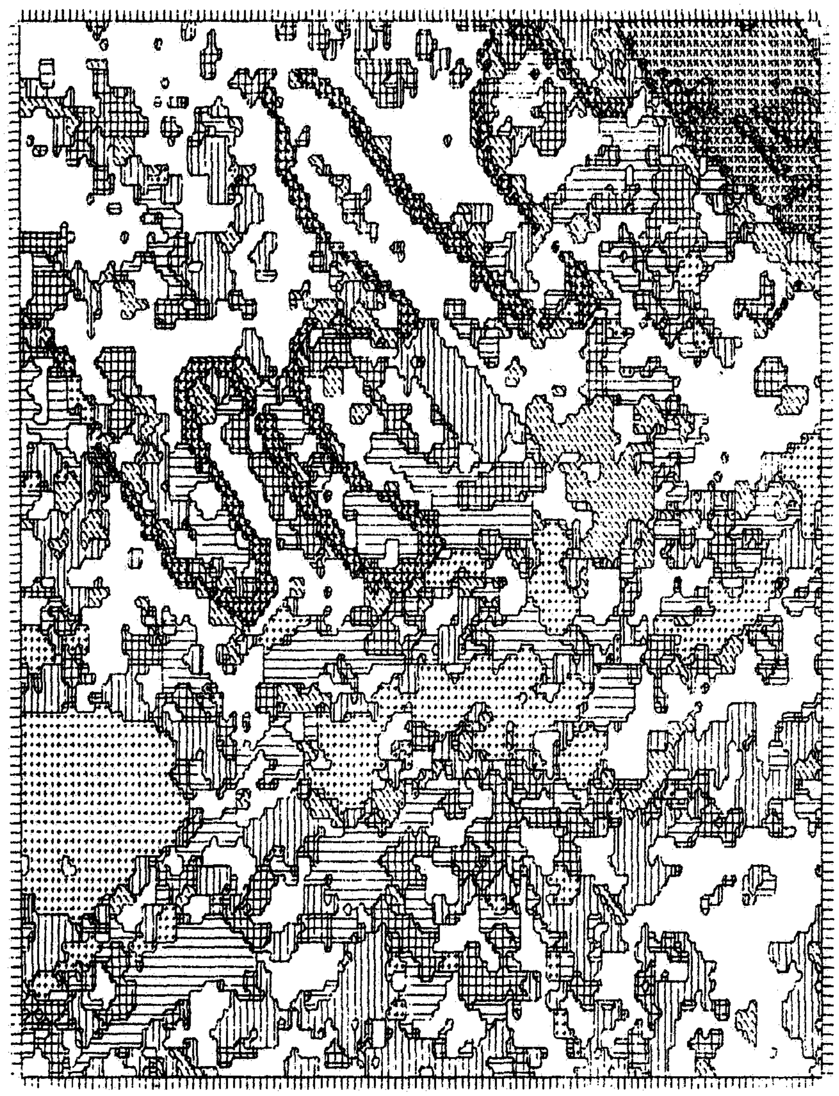


Figure 3

Classification map of suburb and industry.



Creek
River
Suburb
Old suburb

Industrial
Agriculture
Forest, other blark
Suburb confusion

Figure 4. Classification map of all categories.