AN AUTODIGITIZING PROCEDURE FOR GROUND-DATA LABELLING OF LANDSAT PIXELS*

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ABSTRACT

This paper describes an automatic digitizing procedure for use in ground-data labelling of LANDSAT pixels. The described procedure is based on video scanning of line tracings from aerial photographs containing identified ground-truth areas. The key feature of this procedure is that in the data processing of the scan data, no line-following algorithms are used. Instead the procedure directly maps scan pixel labels into LANDSAT pixel labels. An evaluation of the procedure on test cases, plus economic comparisons with alternative manual digitization methods, are presented.

1981

1. INTRODUCTION

Currently, the Economics and Statistics Service (ESS) of the United States Department of Agriculture (USDA) is engaged in research on crop area estimation using LANDSAT data. Besides LANDSAT data, the estimation method being investigated uses ground data collected by USDA enumerators for sampled areas, known as segments. This ground data is collected during ESS's June Enumerative Survey (JES), which is a major data source for ESS's operational (non-LANDSAT) crop statistics program. For each field in a segment, the size of the field and type of ground cover, along with other information, is recorded.

This segment data can be used to label LANDSAT pixels for supervised training of a pixel classifier if one is able to identify the LANDSAT pixels which belong to the fields in each segment. Currently, a major step in this labelling of LANDSAT pixels is the manual digitization of segment field boundaries into polygons using a coordinate digitizer. Table I lists some of the manual digitization characteristics for JES-segment photographs. The new method, described in this paper, replaces manual digitization with automated scanning of field boundaries into a raster format.

2. CURRENT METHOD

Using the present method [1], the segment field boundaries are drawn on an aerial photograph and are digitized using a coordinate digitizer. The

*Presented at the Fifteenth International Symposium on Remote Sensing of Environment, Ann Arbor, MI, May 1981.

processing). This type of thresholding is best done interactively immediately following scanning before the image is stored for further processing. This interactive thresholding is not time-consuming since all segments are presented for scanning in the same way (dark lines on acetate) making thresholding levels quite similar for all segments.

During the connectivity analysis, any two scan image pixels are assigned to the same field if there is some path between them which does not cross a boundary. Four-connectivity is used for non-boundary scan image pixels, meaning that only horizontal and vertical neighbors are considered. Eight-connectivity is used for boundary scan image pixels, meaning that diagonal as well as horizontal and vertical neighbors are considered.

Once the connectivity analysis has been performed, the fields are manually assigned names. Presently, this is done on a coordinate digitizer using a printout of the scanned image. An alternative method, believed to be better, is to assign field names using a graphics terminal. An interesting topic for future research is to determine the feasibility of scanning the field names written on the acetate sheets and interpreting them using pattern recognition techniques.

Next, some editing of the image is performed. This editing involves merging small, isolated boundary elements which have a single non-boundary neighbor field into that non-boundary field on the assumption that such boundary elements are probably dust specks or other forms of noise in the image.

Then, the boundary lines are thinned with the goal of making all boundaries no more than one scan image pixel wide. The thinning is done in iterations. In each iteration, the boundaries are scanned successively from the left, right, bottom, and top. In each of these scans, when a boundary scan image pixel is first encountered after having scanned through a non-boundary field, a check is made to see if that boundary scan image pixel may be reassigned to that last non-boundary field. The reassignment will occur if it will not make two different fields neighbors in the four-connected sense. In a scan, after the first boundary scan image pixel is encountered, all other boundary scan image pixels to the next non-boundary scan image pixel are skipped whether or not the first was reassigned. This is done to try to keep the thinned lines smooth. Thinning iterations continue until no more boundary scan image pixels may be reassigned.

After thinning, a final editing of the image transforms small non-boundary areas which have not been labelled into boundary areas since such small non-boundary areas would not contain even a single LANDSAT pixel.

The location of the segment with respect to a cartographic coordinate system is done in part manually. On the acetate, along with the image boundaries, are placed five small dots known as calibration marks. These calibration marks are placed outside the boundaries of the segment, one in each quadrant, but with two in the upper right quadrant. The extra mark in the upper right quadrant is placed more to the right than above or below the other mark in that quadrant. This provides information on the alignment of the segment allowing the scanned image of the segment to be rotated if it was incorrectly oriented during scanning. The location of the calibration marks in a cartographic coordinate system is found using a coordinate digitizer in the same manner as in the present manual digitization method. A topic for future research is the automation of the location of the segment in a cartographic coordinate system.

The calibration marks constitute corresponding points between the scan image raster coordinate system and the map coordinate system. Then, once the LANDSAT image has also been registered to a map base, the locations of the

These results indicate the suitability of automatic digitization by scanning to accomplish ESS's pixel-labelling objectives for the following reasons:

- Boundary-pixel comparison differences between the two digitization methods do not necessarily indicate labelling errors, but may be caused by the different operational definitions of a LANDSAT boundary pixel used by the two methods.

- Generally, the JES segments provide more training data than the minimum amount required. Thus, associated classifier training is tolerant of limited under-inclusion of field-interior pixels in the pixel labels.

- Classifier training is also tolerant of limited over-inclusion of field-interior pixels in pixel labelling because of data editing based on scattergrams of the labelled LANDSAT data.

5. ECONOMIC ANALYSIS

In 1981 ESS will be conducting statewide LANDSAT projects in Iowa, Kansas, Missouri, and Oklahoma. The segment digitization for these projects will be performed manually using coordinate digitizers located in each project state; i.e., by decentralized manual digitization. The coordinate digitizers and accompanying line plotters will communicate via the TELENET packet-switching network with a time-shared DEC-10 computer located in Cambridge, Massachussetts. Both TELENET and the DEC-10 computer installation are commercial concerns to whom ESS pays normal charges for the services provided.

ESS's current plans are to increase the number of LANDSAT-project states by two states per year so that by 1985 there will be LANDSAT projects in twelve states. The 1985 digitizing workload will be in excess of 4000 segment photographs. A number of different digitizing alternatives exist for accomplishing the 1982 through 1985 digitizing goals. Alternative digitizing approaches include the following, for completion of the projected digitization workload:

- Decentralized manual digitization with timeliness comparable to 1981,

- Decentralized manual digitization with improved timeliness over 1981,

- Centralized manual digitization, resulting in improved timeliness over 1981, and

- Centralized automatic digitization, also resulting in improved timeliness over 1981.

Table VI lists total projected costs, 1981 through 1985, for these alternative digitization approaches. (See [3] for additional details.) Over the five year period, the projected savings resulting from the use of automatic digitization range from $460,000 to $830,000, depending on the configuration and timeliness of comparison manual digitization approaches. Table VII lists timeliness measures for the various digitization approaches.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr. Raymond Luebbe and Paul Cook for their numerous suggestions and ideas; William Wigton for his continual encouragement; the Remote Sensing Branch's Technical Support Group for manual digitization of the test-segment photographs; and Professor Azriel Rosenfeld, Andrew Pilipchuck, and David Notley of the University of Maryland's Computer Vision Laboratory for their expert assistance.

Table I. Typical Characteristics of JES Segment Photographs

	Mean ± Standard deviation	Minimum	Maximum
vertices/photo:			
0.5 mi^2 segments	90 ± 47	9	225
1.0 mi^2 segments	147 ± 90	6	623
fields/photo:			
0.5 mi^2 segments	14 ± 6	3	27
1.0 mi^2 segments	26 ± 12	1	96
Manual-digitizing time/photo (hrs):			
0.5 mi^2 segments	.78 ± .58	0.15	2.8
1.0 mi^2 segments	.61 ± .51	0.08	6.5

SOURCES:
Statistics for 0.5 mi^2 segments are from a sample of 56 segments digitized for ESS's 1979 Missouri LANDSAT study. Statistics for 1.0 mi^2 segments are for the 296 segments digitized for ESS's 1980 Iowa LANDSAT study.

Table II. Physical Characteristics of Test Segments

segment	size (ha)	dimensions (km)	land use	average field size (ha)
S1	54	0.8, 1.2	agri-urban	3.6
S2	163	1.7, 1.4	extensively cultivated	5.1
L1	228	3.7, 1.3	extensively cultivated	5.2
L2	562	3.1, 3.2	range, pasture	37.5
L3	801	4.4, 1.6	range, pasture	66.8

Table III. Automatic-Digitization Characteristics of Test Segments

segment	scanning-area dimensions (cm)	scanning resolution: on the photo (mm)	scanning resolution: at ground scale (m.)	scan pixels per LANDSAT pixel: linearly	scan pixels per LANDSAT pixel: areally
S1	15, 18	0.4	2.8	20.0	400
S2	23, 20	0.7	5.6	10.1	103
l1	53, 20	1.0	8.4	6.8	46
L2	48, 46	1.1	8.7	6.6	44
L3	22, 61	1.2	9.2	6.2	38

Table VII. Projected Number of Weeks to Completion of Segment Digitization

	Winter-Planting States			Spring-Planting States		
	1982	1983	1985	1982	1983	1985
Decentralized, manual, FY80 timeliness	9	9	9	9	9	9
Decentralized, manual, improved timeliness	4	4	4	9	9	9
Centralized, manual, improved timeliness	5	5	5	11	11	11
Centralized, automatic, improved timeliness	3	4	5	6	8	10