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THE USE OF LANDSAT IMAGERY IN SMALL-SCALE MAPPING

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Abstract

Methods and programs have been studied and developed for using digital Landsat imagery in small-scale mapping (1:400 000 and smaller). This work has been done at the Technical Research Centre of Finland in co-operation with the National Board of Survey.

The two main results during 1979 are reported, first, the so-called generalization program (reclassification program) for generalizing classification results and producing outlines, second, the classification results of the main classes of Finnish terrain.

1 INTRODUCTION

Research and development work concerning remote sensing has been done in the Laboratory of Land Use, at the Technical Research Centre of Finland (VTT) in co-operation with the National Board of Survey since the year 1977 when the first research contract was made. At that time the usability of Lansat data in the mapping of vegetation and soil was studied and the first programs for rectification were developed, among other things.

In the year 1978 the development work was directed to map production on small scales motivated by the modernizing of the general map of 1:400 000. In this work attention was focused on the classification of areal objects such as lakes, woods, fields and clearings, as well as on mapping changes in them. In this project an area of 5000 sq.km was classified in central Finland, the results being rectified numerically to the map projection of Gauss-Krüger (middle meridian is 27° E). The classified areas, added with line drawings such as roads and names, were printed with 7 colours to an experimental map on the scale of 1:400 000, in size A4.

In the year 1979 the project was carried on with newer Landsat data. The following methods and programs were being developed and introduced:

- numerical rectification of Landsat data,
- unsupervised interactive interpretation program (clustering),
- generalization program and
- area-counting of freely limited regions.

The image processing system developed for graphic arts research work at VTT was also used for graphic plotting.

The results of the 1979 project are reported in this paper being a summary of report /1/. The system flowchart used in the study is illustrated in figure 1. The paper includes a printed map showing examples on generalization and the final map on the scale of 1:200 000, see appendix.

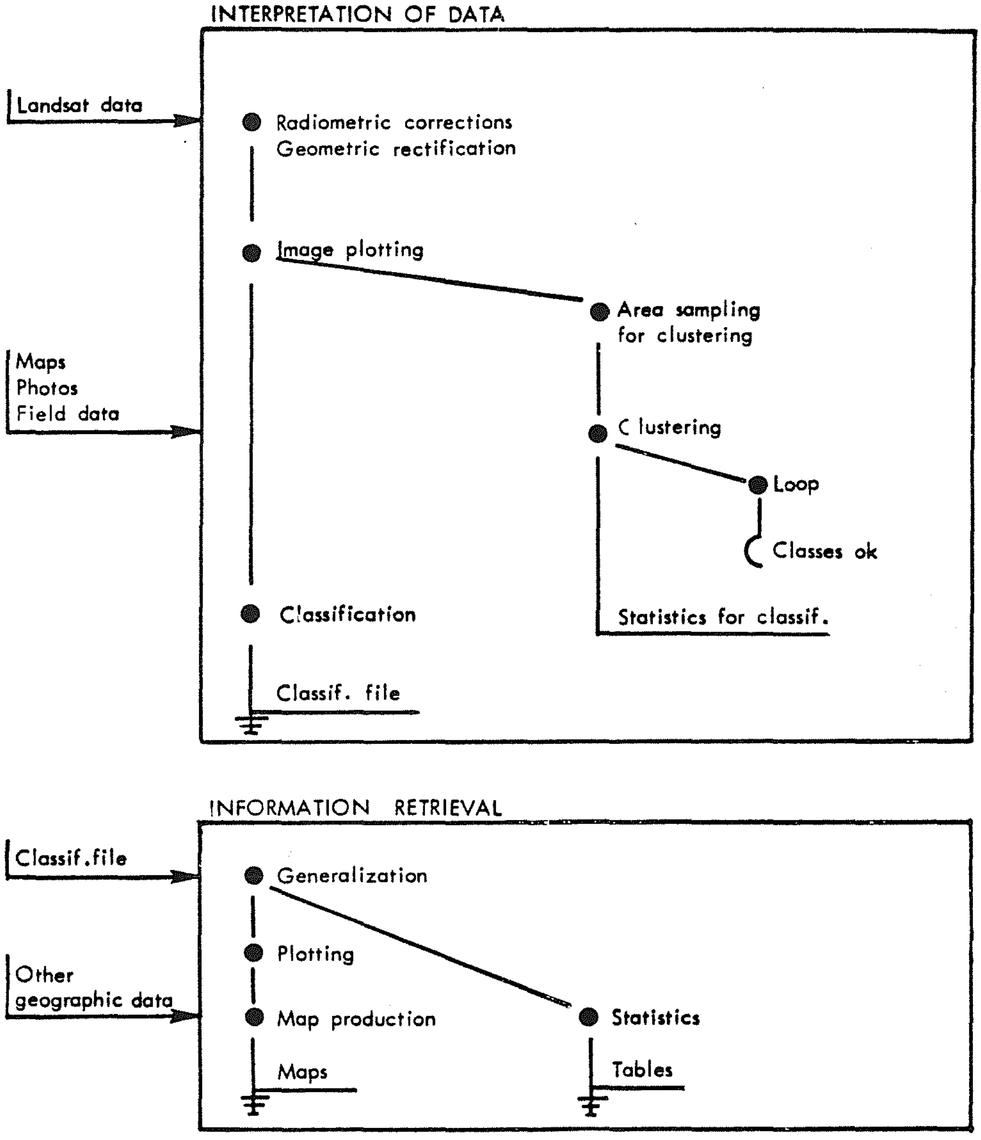


Figure 1. Flowchart for digital small-scale information processing.

2. METHODS AND PROGRAM FOR GENERALIZATION

In order to use satellite imagery in small-scale mapping the classification results have to be corrected and generalized. There are many kinds of cartographic generalization. Besides, generalization belongs to the human activities which are very difficult to automate.

The first aims of the developing work were the following basic generalization tasks:

- clearing of small mostly wrong-classified figures,
- reclassification of figures below the minimum size set for a class (quantitative generalization)
- smoothing of outlines of figures (outline generalization).

Moreover, outlines belonging to cartographic presentation such as shorelines had to be produced.

2.1 Outline generalization and processing

The method used is the weighted median filtering. The surroundings are the fixed nine pixel neighbourhood where to the processed pixel corner- and edge- connected pixels have their own weight matrix by classes, figure 2.

Figure 2. Edge-(1) and corner-connected (2) pixel surroundings of the pixel in process.

2	1	2
1		1
2	1	2

Additional features are the use of a treshold value and a replacement class.

According to the value of the weight sum and treshold vector there are three processing possibilities in the algorithm:

1. No filtering for the pixel in process.
2. Filtering where the new value is determined by the weight sum vector and the hierarchy of the classes.
3. The new value is the value of the replacement class.

The algorithm gives various processing possibilities and it can be used, among other things, in the following tasks:

- to smooth outlines of a certain class, outline generalization,
- to clean isolated pixels,
- to make figures smaller or bigger than the ground figure,
- to produce outlines for figures,
- to calculate the length of outlines,
- to shade certain figures.

Examples are figures 3, 5, 8, 9, 10, 11 and 12, in appendix.

2.2 Quantitative generalization

The task is to reclassify the figures which are smaller than the minimum size for a certain class.

After the literature and software researh the method and program presented in /2/ (Davis & Peet, 1976) were taken as a starting point. The method was rendered more versatile and the program was completely remade having many times higher capacity and efficiency.

There are three main steps in the method:

1. Separating of small figures resulting in a list of those to be reclassified.
2. Sorting of figures. The figures are sorted in reclassification order according to size, class or linecoordinate.
3. Reclassification of these figures being the most important step with regard to the final result.

In steps 1 and 3 it is possible to choose whether edge-connection only or corner-connection as well is taken into account.

In the reclassification of a figure the value of the weight sum vector is calculated from the pixel values surrounding the figure. Input data are weight matrixes, the replacement class vector being as in filtering. The new class for the figure is determined according to the weight sum vector as follows:

- if the weight sum is zero for every class, the new class is replacement class,
- otherwise the new class is determined according to the weight sum vector and the hierarchy of the classes.

Features of the algorithm:

- the figure will be reclassified into a class which dominates the surroundings (including weights),
- a figure will be reclassified only once,
- the use of replacement class makes it possible, for example, to preserve islands within a class for which the weights are zeros,
- when processing a mixed picture the best result will be achieved with the reclassification done in size order.

There are examples in appendix.

As an additional feature a figure list can be processed on a lineprinter from the reclassified area, figure 3. This file will be better produced as a graphic figure map representing only the outlines (produced by filtering) as well as the number and area of a figure.

AREA LIST

NUMBER	CLASS	AREA	X	Y	PIX.	FSTCOL	LSTCOL	FSTLIN	LSTLIN
1	8	3.0	702725.0	423150.0	12	77	82	1	3
2	9	2.5	702650.0	423350.0	10	162	165	2	5
3	9	12.3	702050.0	425275.0	49	120	124	8	23
4	8	35.3	701650.0	429950.0	141	208	223	11	36
5	8	2.3	701775.0	428075.0	9	177	179	20	22
6	8	12.0	701425.0	429025.0	46	192	202	23	33
7	9	13.0	701225.0	422825.0	52	68	73	29	35
8	3	.5	701175.0	427100.0	2	158	159	33	33
9	3	32.3	700700.0	425650.0	129	122	137	33	52
10	8	4.0	701000.0	424550.0	16	106	109	34	39
11	8	3.3	700650.0	423200.0	13	79	82	38	41
12	8	2.3	700725.0	424775.0	9	111	113	41	43
13	8	81.8	699825.0	429050.0	327	165	210	41	79
14	8	2.8	700450.0	424850.0	11	112	115	46	49
15	3	1.0	700350.0	427950.0	4	175	176	49	50
16	9	332.8	698100.0	424575.0	1331	60	136	51	135
17	8	.5	700125.0	422700.0	2	70	71	54	54
18	8	58.0	698075.0	420100.0	232	7	30	76	90
19	3	.5	698550.0	427475.0	2	166	166	85	86
20	9	3.5	699450.0	425975.0	14	193	199	86	89
21	6	7.0	698125.0	423300.0	28	80	85	90	96
22	8	19.8	697825.0	431400.0	79	241	248	93	107
23	3	1.3	697675.0	422425.0	5	64	66	98	100
24	9	5.5	697700.0	427700.0	22	169	172	99	106
25	6	9.3	697450.0	430075.0	37	215	221	104	111
26	8	14.5	697250.0	422875.0	58	71	77	104	119
27	8	47.5	696850.0	419650.0	190	3	16	107	132
28	8	17.0	697050.0	420475.0	68	21	31	110	121
29	8	39.3	696475.0	426525.0	157	177	197	120	134
30	9	12.0	695775.0	419525.0	48	5	9	135	147
31	8	32.8	694875.0	430800.0	131	222	243	149	169
32	8	1.8	695275.0	431125.0	7	238	240	150	152
33	6	4.8	694975.0	423675.0	19	88	92	155	159
34	3	1.3	694075.0	427675.0	7	169	171	174	176

Figure 3. An example of a figure list.

2.3 Software

The program has been made with VTT's central computer CDC Cyber 170, including 7 modules at the main program level. It is documented (in Finnish) and tested.

The limits of the program are the following, with the core memory of about 30 K (wordlenght 60 bits) and mass storage of about 64 MCH:

- the maximum size of the picture at a time is 8191 lines by 4094 columns (approx. four Landsat-images),
- the maximum number of classes is 20,
- the maximum size of a figure to be reclassidied is 2500 pixels, the maximum dimension being 50 pixels,
- the maximum number of pixels to be reclassified is 128 000.

The processing time of a 256 x 256 picture is about one minute. The generalization of the map in appendix including outline processing (filtering twice and quantative generalization) took some 20 minutes and cost about 500 $.

3. INTERPRETATION

3.1 The test area and the data

The test area is about 5000 sq.km in central Finland. Terrain is small-figured and changeable including many lakes, small cultivated figures as well as cut areas. The western part of the area is sparsely populated and boggy. With regare to Landsat's ground resolution the terrain is slightly too requiring as a test area.

The Landsat imagery had been received in Fucino, 6th of July, 1977. The data used in interpretation were rectified on the basis of 25 control points, measured in digital data.

In resampling the pixel size of 60 m x 60 m was used. No radiometric corrections were done because the data seemed to be good. The images were also plotted on film by a film drum scanner at VTT. Enlargements of 1:100 000 were used to help the numerical interpretation. The geometric accuracy after rectification and plotting on the scale of 1:400 000 is better than the graphic accuracy.

Aerial photo coverage almost over the whole test area was available on the scales of 1:30 000 and 1:40 000. The control of clustering and final classification was based on these photos, partly also on the field data gathered during the 1978 project.

3.2 The aims of the interpretation

The original aims were the following:

1. Water - 1.1 Clear water
   1.2 Eutrophic water
2. Forest - 2.1 Wooded areas
   2.2 Cut areas
   2.3 Open bogs
3. Cultivated - 3.1 Fields
   3.2 Meadows
4. Residential areas

Basing on the results of the 1978 project classes 1.2 and 3.2 were excluded from the aims.

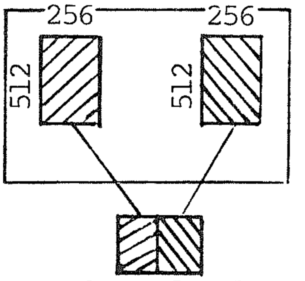
3.3 Interpretation methods and process

The interpretation was made in two steps:

1. Interactive clusering of a sample area.
2. Classification of the whole test area in clustering classes.

The clustering area was sampled by selecting two 256 x 512 strips with every other pixel picked up. The areas were then combined in one imagery, figure 4. Sampling is easy to perform with the rectification program. By sampling the clustering process was speeded up, yet providing a representative area.

Figure 4. The sampling of the clustering area.



Clustering was done by the CLUSTER-program that has been developed in the University of California basing on the ISODATA-algorithm, /3/. The program has been installed in a Nova 3/12 minicomputer. The processing system also includes the Comtal image processing and diplay unit.

In clustering as well as in final classification only channels 4, 5 and 7 were used. The data were normalized prior to clustering.

After thorough clustering 28 classes could be separated in the terrain according to the set criteria. Clustering gave a deep understanding of the possible classes which are related to the interpretation aims in the following summary:

- In order to separate water from thick wooded areas three classes were needed for water. Yet a few downhills and "holes" were classified as water.
- As many as 7 classes of wooded areas were needed for separating these from water and open areas.
- Most of the open bogs and cut areas belong to the same class clustering in three classes in the data. So they cannot be interpreted.
- Cultivated areas gave four classes, rather clearly separate from the other classes. The worst mistakes concern bushed cut areas.
- Built-up areas and certain open bogs are clustering in the same class, so residential areas cannot be immediately interpreted. These and the rest of the classes totalling 11 classes (about 3% of data) were considered an uniterpreted class.

The whole area (about 2 million pixels) was classified in 28 classes using the statistics from clustering. The data were normalized prior to classifying. Each pixel (feature vector) was classified in the closest cluster centroid using the absolute distance measure (same as in CLUSTER). Classification program is in the Nova minicomputer.

A summary of the final classification accuracy has not yet been made, but it will be comparable with the clustering results. On the final map the classification "improves" as the bogmask cuts the open bogs separate from cut and residential areas, see appendix .

4. CARTOGRAPHIC PROCESS

4.1 Generalization

Prior to generalization the interpretation classes (28) were combined in five classes: water, wooded, open, cultitatived and uninterpreted areas.

The classification results were generalized approaching the level of a 1:400 000 map. The program was used in three steps:

1. Outline generalization for open class regarding the ground figure (wooded). Details of other classes were preserved instead.
2. Quantitative generalization with the minimum areas for water 2, cultivated 5, other classes 8. The islands made an exception with the size limit of one pixel.
3. Producing of shoreline on "land side".

4.2 Map process

Masks from other classes than wooded were plotted by a film drum scanner on the scale of 1:300 000. Masks were enlarged and water was screened. Digital screening was not done because the masks had to be enlarged manually. The other masks were prepared from the existing map material where the texts were added. After stationing the map in appendix was printed as a 6-colour print.

All the things presented on the map, exept names, are produced for the scale of 1:400 000, but the maps was printed on the scale of 1:200 000 to help examining.

4.3 Output of areal information

For the municipalities of Saarijärvi and Uurainen, areal data was processed from generalized data (see map legend) in the Laboratory of Geodesy of the Tech. University of Helsinki. As a thesis a program has been developed to produce this kind of information, /4/. Change monitoring can also be done for two different classifications with this program.

5. Conclusion

Conclusions can be drawn on the two levels of the process (figure 1): production of classification data (part of data base) and production of small-scale data on this basis.

Technically the processing, corrections, rectification and interpretation of even large regions can be performed with reasonable costs. The geocoding accuracy is also sufficient on the scale of 1:400 000. The classification process becomes more complicated when changing from stamp-size areas to larger regions. Clustering with sample images is proved indispensable as the first step in interpretation. However, the final accuracy of interpretation remains low, thus restricting the use of classification data on larger scales. Further development has to be directed in particular to improving the interpretation algorithms which at present are defective.

The classification data, being raw material only, have to be corrected and generalized prior to data output. Generalization can be done automatically on a rough scale whereas the final cartographic generalization may only be done by interactive display systems, being one of the targets for further research.

Relating the graphic plotting to map processing is easy as the printing originals can be produced directly as screened. A specific object of study will be the creation of a processing routine for effacing the pixel structure on the scale of persentation.

The classification file is best suited to producing statistical areal information. More of a problem is the lack of other geocoded digital data as well as their data management. With increased areal information the interpretation data, e.g. on open bogs and residential areas, can be improved by integrated processing.

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