XIV Congress of the International Society for Photogrammetry
Hamburg 1980

COMMISSION VII
WORKING GROUP VII-8

PRESENTED PAPER

Janne Larsson

Department of Photogrammetry
Royal Institute of Technology
Stockholm, Sweden

THE USE OF A DTM IN A DIGITAL MULTISPECTRAL ANALYSIS

ABSTRACT

Multispectral scanner data must be geometrically rectified before utilized in a detailed analysis. This rectification must also include corrections for terrain relief displacements. If terrain height information is available this can be utilized in the rectification. In this way an increase in point accuracy of the rectified image can be obtained.

In the multispectral analysis, geometric information is very little utilized. Here an attempt is made to include topographic information, obtained from the DTM, in the multispectral analysis. With this technique a more accurate object classification can be obtained in some cases where the information extracted from the spectral signature is insufficient.

INTRODUCTION

Digital terrain models (DTM) are numerical descriptions of the terrain in discrete points. Storage can be in equidistant grid patterns or in more random patterns, such as characteristic points and breakpoints in the object.

In the production of orthophoto maps in Sweden, digital height information is becoming more utilized. As a by-product of this production a DTM of rather dense spacing can be obtained.
This DTM is already in matrix form similar to the storage of digital image information as it is being obtained from various multispectral line scanners.
A combined use of these two kinds of information is thus close at hand.
In this report two different ways of utilizing this kind of information is presented.

RECTIFICATION OF DIGITAL MULTISPECTRAL DATA USING A DTM

Image data from line scanners show great shortcomings in geometry. These shortcomings depend mainly on:

1 Image geometry (panoramic recording)
2 Conditions during recording (changes of orientation and velocity of recording vehicle)
3 Terrain releif
4 Map projection.

Deformations concerning points 1, 2 and 4 can be corrected for if there is knowledge of image forming geometry and systematic errors in this process and by the use of ground control points. But these corrections do not include corrections for terrain relief displacement.
The effect of neglecting these errors are most easily understood from figure 1.

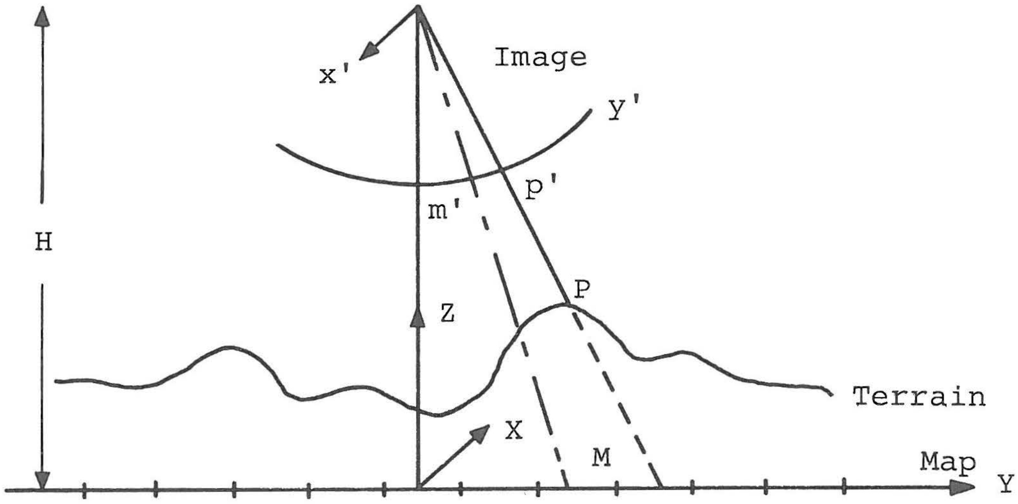

Figure 1

From figure 1 it can be seen that a point P on the terrain surface is recorded as a point p' in the image. In the rectifica-

tion to a map co-ordinate system, the image is resampled into an equidistant grid. If the co-ordinates X, Y and the average height H are used for the mappel M in the map grid, the image co-ordinates corresponding to the pixel m' is computed.
The difference between p' and m' is due to terrain relief and this is the situation in the rectification of single strips of scanner imagery.
If, however, terrain surface is at hand in the form of a DTM, then the true terrain height can be used when computing the image location from the co-ordinates X, Y and Z, and thus the true point p' can be referred to in the image.

Test-Area

To examplify the use of a DTM for the rectification, a test has been performed on real aircraft scanner data. A strip from the MSS-75 campaign, located in the northern part of Sweden was chosen for this experiment (Wastenson, Borg 1977).

Rectification

The rectification is performed schematically in the following way (Larsson 1980)

1 Projection of image co-ordinates for ground control points (GCP's) onto the terrain surface

$$x = x'$$
$$y = (H - Z) \tan \Theta$$

2 Rotation, translation and scaling of (x, y) to ground co-ordinate system

(X, Y)

3 Interpolation of residuals in GCP's.
   a) Multiquadric interpolation to establish a grid with known residuals
   b) Computation of bivariate interpolation polynomials separate in X- and Y-direction (B_x and B_y)

4 Resampling from an equidistant grid in the map (arbitrary locations X Y Z)
   a) Transformation of (X, Y) to (x, y)
   b) Bivariate interpolation of corrections to (x, y)
   c) Computation of x' and y' from (x, y, Z) with equations (1).

Ground-Control Points

Ground control points for this rectification have been measured on the orthophoto map at scale 1:20 000. A number of 21 points has been identified in the infrared band of the scanner (band No 9), mostly located at the shore lines of minor lakes (figure 2).

Digital Terrain Model

The actual area is covered by a relatively new orthophoto map produced at a Gigas Zeiss ortho projector at the National Land Survey.

As a by-product from the orthophoto production a digital terrain model can be produced. The density in this DTM is 100 meters for orthophoto 1:20 000 and 50 meters for 1:10 000 with a height accuracy of 5 and 3 meters respectively. The accuracy is estimated from rms of residuals in the overlapping zone between map sheets.

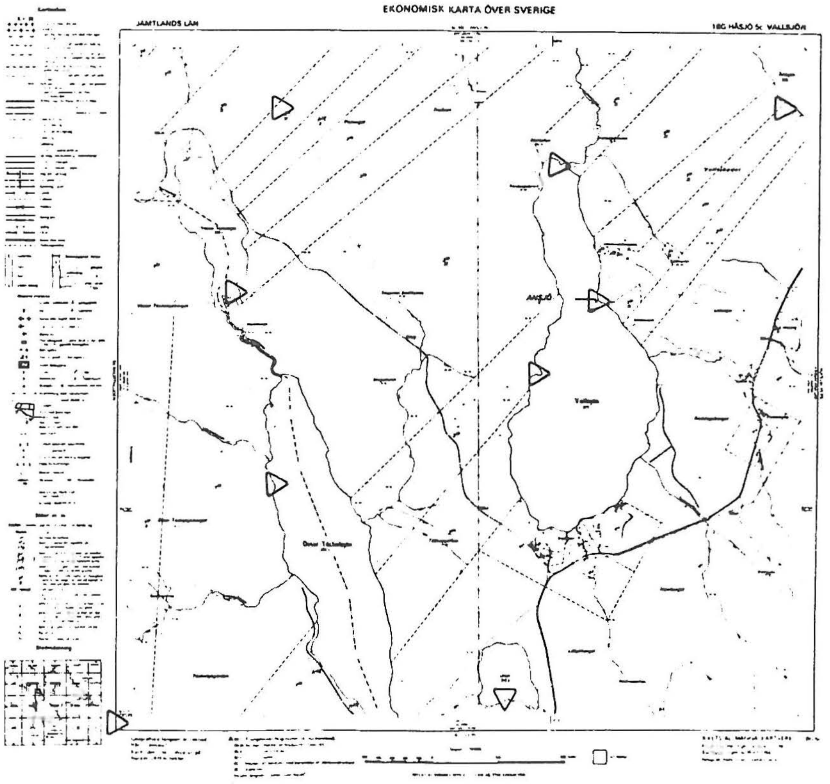

Figure 2 Control Points

Practical Experiment

The test data was rectified with identical ground control points, both to a flat surface and to a DTM.
Rectification parameters were computed for an aera covering 4 sheets of the economic map, and a rectified and resampled picture was produced for one of these maps (18G 5c Håsjö). This is equivalent to 450 lines of the north-east part of the original strip.
It is not possible to evaluate the benfit of a DTM-correction from residual errors in control points only. The explanation to this is to find in the rectification procedure used here. Since this is based on interpolation of residual errors in control points, errors caused by terrain relief displacement are interpolated as well as errors caused by changes in orientation elements. Such an elastic model will of course give a good fit to control points in both cases. So the benefit of using a DTM will only show up between control points.

Check of Rectification Fidelity

For this check diapositives were produced for the IR-channel (mssb 9) for the two cases, and check points were measured on these diapositives using a stereocomparator. Corresponding check points were measured on the orthophoto map used for control points.

The rms residual errors of check points are tabulated in table 1. To stress the effect of terrain relief displacement, the rms have been computed separately for the central and eastern parts of the scan (figure 3).

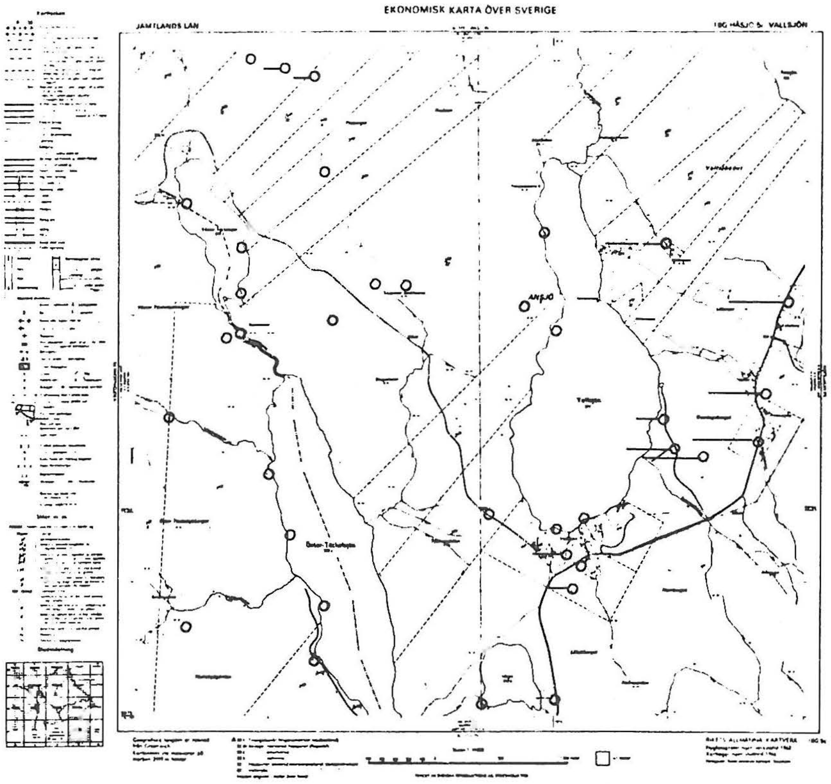

Figure 3 Check Points location and terrain relief displacement

—o = 3 pixels

	Check points (flat)				Check points (DTM)			
Håsjö	rms	x	rms	y	rms	x	rms	y
18G5c	m	pix	m	pix	m	pix	m	pix
Central part	28	1.4	22	1.1	27	1.4	21	1.0
side	29	1.4	36	1.8	28	1.4	22	1.1
all	28	1.4	29	1.4	27	1.4	21	1.0

Table 1

Here we clearly can see the gain in using a DTM for the rectification, since the rms error in y is reduced with 50% for the side part of the scan and with 30% if both central and side parts are computed together.
The conclusion of this is, terrain relief displacement must be considered, if an accurate rectification shall be possible.

TERRAIN RELIEF PARAMETERS IN MULTISPECTRAL CLASSIFICATION

Using rectified picture data in the analysis also gives possibilities to combine spectral information with other properties of

the objects, received from other sources of data.
To the photointerpreter the Z co-ordinate of the topography gives essential information for a correct interpretation, this is commonly utilized by using stereoscopic pictures for the photointerpretation.

Computing Terrain Relief Parameters

To be able to use terrain heght information in the multispectral classification, a value must be found that is correlated to the objects which are to be separated. The absolute and relative height co-ordinates are here of no interest. Instead a measure of terrain roughness was used.
As a measure of terrain roughness, an average of the absolute values of the difference between the four nearest located nodal points of the DTM, was chosen.
Thus for every pixel was computed

$$Z=(|Z(i,j)-Z(i,j+1)|+|Z(i,j)-Z(i+1,j)|+|Z(i+1,j+1)-Z(i,j+1)| + |Z(i+1,j+1)-Z(i+1,j)|)/4$$

This value is included in the original picture as layer No 2. This variable will be assigned values near zero if terrain is flat and high values if terrain is sloping or undulating.
The classification into the preselected classes is now performed without (case A) and with terrain information (case B) into the following categories:

1 Clearcut forest areas
2 Bog
3 Forested areas
4 Other open areas
5 Water
6 Rejects.

Classification Results

The classification results are summarized in table 2 together with the true land use in area percentage.

Object	Interpretation		Photomap
	A	B	
Bog	10	9	6
Clear-cut	6	8	9
Forest	53	49	36

Table 2 Classification results

A detail of the classified scenes can be studied in figures 4 and 5. This clearcut area shows clearly the effect of using auxiliary information in the analysis. In case A this patch is interpreted as 62% bog and 30% clearcut, but in case B this changes to 15% bog and 76% clearcut.

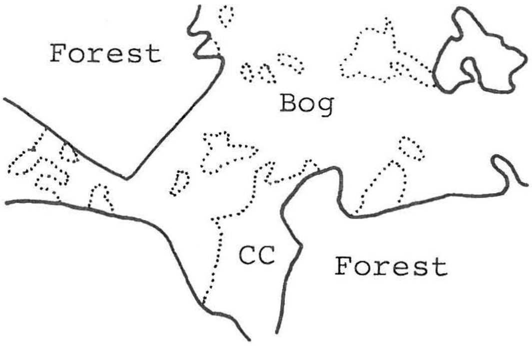

Figure 4

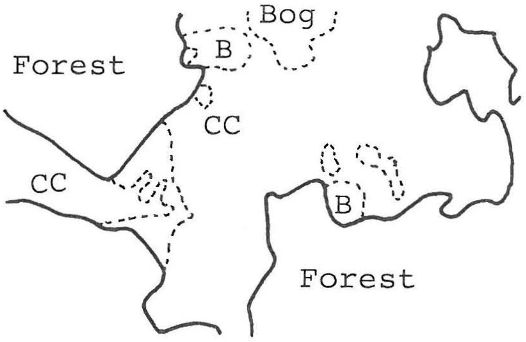

Figure 5

An analysis of the interpretation/misinterpretation of the whole scene is best performed in a matrix, where true class belonging is plotted versus interpreted class belonging. These matrices are shown in table 3. All numbers are in area percentage of respective class.
The true class belonging is obtained from the forest map for classes forest and clearcut and from the economic map for the class bog.

Table 3A	Class	B	CC	F	0	W	R
Case A	B	38	9	29	23	0	1
	CC	32	22	17	28	0	1
	F	5	1	92	2	0	0
Table 3B	B	46	6	20	27	0	1
Case B	CC	19	36	12	32	0	1
	F	5	3	89	3	0	0
Table 3C	B	+8	-3	-9	+4	0	0
Improvement	CC	-13	+14	-5	+4	0	0
	F	0	+2	-3	+1	0	0

In airborne scanner data, the spectral signature shows a systematic variation with scan angle (Åkersten et al 1978). In this test all test-areas except open was chosen in the central part of the scan, and the test-area for this class was located at the edge of the scan. As a consequence of this, the class open has been very exaggerated near the edge of the picture, and includes nearly everything except forested areas.
If the side part of the picture is excluded from the analysis as being a misinterpretation, the interpretation matrix for the remainder of the picture becomes as can be seen in table 4.

Table 4A	Class	B	CC	F	0	W	R
Case A	B	48	11	29	10	0	1
	CC	40	29	22	7	1	1
Table 4B	B	59	8	19	13	0	0
Case B	CC	23	48	16	12	0	0
Table 4C	B	+11	-3	-10	+3	0	-1
Improvement	CC	-17	+19	-6	+5	-1	0

A significant increase in classification reliability of bog and clearcut can be noted from the numbers in tables 4A-C. Clearcut increases with 19% from 29% to 48% and bog increases with 11% from 48% to 59%.
Neither class exceeds 75% classification accuracy, and should consequently be rejected as misclassifications. But, with regard to the ground truth data, the classification accuracy might be higher than what can be read from these numbers. Since ground truth is obtained from map data, based on photo-interpretation, these data are a generalization to yield patches of homogeneous categories, but in reality these patches are not at all homogeneous. To get this clarified in detail, a much more rigorous field check, giving the true classification for each single pixel, must be performed, but this is beyond the scope of this study.

Also there exists other kinds of bog, not necessarily located at flat surfaces. Such are for example overhanging and sloping fens.

In these cases this simple measure of terrain variation will be misleading.
A better approach would be to use terrain heights to construct an image layer of terrain types, such as convexe, concave, slope of different degree and heading, and use this layer in the classification or in a following interpretation procedure.

The results obtained herein show, however, that the classification accuracy of the multispectral classifier can be greatly improved by the use of proper auxiliary data.

ACKNOWLEDGEMENTS

This work is a part of the co-operation between KTH and FOA3, and has been using the PICCOLA-system developed by FOA3.

Larsson, J. Rectification of Digital Images for Remote Sensing Analysis. Thesis to be published

Wastenson, L, Borg, C-G. "MSS-75". Ett svenskt försök med flygburen multispektral svepradiometer (A Swedish Experiment with an airborne Multispectral Scanner). FOA report B 30019-E1 1977/78:1

Wasteson, R, Åkersten, S I A. PICCOLA An Interactive Aid in Digital Image Processing. FOA report c30143-E1 1978

Åkersten, S I Å, Gustafsson, L-E, Orhaug, T. MSS-75: Data Handling and Data Processing. Foa report A 30019-E1 August 1978.