14th Congress of the International Society of Photogrammetry

Hamburg 1980

Commission VII   Working Group 8

Presented Paper

S. Vetrella - A. Moccia - L. De Fusco
Istituto di Aerodinamica
Facoltà di Ingegneria
Università di Napoli

Spectral, morphological and textural data integration for remote sensing applications

Abstract

Several papers have already emphasized the need to integrate morphological and textural land information with remotely sensed multispectral data, in order to improve classification and to identify shadowed areas for radiometric corrections.
This paper is focused on an interactive software program that gives the digital three dimensional model of land, having as inputs contour lines automatically recorded and/or conventional stereoscopic data. Geometrically registered contour lines and satellite or aircraft images are contemporarely shown on an interactive colour monitor, superimposed on a grid in which each mesh can be subdivided. In this way the operator can choose interactively the best distribution of input points and grids before running the analytical program. This program finds z, zx and zy for all mesh points and then applies a cubic polinomial function to find the pixel altitude in each grid and subgrid. This information is then added to the spectral data.

Introduction

Several papers have already emphatized the need to integrate morphological and textural land information with remotely sensed multispectral data, in order to improve classification results.
During the last years, experience has shown that there are many different techniques in the methodology for obtaining the training statistics and for integrating spectral with textural data. It is well known that the two basic techniques for defining trainig classes are the supervised approach and the unsupervised (or clustering) approach. The two approaches represent

extremes, both in terms of the method of defining the training sample and
the method of grouping the training sample into unimodal training classes.
Due to this contrast, the possibility exists for four intermediate steps
between the two extremes in both parts of the training procedure [1,2] .
A demonstration project has been conducted in Italy which used Landsat
digital data as one segment of a multistage sampling plan designed to
produce a land-use thematic map in Southern Italy. In this project a multi-
cluster blocks approach has been used with multiple clustering of hetero-
geneous blocks. This requires the division of the training sample into a
series of areas, each containing a mixture of several cover types, which
are clustered separately. The numerous cluster classes must then be com-
bined into meaningful training classes, using a bispectral plot with dif-
ferent transformed divergence values, as a measure of the distance between
classes in multidimensional space.
The topography of the test site area is rugged, ranging in elevation up to
2000 meters. Within this range of elevation, a distinct distribution of
cover types occurs according to altitude and aspect.
Therefore each heterogeneous block has been chosen as representative of
various species occurring in defined elevation ranges.
The method applied to extract spatial information based on shape, context,
texture and other forms of spatial ralationships is a modified version of
ECHO (Extraction and Classification of Homogeneous Objects) classifier
[3,4] .
This paper is focused on the procedure for obtaining a digital three-
dimensional model of the test area and on its interaction with the clas-
sification process, both in identifying training-areas and in correcting
spectral data in shadowed areas. The digital representation of three-
dimensional surfaces plays an important role in photogrammetry, cartography,
image processing, computer graphics and other disciplines.
The CIDAS (Catart Interactive Digital Analysis System) is a software-
hardware system oriented to the analysis of aerospace remote sensing data
developed in the Institute of Aerodynamics of the University of Naples [5].
The hardware system is based on a CDC-17 computer of 65K words of 16 bits
connected to two tape and disk units, tty, card reader, line printer, Cal-
comp plotter and a Ramtek GX-100B video colour system.
An integrated structure of overlays constitutes the interactive software
system (fig. 1).

Three-dimensional surface model

The three-dimensional surface program divides the area in a grid of square
meshes in which each mesh can be sub-divided in subgrids.
It is assumed that the surface to be modelled already exists in a suitable
representation of height values obtained by direct analysis of digitalized
contour lines or by stereocorrelation.
The software procedure is divided in three programs, due to the limited

-MULTISPECTRAL
 PHOTOS
-MAPS

COMPUTER
EYE

LANDSAT
MSS

LANDSAT
RBV

NIMBUS-7
CZCS .

SEASAT
SAR

728

REFORMATTING

-NC2
-NC3
-NC5
-NC7
-NC8
-NC9

-VIDEO2
-REGEO2
-REGEO3
-REGDIS
-BIPOL

GEOMETRIC CORRECTION
AND REGISTRATION

LOCATION
AND
EXTRACTION
OF
TEST-SITES
AND
GEOMETRIC
POINTS

-TESITE
-TRSETS
-COORD
-VIDEO4

-DC1
-EFNAST
-EFDISC
-NASDIS
-RANDO1
-SCRNAS
-SCRDIS
-MODIND

EXTRACTION
OF
STATISTICS

-STATIS
-PRINCO
-ISTOG

-CERPE1
-CERPE2
-CLASFO
-CLASF1
-CLASF2
-RATIO
-CHANGE
-MAXLIK
-MAXPAR
-CLUSTE

CLASSIFICATION

TAPE AND DISK
STANDARD FORMAT

ANALYSIS
OF
MORPHOLOGY

-MODUNO
-MODDUE
-MODTRE
-VIDEO3
-VIDEO5
-DISCR

-VIDEO1
-SCRIVE
-NORX
-ESPANS
-CONDEN

INTERACTIVE
COLOUR
MONITOR

PLOTTER

-MAPPA
-MAPPA1

AUTOMATIC
THEMATIC
MAPS

-MATUNO
-MATDUE

Fig.1 The main programs of the CIDAS software

available core memory.
The inputs of the first program are the height values and the grid and sub-
grid parameters. This program gives the height and the slope values in each
grid point of the square mesh. To realize this calculation these parameters
are computed through the least square method, constructing a plane that
approximates the height values of data points closest to the grid point
being checked; the interception of this plane with the vertical segment
conducted for the grid point gives the height; the pertial derivatives are
computed in the principal axis directions [6].
The second program gives the height of each pixel of the image. In each
grid and subgrid mesh a relative reference is considered. In this way the
heights are given through a cubic polinomial, which coefficients are com-
puted taking into account the continuity conditions among the various
meshes.
The third program makes a correction in the grid meshes next to the sub-
grids: in fact, along the common side between the grid and subgrid meshes
new continuity conditions must be found. Since the polinomial function
gives a better precision in the subgrids, a fictitious rectangular area is
built into the grid mesh having a common side with the subgrid; in this
way it is possible to get the continuity conditions through a correction
of height values calculated in the different pixels of the above-mentioned
fictitious area.
Finally, the program constitutes the different pixels of each mesh in scan
lines that are recorded in standard format on the magnetic tape. The
resulting image is composed of pixels to which the height real value is
associated and which requires the eventual quantization in order to obtain
the vision on the colour monitor screen.
Fig.2 shows a flow chart of the above-mentioned procedure.
The height value input points are interactively assigned by means of
contour lines topographic maps. In the near future the height input points
will be given by an on-line stereocomparator already obtained.

Contour lines digitalization with Computer Eye

The Spatial Data 108-A Computer Eye is an image off-line digitalizer, that
reads the print or transparent through a telecamera and records it on
magnetic tape as a file of 512 scan lines of 512 bytes. Changing the
diaphragm opening of the telecamera and the reference values of the radian-
ce histograms, which can be analyzed on a B/W monitor, it is possible to
obtain a digital output image in which each pixel has radiance values bet-
ween 0 and 255.
The contour lines are available in scale 1:25.000 and 1:100.000 and are
furnished by the Italian Military Geographical Institute. They can be ob-
tained inserted on a topographic map or isolated on transparent sheets.
This latter method results in a digital output that can be more readly
analysed.

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┌─────────────────────────┐        ┌──────────────┐
│   GRID AND SUBGRID      │        │  HEIGHT      │
│      PARAMETERS         │        │  POINTS      │
└─────────────────────────┘        └──────────────┘
```

HEIGHT AND SLOPE
VALUES OF EACH GRID
AND SUBGRID POINT

HEIGHT OF EACH
PIXEL OF THE IMAGE

CORRECTION IN THE
GRID MESHES NEXT
TO THE SUBGRIDS

QUANTIZATION OF THE
HEIGHT REAL VALUES
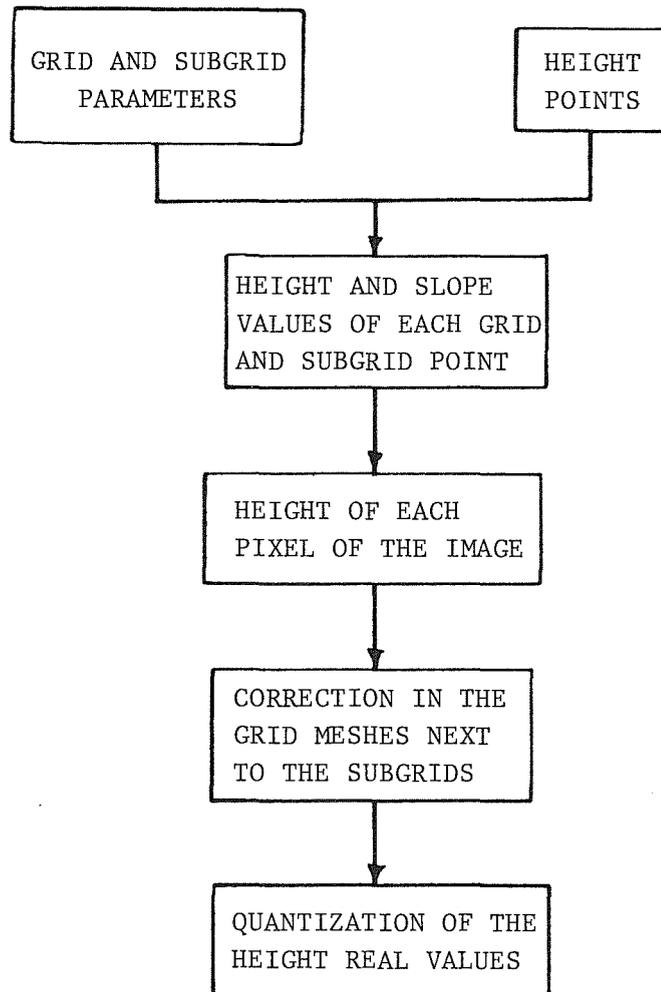
Fig.2 Flow chart of the three-dimensional surface procedure.

Changing the Computer Eye parameters it is possible to get a good con-
trasted image in which the black contour lines are seen in evidence on a
white background. In other words, it is sought to have a rather flat histo-
gram on the radiance high values of the background and peaks corresponding
to the black contour line values.

Interactive program for tracking the contour lines

Generally the input image dimensions are greater than the Ramtek colour
monitor screen (480 scan lines X 640 pixels of which only 510 commonly

used) and therefore only a part of it is visible on the display. This problem is solved by scrolling the image and using the screen as a window. Obviously this requires the image transfer from tape to disk in a suitable format and the random addressing to each sub-area. Due to hardware characteristics of the system the shifting along the lines is much more rapid than along the pixels. Some keyboard functions, a cancelling technique of the image and the displaying of the new area read from the disk have been, by software, associated to the scrolling.

The tracking of the contour line starts identifying an adjacent point by joystick and goes on by means of an algorithm that follows counterclockwise each element of a single class.

Since the image is assumed to be 2500 pixels X 2500 scan lines, it is not possible to have it completely in the core memory. On the other hand, in order to track the contour line, it is necessary to have the access to the image in any direction. This result is obtained dividing the image in a series of stripes, having the same horizontal dimension of the image and the vertical dimension as large as possible compatible with the core memory capacity. Each stripe will have the last scan line overlapping the first of the following stripe and viceversa. During the tracking of the contour line the control goes from one stripe to the other taking into account the contour line pattern, using the overlap between the stripes. This analysis ends when the starting point is again reached.

The three output crosses (blue, green and red) reveal to the user the point reached during each step of the tracking.

Finally the contour line is displayed on the white overlay, that is a binary subchannel of the Ramtek system, choosing a suitable increment.

Once the contour line and its increment have been accepted, the points are written on the image in order to be able to display the curve in any future scrolling.

The height (assigned by tty) and position of each point are recorded on an output magnetic tape (fig. 3,4).

The flow chart of the procedure is shown in fig.5.

Interactive program for assigning the grid and subgrids

Contemporaneously with the height points it is necessary to give the grid and subgrids parameters. The optimisation of the mathematical model requires a number of points in each mesh less than 4. Therefore the subgrids must be used in those areas of the image where too many representative points are available.

The advantage of using subgrids is in the possibility of changing the mesh dimension in different parts of the image, saving time and core memory and obtaining a better precision than with a constant mesh dimension.

Fig.6 shows the flow chart of the interactive program for assigning the grid and subgrids parameters.

First of all a preliminary white grid is superimposed on the coloured image.

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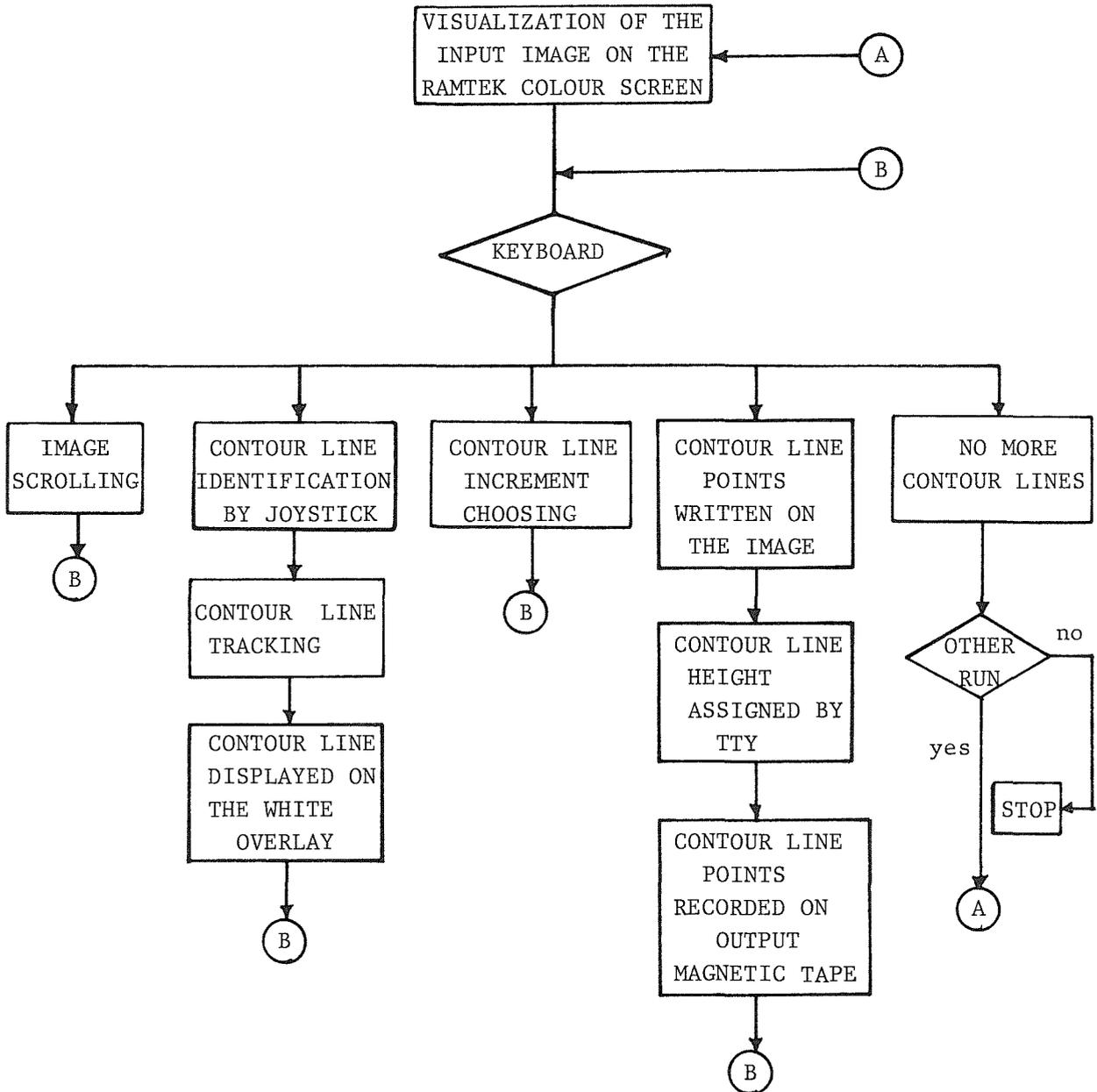
Fig.5 Flow chart of the interactive program for tracking the contour lines.

Its final dimension is chosen moving the image and controlling the input points distribution.
The grid chosen in this way is written on the image that is on the disk before the identification of subgrids.
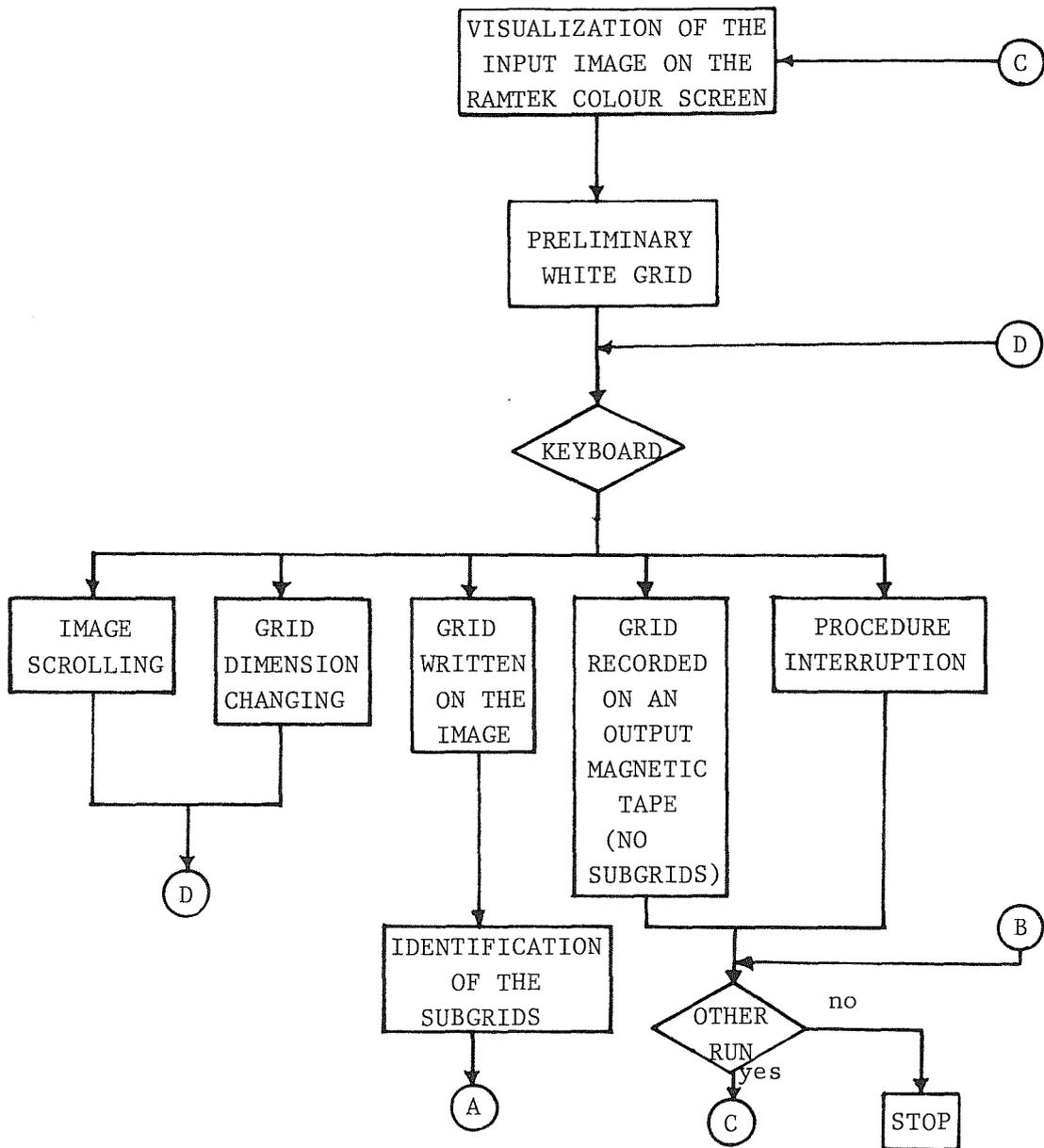
Fig.6 Flow chart of the interactive program for assigning the grid and subgrids (1st part).

First of all, the subgrid is localized by positioning of the joystick into the square mesh of the grid. The dimension of the subgrid mesh must be a submultiple of that of the grid.
Any fault in the interactive inputs of the program results in a new request. When accepted, the subgrid is also written on the image (fig.7).
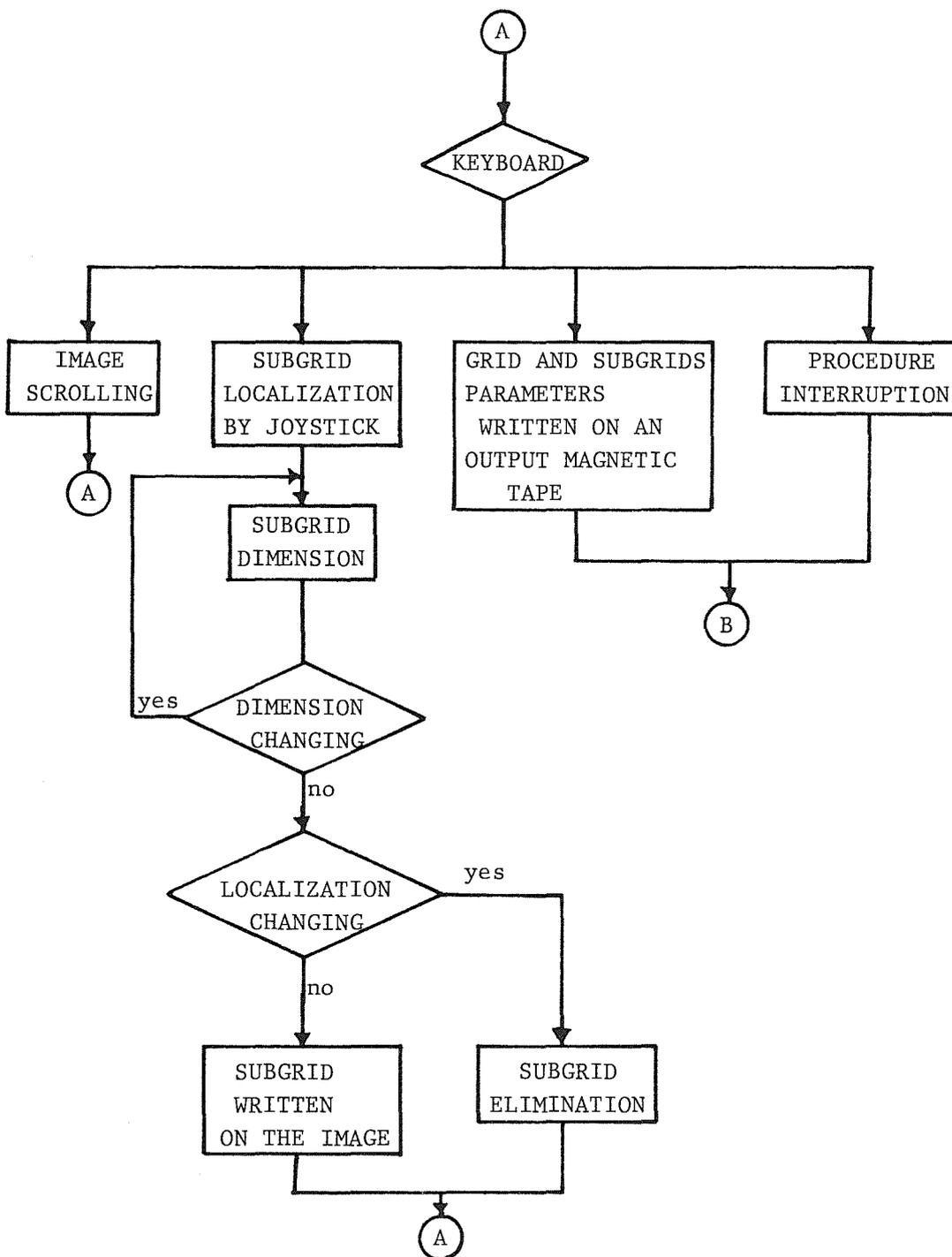
Fig.6 (2nd part).

At the end the grid and subgrids parameters are recorded on magnetic tape.

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Conclusions

The flow chart in fig.8 shows the integration of the three-dimensional sur-
face reconstruction procedure with the other programs applied in the de-
monstration project.
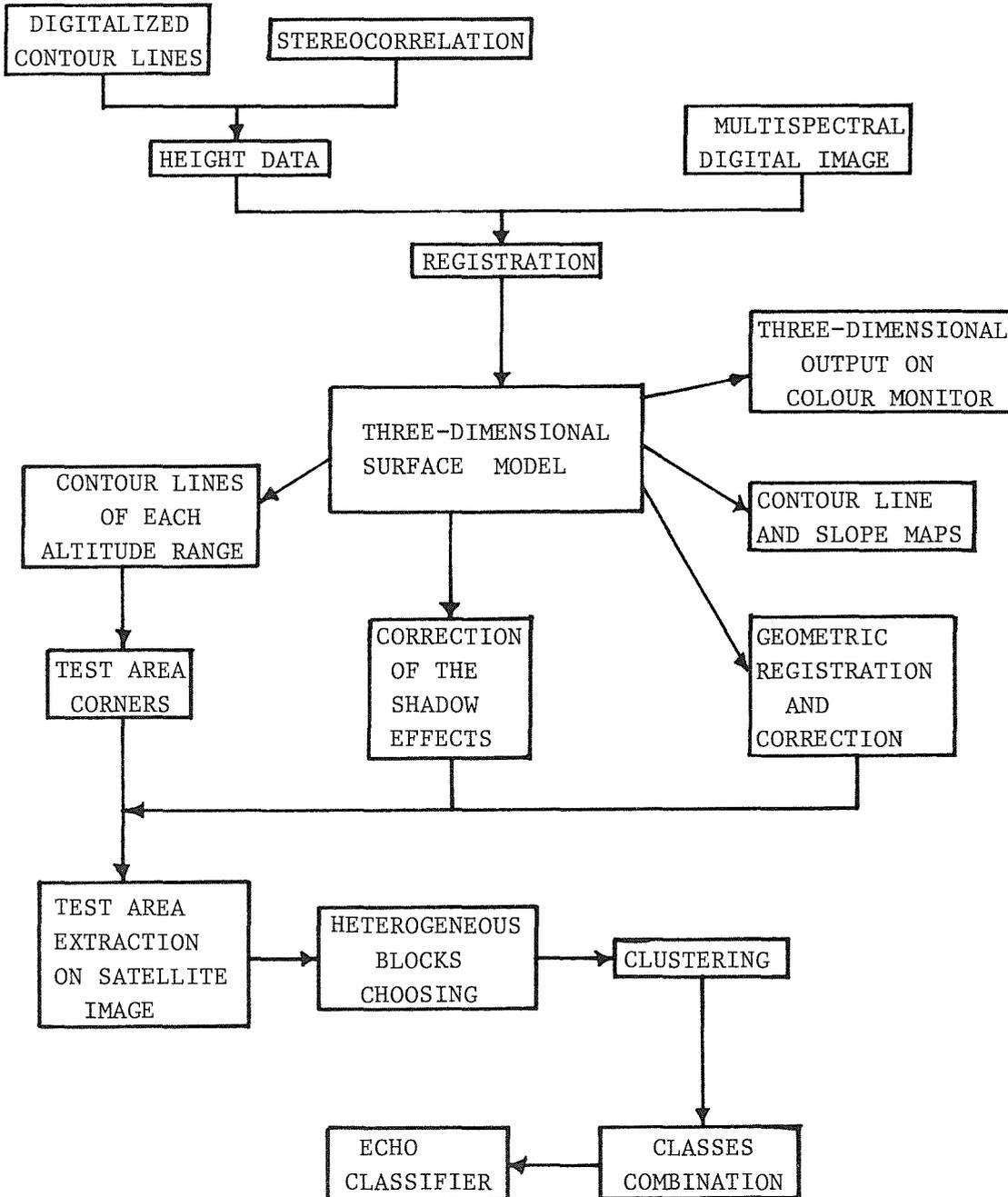
Fig.8 Integration of the three-dimensional surface reconstruction procedure
with the other programs applied in the demonstration project.

The various altitude ranges of the test-area are displayed in different
colours in fig.9 as shown in the colour scale.
The contour lines of each altitude range are interactively or automatically
obtained and the corners of each line are considered as input of the pro-
gram for the extraction of each sub-area.
The other different steps of analysis give as result the classification.
The output on plotter of the classification program is shown in fig.10.
The same three-dimensional surface reconstruction program with slight va-
riations is applied for the geometric registration and correction of multi-
spectral and/or multitemporal remote sensing images.
The digital model of the earth and the shading technique are used for the
three-dimensional visualization on the colour display.
The same model is the input for the programs of output on plotter (slope,
contour lines etc.) and the correction of the shadow effects.

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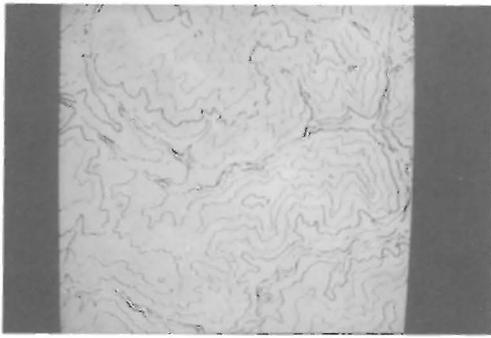
Fig.3 Contour lines on colour monitor.
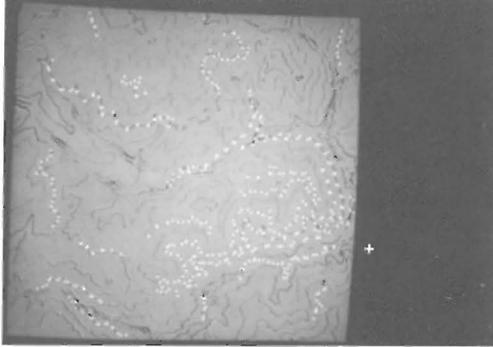
Fig.4 Contour lines on colour monitor after tracking.
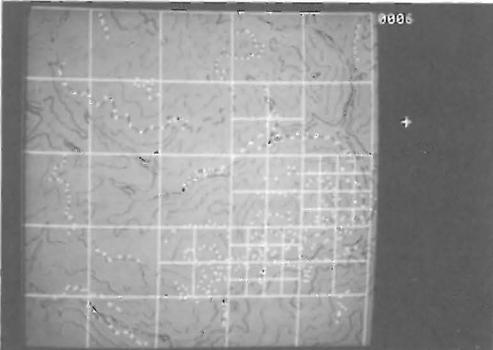
Fig.7 Grid and subgrids on colour monitor.
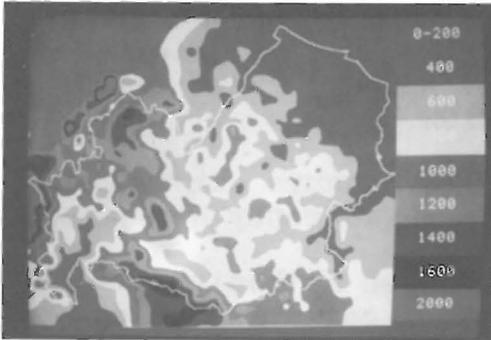
Fig.9 Test-area altitude ranges in different colours.

Fig.10 Output on plotter of the final classification.

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