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Computer Assisted Cartography for Multitemporal Observations

OLE HEBIN

Hebin, Ole: Computer Assisted Cartography for Multitemporal Observations. Geografisk Tidsskrift 81: 48-54. Copenhagen, sept. 15, 1981.

This paper describes the construction and use of an automated system for drawing maps in multitemporal surveyed areas. In the system are included many options for plotting and the analysis procedures. The system is called COMA (Computer Assisted Mapping).

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INTRODUCTION

The scope of this paper is to show how computer assisted cartography can facilitate the geographers task in analysing multitemporal observations carried out in the same physical or abstract area.

As stated in the title we are concerned with a system that handles many maps of the same area surveyed at different time-points. The goals set out for the system are:

1. It must be easy to use for persons not familiar with computer technic.
2. It must answer the questions raised by the research worker.
3. The turn-around time from surveying to the produced map must be short.
4. It should be an inspiration for applying new technical tools that have not previously been used because of their requirements of work.
5. The graphical output should be nice and clean, although it is not intended to produce maps of the high quality that are made by skilled cartographers.

Of course there are a series of subsidiary goals specified concerning: reliability, speed, storage use, input and updating procedures and, last but not least, cost.

THE COMPUTER CARTOGRAPHY SYSTEM

The system is split into two main parts which are the database and the manipulating procedures, but as the two are closely integrated in the soft-ware and their applications interwoven this paper will not stress this feature - instead the users line of work will be considered the structuring principle.

The Data

The information may be collected in two different ways:

1. Measurements may be taken in fixed locations:
   1. Steel-pipes washed into the sea bottom.
   2. Wave-recording instruments placed at fixed locations in the sea.
   3. Climatic recording instruments placed in the landscape.
   4. Statistical information collected on f.ex counties (population, income, ...).

   etc.

   which means, that only the location number and the measurement for that particular point has to be recorded, when data are collected, - assuming that the x,y-coordinates are known and already placed in the system.
2. Data may be collected from arbitrary datapoints, which means that you have to input point-numbers, x,y-coordinates and the information. Once such a special data-point has been introduced, it is part of the system and in the future it can be referenced by it's number only. This is particularly useful if new features are found for which fixed locations are less suited.

If you want to correct the coordinates of the fixed locations and/or the special points, all you have to do is to introduce a point with the same number and this will automatically up-date the already existing point-file (KORTSTOK) and the original datavalues (KORTORIG) for that particular map number, if necessary.

Point numbers must be given as integers, and x, y and z-values as floating point numbers or integers.

If up-dating takes place, a note will be printed with as well the original as the new values allowing the user to follow the up-dating procedure very closely.

The Grid

For many applications it is nescessary to compare (add/subtract/manipulate in other ways) two or more maps, which the system can do in two different ways. Let's take the difference between two maps as an example:

1. If a subtraction is specified, the original datapoints for the two maps are compared, and if this comparison shows that they consist of exactly the same locations the subtraction is carried out on the original point-values - point by point. If the two maps consist of different datapoints they will be interpolated into two matrices that are then used for the subtraction - cell by cell.
2. There is one exception to this rule, namely: if you want the difference between map A and map B, and map B has a special number (f.ex. 1) then the subtraction is carried out on a point by point basis despite the fact that map B contains more points than map A. The reason for this is that it may be convenient to have a special reference map of some kind.

Quite often only part of the measured area is of interest for a particular research, so we made it possible to cut away or out any area that can be delineated by a polygon. This feature is often useful in producing maps consisting of the same datapoints so that f.ex. a subtraction can be performed without any interpolations.

The grid used for interpolation is built according to the user's wishes and only has to stay within the dimension restrictions in the main program. The grid is constructed in the conventional way, following the scheme in figure 1.

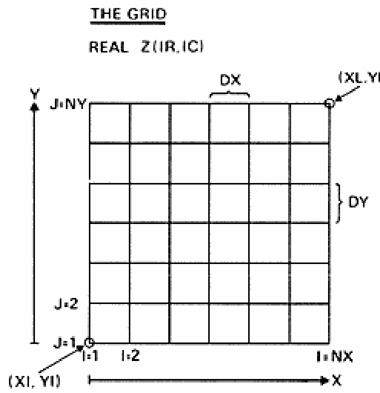


Fig. 1.

Interpolation

Interpolation from irregularly spaced data-points into a regular net may be done by means of either cubic-spline or Laplacian functions or a combination of the two.

If the cubic-spline interpolation is used you'll get a smooth and quite often a nicely looking surface while the Laplacian interpolated surface has steep dips and sharp peaks. By varying the interpolation parametre, it's possible to produce a combined cubic-spline/Laplacian interpolated surface that fits into the users' wishes.

It's possible to specify how far away the interpolation procedure shall look for data-points during the interpolation. This distance is given in grid spaces. We have found this procedure very useful in avoiding interpolations resulting in very illdefined regions.

If the resulting surface is still too peaky or noisy further Laplacian smoothings can be performed on the already existing surface, which, of course, is a cosmetic operation more than producing truth!

The Database

The database consists of 4 disk-based files.

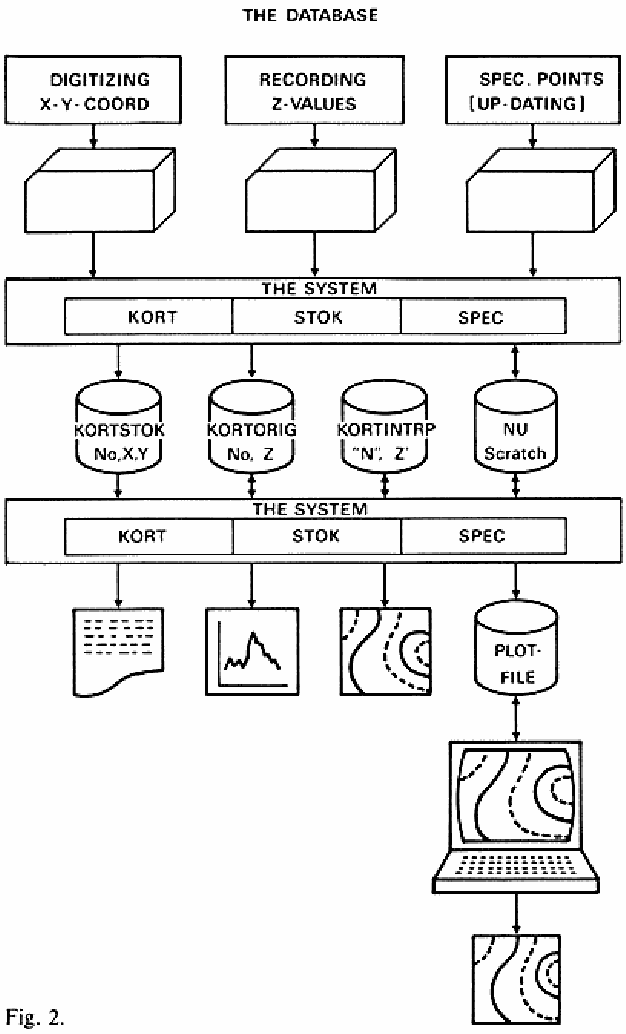


Fig. 2.

Table 1					THE DATA BASE
	File No.	Type	Device	Device (tracks)	Use
GEO*KORTSTOK	18	Seq.	Disk	50	x,y-coordinates
GEO*KORTORIG	16	Dir.	Disk	200	Original z-values
GEO*KORTINTRP	17	Dir.	Disk	350	Interpol.matrices
GEO*KORT.elem		Sec.	Disk	350	The System
GEO*NU	20	Seq.	Disk	128	Temp.scratch file

1. KORTSTOK contains all the data-point's x,y-coordinates (sequential).
2. KORTORIG contains the original z-values and the non-interpolated maps (direct access).
3. KORTINTRP contains all interpolated maps (direct access).
4. KORT contains the program as symbolic elements and as an absolute element.
5. NU is a scratch file.

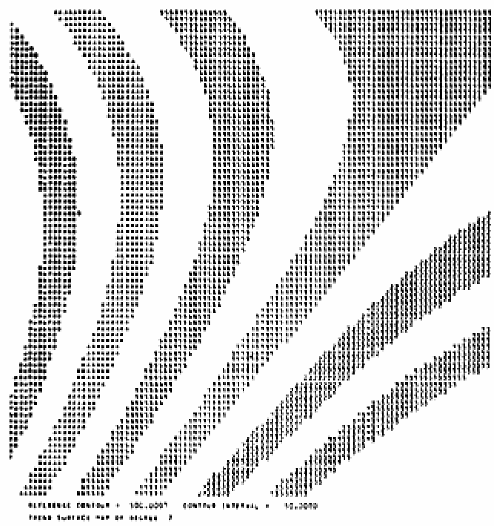


Fig. 3. Trend surface of 2. order.
Fig. 3. Polynomial overflade af 2. grad.

The first record in the file with the original maps (KORTORIG) contains the database numbering-table for translating user map-numbers into database numbers.

In the present version the database is able to contain:
200 original maps
350 interpolated maps

Each original map may consist of up to 250 points and each interpolated map of 2625 points.

Numbering System

The numbering of the maps has to follow a set of strict, but very simple rules:

1. All map numbers must be integers.
2. Positive numbers are used for original data-points (maps) or for maps produced without interpolations.
3. Negative numbers are used for interpolated maps.
4. Map number 0 (zero) is used for storing intermediate maps (originals or interpolated).

The map numbers can be any integer as long as they don't overlap, but for convenience it's recommended that the same map as an original and as an interpolation has the same number except for the sign.

The database has its own sequential number system, but the translation between user numbers and database numbers is neither seen nor felt by the user.

Manipulations possible on the maps

A series of operations can be carried out on each individual map or on more maps. These operations include subtractions, additions and averagings of two or more maps. These three operations are carried out according to the following scheme:

(map 1 (sign of operator) map 2)* operator

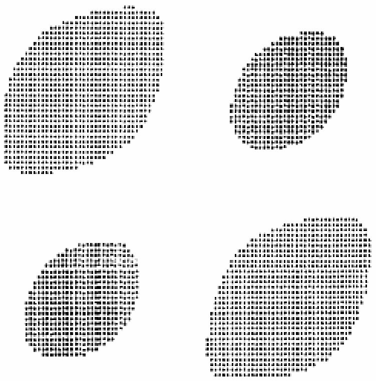


Fig. 4. Harmonic surface with 2 harmonics.
Fig. 4. Harmonisk overflade med 2 led.

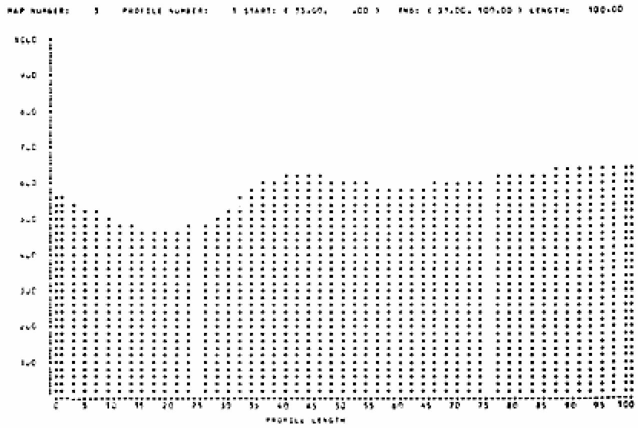


Fig. 5. Profile between (33,0) and (33,100) in map 3.
Fig. 5. Profil mellem (33,0) og (33,100) i kort 3.

which means that -1.0 gives the difference and +0.5 gives the mean of the two maps. By stacking the results you can, of course, work on as many maps as you like at the same time.

Trend-surface analysis can be performed to an order of 4 and the resulting map, the equations and the statistics will be printed on the line-printer. If core space is available, the order may be increased (fig. 3).

Harmonic analysis can be carried out on the maps, and you can specify the subscripts of the harmonics you want treated in the equations. The present version is able to handle 100 harmonics in each direction, which should be far beyond anyone's wishes. All the coefficients, the raw power spectrum, various statistics and the map is printed on the line-printer (fig. 4).

For physical applications volume calculations are of great importance and the program is able to compute these volumes in three different ways:

1. Volumes relative to a specified reference level.
2. Volume calculations according to the profile method.
3. Volume differences between two surfaces.

For all volume calculations you'll get the results as positive and negative differences and the gross and net volume.

The profile method is incorporated because it's the traditional way physical geographers and sedimentologists used to calculate volumes by hand.

The hypsometric statistics and curve is a natural extension of the volume computations and gives the distribution of areas in the different height-intervals.

The produced matrices may be plotted out as maps on the line-printer and/or the plotter.

The line-printer maps are rather primitive but in many situations well suited for preliminary analysis. These maps can be produced as:

COASTAL STUDIES IN KOEGE BAY, KBS, 1978-79, J.NIELSEN & N.NIELSEN
KBS DATE: 060879 HOUR: 1500 LB.NR. 156

MAP NO.:-156 REFERENCE CONTOUR: .00 CONTOUR INTERVAL: .1000

MIN AND MAX CELL VALUES: -1.39 1.53

NO.	LEVEL (.LT.)	AREA	REL. AREA	CUM. %
1	-1.3	164.0	6.6	6.6
2	-1.2	283.5	11.4	18.0
3	-1.1	294.5	11.9	29.9
4	-1.0	144.0	5.8	35.7
5	-.9	76.5	3.1	38.8
6	-.8	201.0	8.1	46.9
7	-.7	168.5	6.8	53.7
8	-.6	146.0	5.9	59.6
9	-.5	141.0	5.7	65.3
10	-.4	138.5	5.6	70.9
11	-.3	138.0	5.6	76.4
12	-.2	34.0	1.4	77.8
13	-.1	19.0	.8	78.6
14	.0	18.0	.7	79.3
15	.1	17.5	.7	80.0
16	.2	18.0	.7	80.7
17	.3	19.0	.8	81.5
18	.4	23.0	.9	82.4
19	.5	22.0	.9	83.3
20	.6	24.5	1.0	84.3
21	.7	20.0	.8	85.1
22	.8	22.5	.9	86.0
23	.9	26.5	1.1	87.1
24	1.0	27.0	1.1	88.2
25	1.1	29.0	1.2	89.3
26	1.2	33.5	1.4	90.7
27	1.3	42.0	1.7	92.4
28	1.4	95.5	3.9	96.2
29	1.5	84.5	3.4	99.6
30	1.6	10.0	.4	100.0

CUMULATED AREA-% : •
AREA IN INTERVAL-% : +

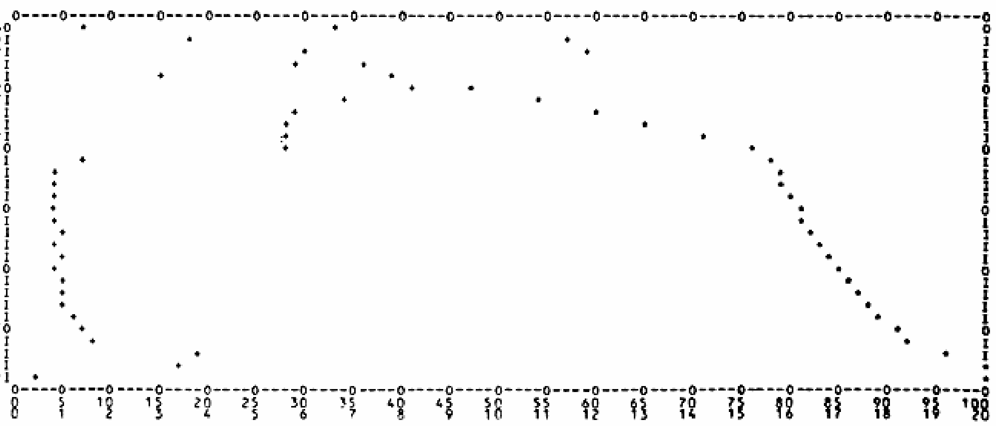
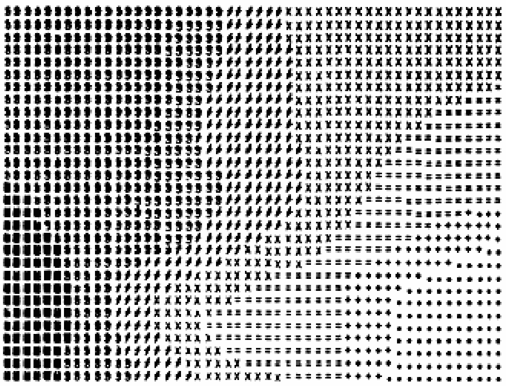


Fig. 6. Hypsographic curves for interpolated map No. -156.
Fig. 6. Hypsografiske kurver for interpoleret kort nr. -156.

OLE HEBIN, GEOGRAFISK INSTITUT, KOEGE BUGT UNDERSOEGELSEN
KOLS ID11=-1 AEKV2=1C. SKALA2=1.0 ITYPE=2
(MAP2)



CLASS NUMBER	GRAY LEVEL	LOWER BOUND	UPPER BOUND
1	.	137.89	221.73
2	+	221.73	305.57
3	=	305.57	389.42
4	X	389.42	473.26
5	/	473.26	557.10
6	$	557.10	640.94
7	■	640.94	724.79

Map type 2, 1 strip, data in equal intervals,
7 gray-tone levels

Fig. 7.

Fig. 9. 3-dimensional diagram of section of map No. 114.
Fig. 9. 3-dimensionalt diagram af del af kort nr. 114.

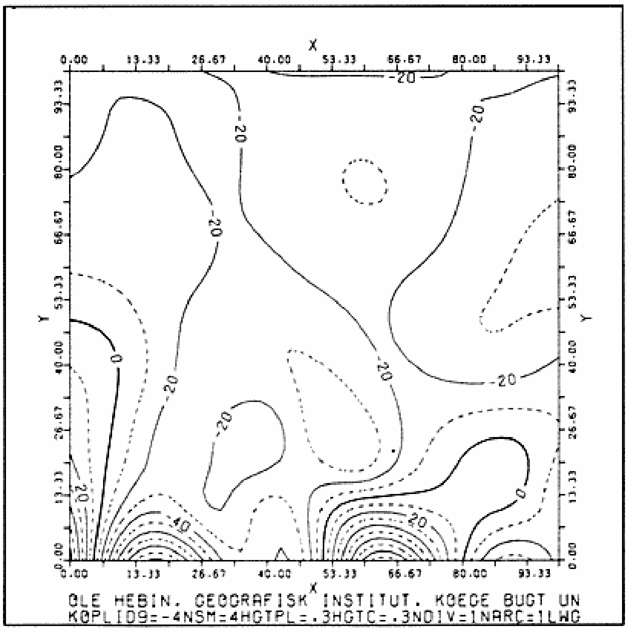


Fig. 8.

1. Maps with 7 gray-tone levels with the data in equal intervals. Size: multi-strips.
2. Maps with 7 gray-tone levels with the data in equal intervals. Size: 1 strip.
3. Maps with 7 gray-tone levels with the data split into equal areas. Size: 1 strip.

The matrices may also be plotted on the plotter, and here the flexibility is much greater. The maps may be drawn up to a width of 80 cm (31 inches) and with a practically unlimited length. The specifications for the individual map include:

1. Laplacian smoothing.
2. Heigth of labels on contours and/or on data-points.
3. Subdivision of the existing grid by means of cubic polynomials in both directions in order to smooth the surface even further.
4. Number of straight line segments that are to be replaced by an arc to smooth the individual contours. Overlapping may occur by this procedure!
5. Contour-spacing.
6. Contour type. For the user's convenience a series of options are available for combinations of dotted lines, normal lines, and heavy lines.
7. Posting and labelling of data-points.
8. Plotting with ball-point pen or magic ink.

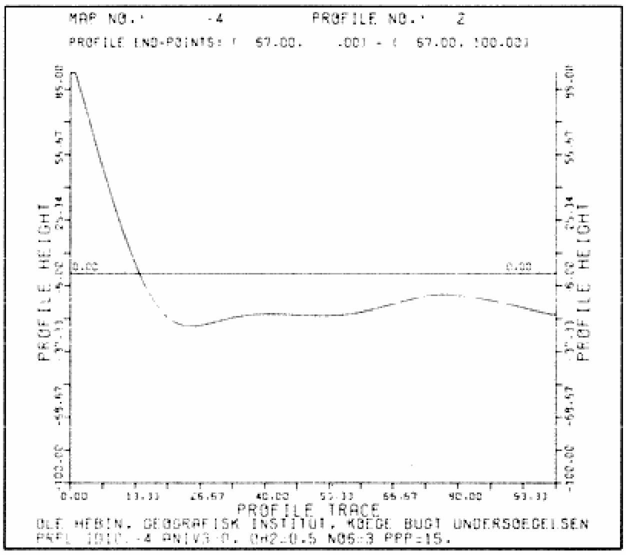


Fig. 10.

For demonstrations or illustrations 3-dimensional diagrams of the surfaces are very useful and the program can plot a variety of these, using the specifications from the map plotting, plus:

1. Vertical multiplication.
2. Base level specification.
3. Eye-point position (point-of-vision).

As the point of vision can be moved around, stereoplots may be produced.

In many applications profiles of the computed surfaces are used. The program can produce, print or plot, profiles along any coordinate track on the surface. The profiles can be exaggerated vertically by a multiplier and reference levels can be drawn in the diagrams. Besides plotting or printing the profiles various statistics are computed, including length of the profile surface.

The plotfile

The plotfile that is produced by the program can be saved and used on the interactive graphic terminal, so that editing, f.ex. addition of names and symbols, deletion and addition of contours, changing of lines types, production of a special colour-file which may be send to the Applikon colour-plotter and so on.

Commands

All instructions to the program are given by key-words or command-words plus parametres. The parametres are given in free format in order to facilitate the job and to reduce the possibility of mistakes.

The general format for an instruction is:

Command parameter 1, parameter 2, ...

example (table 2):

Table 2 — DIFF - Perform calculations on two maps

Field Number	Parametre Description	
1	Map number 1	I
2	Map number 2	I
3	New map number	I
4	Numerical operator	F

New map = (map 1 (sign of operator) map 2) * |operator|

Example

```
DIFF 3,4,-1,-1.o
```

For operators equal to:

-1.o	Difference between the two maps is calculated
+o.5	The mean of the two maps is calculated
	etc.

Table 3 — COMMANDS

Key word	Short description
DIFF	Calculations on two maps
FILE	Initialize the storage files
FOUR	Fourier-analysis
HYPS	Compute and plot hypsographic information
INDX	Changing of identification numbers
INTR	Compute interpolated grid
KNTR	Control output of parametres and data
KOLS	"Plotting" of line-printer maps
KOPL	Plotting of maps on the plotter
KORT	Input of z-values for map
PARM	Input of basic parametres
POST	Posting of datapoints on the plotter
PRLS	"Plotting" of profiles on the line-printer
PRPL	Plot profiles on the plotter
SLCT	Select data-points inside specified polygon
SPEC	Input of special data-points or up-dating
STOK	Input of data-point coordinates
TDIM	Plotting of 3-dimensional diagrams
TIME	Prints elapsed time, when requested
TRND	Trend-surface analysis
TXT1	Input of main heading
TXT2	Input of sub-heading
VOLN	Volume calculations relative to reference level
VOLP	Volume calculations by the profile method
VOLT	Volume difference between two maps
GRAD	Produce gradient map
HIGH	Apply high-pass filter to map surface
LOWF	Apply low-pass filter to map surface
SMTH	Apply smoothing function to map surface

Table 3 is a direct copy of a page in the manual.

For some of the commands, parametres from other instructions may be used as defaults, so you should not have to change a lot of instructions when you want to change a single or a few parametres.

The present version of the program contains facilities for 23 general commands with a high number of parametres for each command. The following commands are now working (see table 3).

The commands in the lower box are now being tested.

RUNNING EXPENSES

It is very difficult to say anything general about running expenses for the different procedures, but as an approximation you may use the number of CPU-seconds.

Interpolation of a surface from 193 data-points to 2625 cells takes around 22 seconds.

Plotting of a map from an already interpolated surface with 2625 cells and a moderate number of contours takes 5.5 seconds if the size is 10x62 cm (4x25 inches). If the number of contours is very high the plotting time may be doubled.

Posting of the original 193 data-points takes from 5.5 to 6.1 seconds depending on the size of the plotter-output.

Plotting of a profile takes 2-3 seconds.

3-dimensional diagrams take from 20 to 50 seconds, depending on size of diagram, plotting of contours on the surface and posting of data-points.

Trend-surface analysis is cheap. For 193 points and the second-order surface it takes 2.7 seconds, while harmonic analysis with 8 harmonics takes more than 50 seconds.

THE PROGRAMS

All programs are written in FORTRAN IV, except for the elementary plotter routines, that are system routines. The programs have been tested and run on a UNIVAC 1100/82 computer but only standard FORTRAN has been used.

The size of the program has deliberately been kept as low as possible. Maximum core usage is approximately 27000 words for the instruction bank and 35000 words for the databank or all in all less than 60K words. To keep core-size down, the program has been split into two segments, but if you have around 80K storage, there is no need for segmentation at all.

When starting the program for the first time, the direct access files have to be initiated which can be done by a special key-word in the data-stream, but it's recommended that this is done by an experienced programmer as any errors in this procedure may introduce problems for all the future runs with the data-base.

Running the program, after initialization, is very straightforward and requires only 2 to 3 system cards (magic cards) plus the command- and data-cards.

RESUMÉ

Artiklens formål er at vise anvendelsen af et EDB-baseret kortudtegnings- og analysesystem, der hvad angår arbejdsbyrde og beregningsmuligheder langt overgår de sædvanlige manuelle metoder.

De anvendte data-punkters koordinater indlæses kun én gang i systemet, hvorefter data-værdierne kan henføres til disse lokaliteter ved en simpel numerisk reference.

Der kan produceres kort på såvel linieskriver som plotter med et utal af specifikationer. Blandt de mere centrale analysemuligheder kan nævnes: volumen-bestemmelser, profil-beregning og -tegning, hypsografisk beregning, polynomial trend surface og flerdimensional Fourier-analyse. Der kan tillige udtegnes 3-dimensionale diagrammer. Alle analyser og udtegninger kan foretages for enten et helt kortblad eller et specificeret udsnit heraf.

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This program was written at the Department of Geography by the author, but of course all labor-saving applications of already existing subroutines have been used.

Some of the plotting-routines were developed at the SACLANT Research Center, Naples, but all of them have been changed or modified.

Some of the line-printer »plotting«-routines are modifications of programs written by Bruce MacDougall, University Toronto, and finally the two routines for trend-surface analysis and for harmonic analysis were originally inspired by work done by John Davis, Kansas Geological Survey.

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