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DESIGN, OPERATION AND RESULTS OF THE DIGITAL MAPPING SYSTEM AT FINNMAP

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1. Introduction

Finnmap is the third biggest privately owned consulting company in Finland. The main activities, in addition to construction design, are surveying and mapping (including aerial photography, field surveys, photogrammetry, automatic data processing, cartography and photo laboratory work), forest inventories and urban and regional planning.
In 1981 the company started to develop a computer-aided mapping system based on interactive graphics. The system was taken into use in 1982. The design, operation and experiences are reported below and the future development of the system is outlined.

2. Design of the System

The following requirements were discussed as background for the subsystem:

a) Photogrammetric digitizing
- connection to existing plotters (Wild A8, Wild B8S, Zeiss Topocart B and Kern PG2)
- computer-aided absolute orientation
- easy feature coding (menu system)
- digitizing assisted by definable rules (e. g. automatic mode selection, predefined filtering method, squaring of objects, reduction of roof overhangs, parallel lines, predefined interpolation method)
- simple editing possibilities during digitizing
- assisted documentation during the work
- easy data transfer to the host computer
- feedback to the operator (graphic response and alarm in case of errors)
- accuracy (resolution and position accuracy)
- good reliability, low error frequency
- easy and fast to use
- good price/performance relation.

b) Alternative table digitizing possibility with respective requirements

c) Flexible editing possibilities with the help of an interactive graphic terminal:
- insertion of new objects
- deleting of erroneous objects
- moving of texts and symbols
- changing of feature codes
- connection of lines.

d) Good cartographic database system including:
- flexible database structure
- fast, selective search of graphic elements
- management of topology (areas)
- basic elements: point, line, area, object and text
- utilities for manipulations.

e) High quality drafting system:
- good position accuracy
- good cartographic quality
- fast plotting of manuscripts.

In 1981 not many cartographic database systems were available. The Norwegian SysScan system fulfilled many of the above requirements and was selected as a basis. The photogrammetric digitizing had to be developed by Finnmap, because no suitable system was found at that time on the market. The output requirements for different customers were so complex that own solutions had to be developed for fairdrawing. Thus the system configuration has been formed as follows:

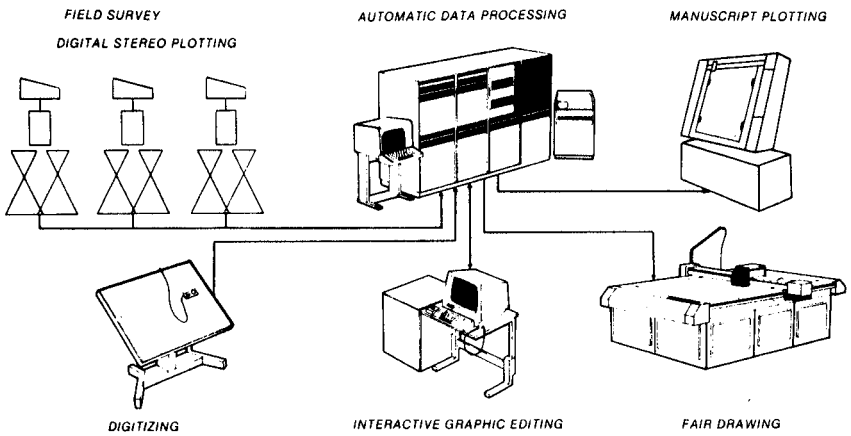

Fig. 1: Configuration of Finnmap's digital mapping system

2.1 Digital Photogrammetric Compilation

Photogrammetric digitizers AND-4, developed by the Finnish Geopolar company, are used for recording in an analog plotters by rotary encoders. Coordinates are stored directly on microcomputer disk (MicroVAX I). Stream mode can be used either by time or distance interval.
Feature codes are selected with the help of a menu keyboard (2 x 48 keys).
The digitizer can be controlled by signals from the collecting microcomputer.
For graphic feedback a simple plotter (Houston DMP42) is used.
Alternatively a graphic screen could be used, but windowing requires a lot of capacity.

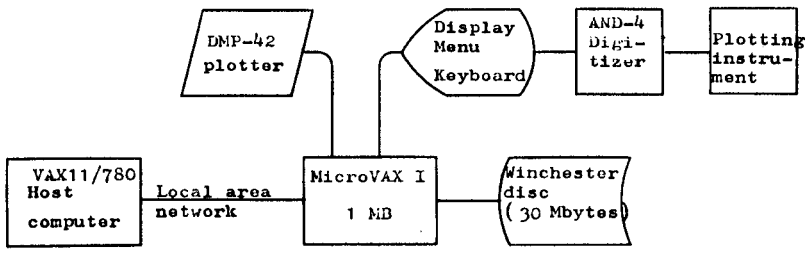

Fig. 2: The photogrammetric digitizing system

2.2 Interactive Graphic Editing and Data Processing

The heart of the system is the cartographic database of SysScan, called GINIS. It includes flexible interactive graphic editing possibilities. The graphic workstation consists of Altek-digitizer (90 cm x 120 cm) and a graphic terminal, either Graphic 7 vector refresh screen or Vistagraphic coloured raster screen.

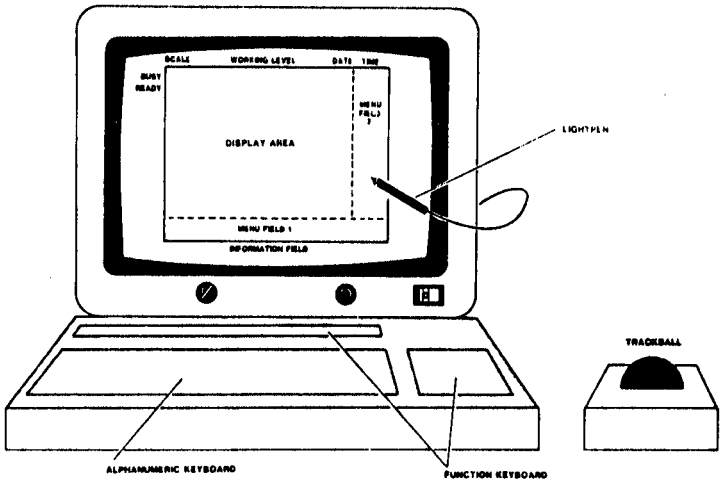

Fig. 3: Graphic 7 refresh terminal

Existing maps are digitized interactively with the help of our own digitizing software. In order to increase capacity, such digitizing is displayed on a separate cheap raster screen (e. g. Pericom) simultaneously as the high resolution screen is used for the editing of another map sheet.
Graphic 7 terminal is connected to the host computer with a fast parallel interface. Both Graphic 7 and Vistagraphic have better than 1000 x 1000 pixels resolution and they are operated with help of function keyboard and light pen/track ball or data tablet.
GINIS software includes a variety of functional operations, such as the following:
- data structure editing (manipulation of logic levels)
- display manipulation (windowing etc.)
- graphic editing (insert, change, move, connect, transform etc.)
- geometric calculations (areas, distances etc.)
- utilities (plot, list etc.)

The operation is guided and only the possible steps are displayed on the screen.
The host computer is a VAX 11/780 with 4 MB memory and 770 MB disks. Local area network (ETHERNET) connects the photogrammetric digitizing performed by MicroVAX to the host system with high transfer speed.

2.3 Drafting System

Manuscripts are plotted with a fast beltbed plotter Calcomp 960 using ball point pens of different colours. The maximum speed is 1 m/sec and the acceleration is 4 G.
Fairdrawing is performed by Kongsberg GT5000 flatbed plotter of plotting size 120 cm x 160 cm using tangentially controlled scribing or PS5 photo head. We prefer photo plotting, because it gives the best quality and flexibility in line width of the range 0.05-6 mm. It is also much faster when plotting dash lines or symbols located on the photo head.
The position accuracy is promised to be better than 75 microns. Both plotters are connected on-line to the host computer via intelligent controllers.
The same plot file can be used for both plotters with the help of post processing software.

3. Operation of the System

The computational phases of our digital mapping process are:
- geodetic computations
- aerial triangulation
- digital photogrammetric compilation
- creation of cartographic database
- automatic plotting of manuscripts
- interactive graphic editing
- automatic fairdrawing.

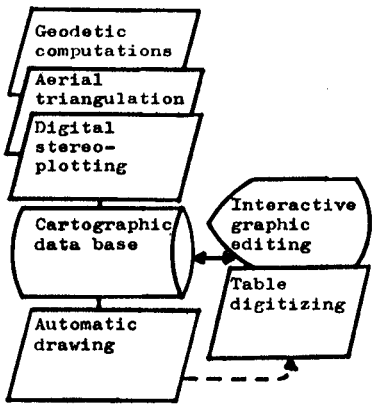

Fig. 4: The digital mapping process

The results of geodetic computations and aerial triangulation are stored on their own levels in the database.
The major part of the datacapture is carried out by photogrammetric digitizing in analog plotters. This is a very important phase considering the amount of graphic editing. Digitizing errors may considerably reduce the cost-efficiency of the whole process, if a lot of interactive editing is needed by expensive workstations.
Normally the digitizing is performed per model, not per map sheet. The reason for this is that it is much easier to perform edge matching inside the database unit (map sheet) than between neighbouring database files.

The detected errors, which cannot be corrected during digitizing will be marked on the proof plot produced by the verification plotter. The beltbed plotter manuscript is used for field checking and completion. All corrections are marked on the manuscript and then carried out by using the editing workstation. The final plot file is produced from the database and then plotted with photo head or by scribing.
The photo plot is often made as a mirror image on the back side of the foil. The customer can update the map on the upper side by manual plotting, if he has no facilities for digital work.
The variety of different database systems and the lack of standardization in data transfer means that the consultant must have very flexible digital output possibilites from his database.

4. Results and Experiences

We started the photogrammetric compilation by using recording on cartridge tapes, because the host computer could not read all data in stream mode. However, these tapes were too unreliable and the digitizing errors could not be corrected immediately during digitizing. Therefore a powerful microcomputer (MicroVAX) was purchased for data collection.
In the beginning we used blind digitizing both in analog plotters and on digitizing tables. However, visual feedback to the operator seems to be very important. A simple plotter (DMP-42) was purchased for the verification of the photogrammetric data capture. It has two advantages as compared to a graphic screen: Firstly we have no windowing problems, and secondly, a concept document is prepared for later editing.
Table digitizing is now verified on a simple graphic screen, because it is much cheaper than the high quality editing screen which is used simultaneously for editing of other map sheets.

Windowing is not a major problem, because windows can be accurately selected by the operator, with more ease than in photogrammetric digitizing.
Originally the editing results were first stored in sequential files before loading into the database. Interactive editing during digitizing in such case was not possible. Nowadays the digitized data is stored immediately into the database and many editing functions can be used already during digitizing.

4.1 Qualitative and Quantitative Results

The quality of maps produced by photo plotting and scribing has occured very good. The only problems have occured in stabilizing the photographic laboratory process. The exposure values must be changed, if the process parameters are not constant.
The geometric quality has also normally been very good. However, if the temperature and the humidity vary too much, correcting scale factors should be set on the drafting machine. Also the inner accuracy of the plotter must be controlled daily in order to detect possible servo failures.
The capacity of the system depends largely on the quality of digitizing. Interactive editing will easily form the bottleneck, if many mistakes must be corrected after digitizing. Fair-drawing no longer causes problems. It is performed at least 20 times faster than by manual methods.
However, photogrammetric digitizing cannot produce as faultless data as digitizing on tables. Many aesthetic corrections have to be carried out afterwards. A lot of them can be eliminated by software processing, which has a great effect on the cost-efficiency of the system.

4.2 Main Advantages of the Digital Mapping System

The following aspects are of great importance:
- fairdrawing is much faster than manual fairdrawing
- different types of map (variable contents, symbol selection, scale) can be easily produced from the same data
- interactive editing is much easier than manual editing
- digital data can be used for other calculations and data processing (e. g. orthophoto production)
- the cartographic quality of maps may become better (more accurate, homogenous, high line quality)
- the digital database itself is most useful for many purposes and it is very flexible considering future requirements
- the hardware has in general worked reliably.

4.3 Disadvantages and Problems

The following problems have occurred with the system:
- in the first software versions there were some errors and shortcomings; most of them have been corrected in the later versions
- the system needs a lost of computer capacity (both CPU, I/O and disk space)
- the price of the hardware is rather high and the software is quite strongly hardware dependent
- the checking of manuscripts becomes much more important and time consuming than when manual methods are used
- very specialized symbology defined by the user can be extremely difficult to produce with a general system; therefore own plotting software has been used instead of the standard plot package of SysScan.

5. Future Developments

The following ideas are suggested for development and have partly been executed:
- the digitizing results should be stored immediately into the database (not in the intermediate file), because then the data can be edited during digitizing
- the requirement of disk space should be minimized, at least when archiving database files
- a good relational database system should be connected to the graphic database for associate (attribute) data processing
- some editing functions (e. g. edge matching) should be made easier to operate
- cheaper workstations should be available for simple work
- an economical photogrammetric digitizing system should be developed based on microcomputers, local area networks, graphic screens and superimposition.

6. Concluding Remarks

Reliability and feedback for quality control purposes are essential features of an efficient digital mapping system. An operator cannot produce final maps using the photogrammetric plotting machine as many aesthetic corrections are normally necessary prior to fairdrawing. The graphic workstation could thus become an expensive bottleneck in the system.

Economical use of a digital mapping system depends to a great extent on the quality of the data capturing system. The superimposition system may greatly assist in producing clean data whilst in updating it is almost essential. Therefore, an economical solution to superimposition in existing analog plotters would be most welcome.

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