EXPERIENCES WITH PHOTOGRAMMETRIC MAP COMPILATION AS PART OF A DIGITAL MAPPING SYSTEM

Mr. Reino Ruotsalainen
Finnmap Oy
Finland
Comm. IV/8

1. Introduction

After the previous photogrammetric congress in Hamburg in 1980, digital mapping methods have become increasingly popular. Many companies have launched new digital production techniques. Also Finnmap, which is the leading private mapping consultant in Finland, has strongly developed its digital mapping systems based mainly on photogrammetric data capture /1/. The well-known Norwegian SysScan-system is used for editing and maintenance of the cartographic database /2/. Final maps are fairdrawn with a high-precision drafting table (Fig. 1).

In the course of the development work the importance of reliable photogrammetric data capture has become very obvious. So far there have been very few photogrammetric digitizing systems of good quality on the market, if any.

The experiences with different photogrammetric recording systems will be reported below and the requirements for a good system will be suggested.

2. Photogrammetric data capture as part of a digital mapping system

2.1 Structure of a digital mapping system

The typical configuration of a digital mapping system is presented in Fig. 1.

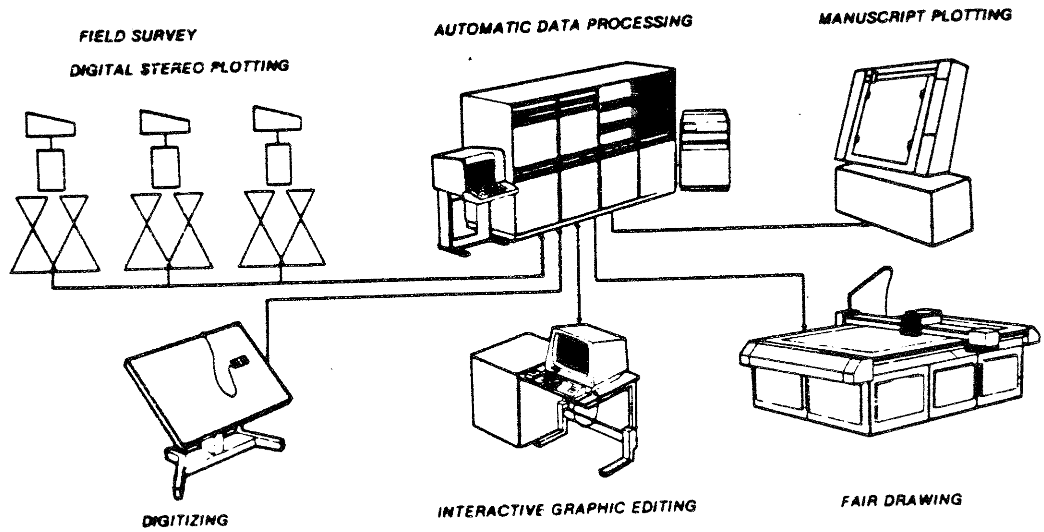


Fig. 1: Configuration of Finnmap's digital mapping system

2.2 Photogrammetric map compilation

The following equipment is required in digital map compilation:

- analog or analytical plotter
- encoders for conversion from analog to digital form; rotary encoders are simple and inexpensive as compared with linear encoders; linear encoders are, however, required for free hand movement
- counter boards for calculating the respective coordinate values
- processor for input, conversion and output of data
- auxiliary output device or on-line connection to the host computer.

Feature coding is a very important part of data capture. It can be made in different ways:

- by giving character strings via keyboard
- with a menu system by identifying squares (menu keyboard or data tablet)
- by voice recognition (voice input) or
- by coordinate coding /3/.

Menu keyboard seems to be an easy and simple way of coding, until voice input becomes an economic method.

Recording can be carried out in different operating modes:

- point mode (point by point)
- stream mode by time interval
- stream mode by distance interval
- stream mode by significance filtering (angle or distance tolerances).

When using time interval the same coordinates should not be recorded twice (e.g. recording is suppressed while stationary).

The photogrammetric recorder can operate either off-line or on-line to the host computer. Buffering is usually needed in on-line systems. The operator needs feedback especially from error occurrences. The quality is difficult to control in off-line systems. However, off-line equipment is independent from breaks in host computer.

The following flow chart summarizes the digital photogrammetric compilation system:

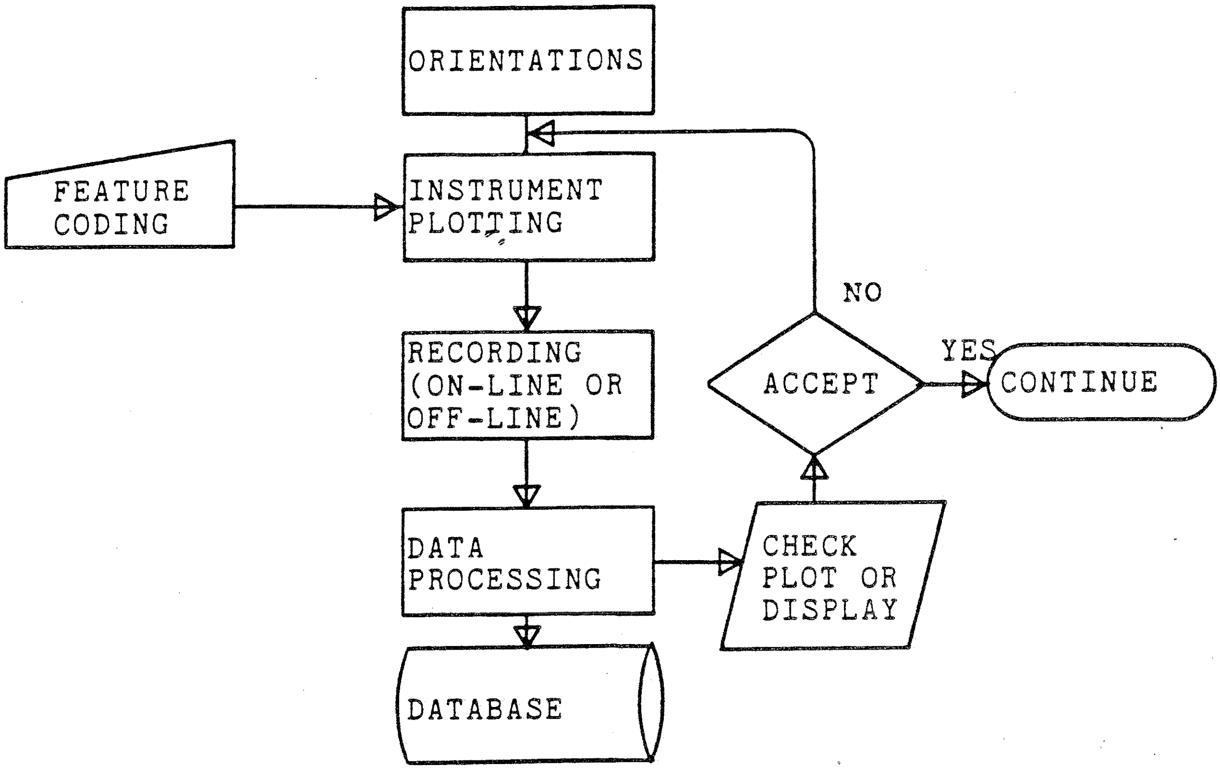


Fig. 2: The digital photogrammetric compilation system

Digital recording may result in many advantages:
- fast operating of complex symbols, spot heights, parallel lines, squared houses, broken lines and other computer assisted operations
- better accuracy
- mechanical table no longer required
- flexible output and possibilities for later processing
- faster orientations
- scale freedom
- digital database for various purposes.

Different system solutions have been developed:
- recording only (blind digitizing)
- recording and mechanical check plot
- computer assisted plotting (without digital output)
- computer assisted plotting and recording into database.

3. Requirements for a good digital map compilation system

3.1 Hardware independence

- connection to the most common analog plotters (selection of axes, resolution, scale factors, axis orientation and other instrument parameters)
- common programming language (for example FORTRAN-77 source code available)
- graphic standardization for peripherals (Graphical Kernel System, GKS)
- independent operating system (for example UNIX).

3.2 Computer aided orientations
- relative orientation for the most common analog plotters
- absolute orientation using 3D orthogonal algorithm and least squares solution; elimination of systematic errors in transformation
- quality control of orientations (residuals, accuracy, corrections to orientation elements, documentation of results).

3.3 Feature coding
- easy menu system (enough menu squares)
- easy pen up/pen down function (start, intermediate and end points)
- closing of node points (clipping, stretching)
- possible voice recognition
- dual foot pedal for feature coding

3.4 Digitizing rules
- the possibility to define rules for objects (for different feature codes); these rules may include the following functions:
- operating mode: point or stream mode, text
- filtering method: time and/or distance interval, direction or distance significant filtering, alignment etc.
- squaring of objects
- hidden points and reduction of roof overhangs
- parallel lines
- interpolation method: linear, circular, curved (smoothing).

3.5 Editing possibilities
- identification of digitized objects
- deletion of the previous or identified object
- changing of feature code of an identified object.

3.6 Documentation of the work
- project data
- orientation data (quality control)
- statistical data (number of objects, time required).

3.7 Data transmission
- standard interchange format (IGES, GKS Metafile etc.)
- asynchronous serial line (EIA RS232C); speed at least 9600 baud
- possible connection to a local area network (LAN)
- alternative off-line output on magnetic tape or other storage media with reasonable capacity (1-2 megabytes)
- dual buffering system for on-line connections.

3.8 Feedback to the operator
- graphic response either on terminal with reasonable resolution or on a simple plotter (bigger than map sheet size)
- flexible symbology for graphic output (point symbols, line types)
- A/N status display
- alarm with bell from detected errors (quality control)
- possible voice feedback for checking
- possible economic superimposition.

3.9 Other common aspects
- -resolution at least 5 microns; linear encoders better than rotary
- -reasonable digitizing rate (at least 5 points/sec)
- -high reliability (no loss of origin, low error frequence)
- -easy and fast to use (productive)
- -economic (price/performance of many workstations).

4. Example of a data capturing system

The Stereo-Track system of SysScan A/S will be described in brief as an example.
The hardware configuration is presented in Fig. 3 and the main software modules in Fig. 4.

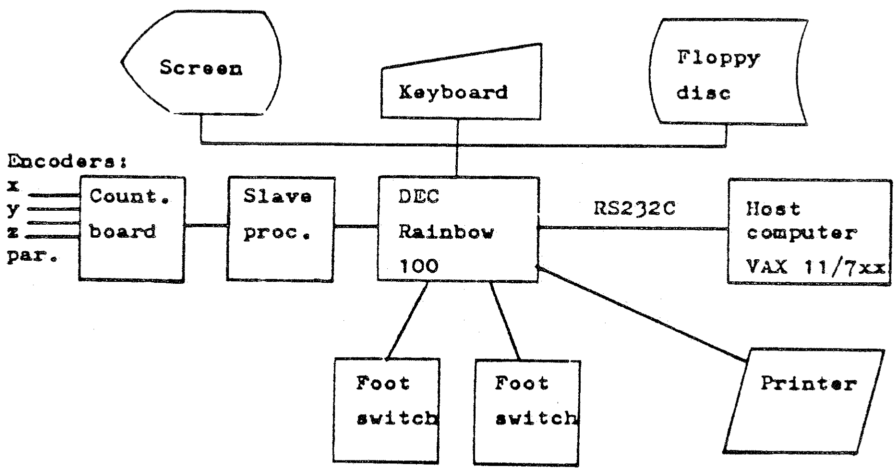


Fig. 3: Hardware configuration of Stereo-Track data capturing

4.1 Hardware
The computer used is DEC Rainbow 100, which is a 16 bit microcomputer with a CP/M operating system. Programs are written with Basic and GKS interface is used for graphic applications.
A separate slave processor and counter board electronics are used for coordinate reading and filtering.
The graphic screen has resolution of 800x240 pixels and it can display 4 colours.
Commands can be given via A/N keyboard and many function keys.
Winchester disc (5-10 Mbytes) or floppy disc (800 Kbytes) can be used as output device. Documentation is printed on a matrix printer.
Asynchronous serial line to host computer is available.

4.2 Computer aided orientations
Both relative orientation and absolute orieentation can be assisted with software. The ground points may be loaded from the host computer to the micro.
The absolute orientation is performed by a three-dimensional orthogonal algorithm.
The following documentation is printed on a separate file:
- -ground and model coordinates and residuals
- -mean square errors of each point and of the whole transformation
- -corrections to the orientation elements.

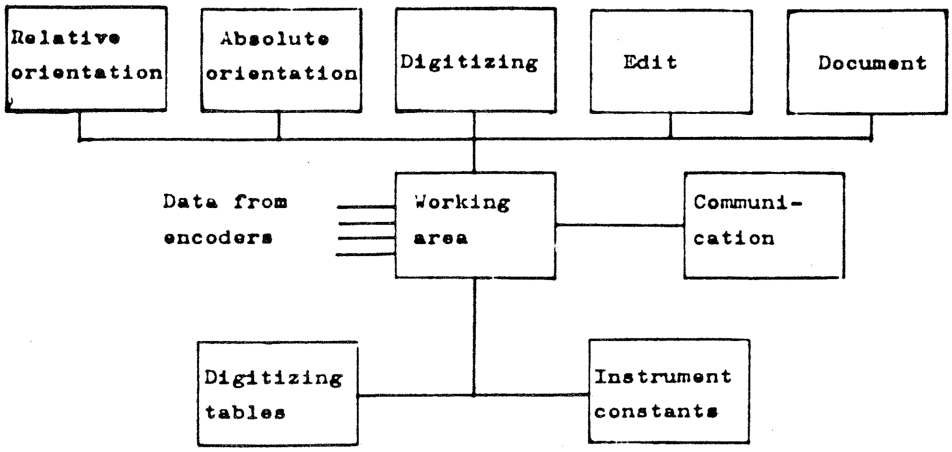


Fig. 4: Software modules of Stereo-Track data capturing

4.3 Feature coding and digitizing rules

No special menu keyboard is available. Feature codes are connected to so called definition tables, which include rules for different types of theme codes (max. 400 types of rules). Each type of object can have an address, where to jump in the table. Each table therefore includes:
-number and name of each themecode (20 rules/table)
-digitizing mode (point or stream mode)
-digitizing interval parameter (direction/distance significant)
-axes used
-graphic presentation code
-switching address with control pedal
-output coordinate selection
-numbering of objects.
Vertices may be labeled during stream mode as:
-start point
-intermediate point
-end point
-node point (between different lines).

The following rules are only labelled during recording and executed afterwards in post-processing:
-squaring of objects
-reduction of roof overhangs
-hidden points
-circular arc via three points
-parallel lines etc.

4.4 Editing possibilities

Only the following editing methods are possible:
-search with help of coordinate positioning in plotting machine
-deleting of the searched object
-display on screen.

4.5 Documentation

A separate documentation file is created including:
-flight and model data
-orientation data and quality control
-statistics of objects at each level.

4.6 Data transmission

A special data communication program is available for DEC computers. Files can be transferred both ways between the micro and host computer.
The micro can be used as asynchronous terminal to any computer with a RS232C interface.

4.7 Feedback to the operator

A/N display shows the status to the operator. If graphic option is in use, the data of a preselected window can be shown to the operator. The resolution is limited to 800x240 dots and the number of colours is 4.

4.8 Other aspects

Other aspects of Stereo-Track inlude:
- -maximum digitizing rate 20 points/sec
- -easy to connect and use
- -price level 27.000 USD.

5. Experiences with various systems

The following systems have been tested by Finnmap:
- -AND-3 photogrammetric recorder of Geopolar Co, Finland /4/
- -Wild RAP-system, Switzerland /5/
- -LDC-5000 photogrammtric digitizer of Aswell Engineering Co, Denmark /6/
- -Stereo-Track data capturing system of SysScan A/S, Norway /7/
- -MAPS200 system of Kern, Switzerland /8/.

5.1 Error possibilities

Most of the digital data is usually captured with the help of plotting machines. Thus the quality of photogrammetric data is extremely important. Many types of errors may occur:
- -loss of origin in recording device (fatal error)
- -loss of data while buffering
- -errors in feature coding (wrong codes)
- -errors in separation of different objects (pen up/ pen down detection)
- -tracking errors in line following
- -errors in orientation elements (fatal error)
- -inaccuracy of encoders
- -inaccuracy of node points (open node points)
- -missing objects (forgotten)
- -duplicated recording of objects
- -errors in digitizing rules (squaring of houses, roof overhangs, parallel lines etc.)
- -systematic errors in mathematical model
- -software errors
- -hardware failures.

5.2 Some disadvantages of the systems

We have experienced the following typical disadvantages:
- -AND-3: sensitive for electronic disturbances
- -RAP: not originally made for digital data capture in stream mode
- -LDC-5000: no supress of recording in time mode while stationary
- -Stereo-Track: limited capacity of output device (floppy disc)
- -MAPS200: expensive, hardware dependent.

5.3 Some advantages of the systems

The tested systems have for example the following advantages:

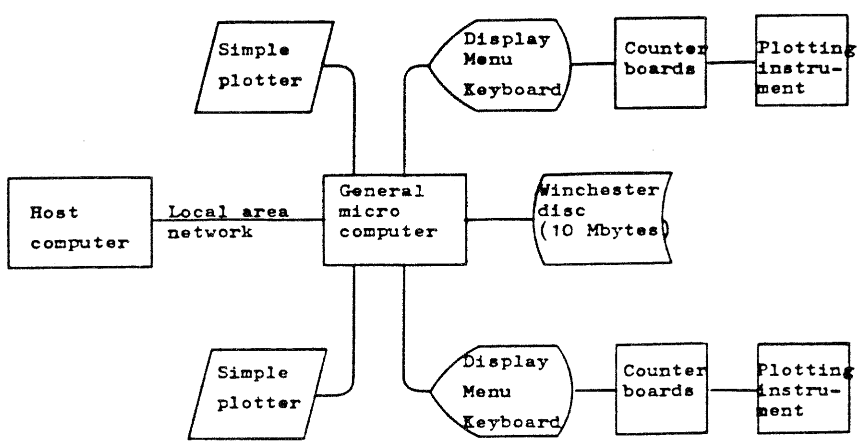
- -AND-3: cheap basic equipment
- -RAP: good camputer assistance and simultaneous check plot
- -LDC-5000: reliable basic equipment with standard interface
- -Stereo-Track: possibility to define digitizing rules
- -MAPS200: large supporting software specially for project management.

6. Suggestions for future development

Considering the requirements for a good map compilation system, it is hoped that the manufacturers will take the following into account:

1) Connection to most common analog plotters should be possible. Software should be written with a common programming language in general form.
2) Orientations should be assisted with the computer, controlled and documented.
3) Feature coding must be easy to learn and use.
4) It is recommended that every object type should have its own digitizing rules in order to make the operation easy and to reduce errors.
5) Simple editing possibilities (deleting and changing of feature codes) should be connected with data capture.
6) The documentation of the work ought to be printed on control file.
7) Data transmission should be standardized both physically and logically (stardard interchange format).
8) It is very important for the operator to get feedback from all errors in operating. Voice and graphic responses are therefore almost necessary.
9) Last but not least, the system should be productive (price/performance).

An example of the hardware configuration of the proposed digitizing system is described in Fig. 5.



7. Concluding remarks

The reliability and quality control feedback are obligatory for a good recording system. However, the operator cannot produce a final map with the plotting machine. Many aesthetic corrections are needed before fairdrawing, specially in small-scale mapping.

Economical use of a digital mapping system depends to a great extend on the quality of the data capturing system. If many corrections must be made in the interactive way, the graphic workstation becomes an expensive bottleneck in the system.

The biggest revolution in instrument plotting will be brought about by the superimposition system, if it can be supplied at a reasonable price /9/. The superimposition will be a solution to many updating problems, as the existing map can be seen on the stereo model.

References

/1/ Ruotsalainen R., A digital mapping system, Surveying Science in Finland, 1983 (1), pp. 33-36.
/2/ Ruotsalainen R., Experiences with the Installation of a Turnkey Computer Graphics System. SORSA (Spatial Oriented Referencing System Association) Forum 82, Helsinki 1982.
/3/ Simonson G., Storskalig halvautomatisk kartering (SHAFK). R86:1981 Statens råd för byggnadsforskning Stockholm, ISBN 91-540-3503-1 (Swedish).
/4/ Geopolar Co, AND-3 Photogrammetric Digitizer, Technical Description, 1980, Helsinki.
/5/ Höhle J., Jakob A., Computer-aided mapping with the Wild AVIOPLOT RAP System, Presented Paper: Commission II XIV International Congress for Photogrammetry, Hamburg, 1980.
/6/ Aswell Engineering Co, LDC-5000 Photogrammetric Digitizer, Technical description, 1983, Slangerup, Denmark.
/7/ SysScan A/S, Technical description of Stereo-Track data capturing from stereo-plotters, 1983, Kongsberg.
/8/ Kern Co, Kern MAPS 200 Computer-aided data compilation, 1982, Aarau.
/9/ Intergraph, Stereodigitizer Workstation DSP030, Product Description, 1982, Huntsville, Alabama.