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DIGITAL PHOTOGRAMMETIC MAPPING AT THE DUTCH CADASTRE SERVICE

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1. INTRODUCTION

The Cadastral and Public registers has a main tasks:
- the maintenance of public registers on property, ships and aircraft
- the production and maintenance of cadastral maps and cadastral map information
- the maintenance of a geodetic network
- the supply of data from registers and the supply of maps, etc. to the general public
- assistance in realising land consolidation programs
- production, maintenance and issue of the Large Scale Base Map of The Netherlands (the GBKN)

For the execution of these tasks, the Cadastral Service has set up two basic registration systems, wherein the required data is stored and revised, namely:
- the cadastral and mortgage registration of property rights
- the land surveying and cartographic system (LKI-system) for the production, up-dating and supply of maps.

Besides this, the Cadastre has other users of these basic registration systems, namely for planning purposes.

Fourteen regional centers are involved in the collection and distribution of information form these two basic registration systems.

The basic registrations are maintained by the departments of Filing and Legal Affairs (BJZ) and the Internal Survey Service (LBD). The input comprises deeds, transfers etc.. A deed or a building permit can require terrain measurements, to be carried out by the revision section. The results of the measurements of this section are used to revise the relevant maps i.e. in land consolidation projects and the Large Scale Base Map program.

a. The aims of the LKI system

The aims of the LKI-system are the control of the survey and cartographic basic registration through automation; the automation of the necessary data collection processes and the automation of the map production processes through integration of the map products. These map products include:

- the cadastral maps, a thematic map unit
  the parcel layout as main map element
- the Large Scale Base Map, a topographic map
- the land consolidation map; a working plan on which the mutation from the old to the new parcels layouts are kept up to date.

This introduction of automation is partially due to the user requirements to have a digital Large Scale Base Map, the data of which can be incorporated into their own automated systems. The LKI-system furthermore aims to make the basis registration independent of the products delivered and thus independent or the type of map produced, this since the data collected should serve a wide variety of applications such as land use planning, the design of extension plans, road planning, building planning, the registration of utility networks, etc..

In addition, the automated registration offers the possibility to control the quality of the data through the registration of its precision, idealisation, realiability and completeness.

b. Photogrammetic digital mapping

One of the subprojects of project LKI (countrywide cadastral information system) delt with Photogrammetric Digital Mapping (DFK).
The purpose of the project was to investigate, introduce and implement photogrammetric digital mapping such, that the final product is a digital data set suitable for

a database.

At the time the stereo-restitution instruments of the department which were used to plot the maps directly using either ballpoint or scribing. In case of the Large Scale Base Map Of The Netherlands (GBKN) the maps were produced directly in the instruments and then sent to the Provincial Directorates for fieldcompletion and finalisation. In case of mapping for a reallotment (workplan II) the plotted sheets were assembled into workplans II. The map scales varied from 1 : 500 to 1 : 2.000 for the GBKN, while workplans II were produced mainly at 1 : 2.000 and only in a few cases at 1 : 1.000.

The aim of subproject DFK was to replace the process of analogue mapping by digital mapping. To reach this aim a project group was formed such, that the future users (photogrammetric operators) had a considerable influence. Three of the eight members of the project group belonged to this group of future users.

Different aspects have been subject of investigation in a total of three experiments. Without underestimating the contribution of the other members one can state, that owing to the important contribution of the users a system has been created, which is well accepted by all users and has a good performance and gives good results.

An important element of the system is the fact, that the user has a number of editing possibilities during plotting in order to correct restitution errors. This philosophy deviates clearly from the internationally accepted one. At the time the trend was international to digitize first and correct errors later in a seperate editing session at an interactive graphic system. Slowly the trend is changing now to the philosophy indicated above. Software developed by mapping institutions themselves as well as software offered by suppliers of interactive graphic systems is showing this.

Choise has been made clearly also for the principle of a stand alone interactive graphic system, whereby each operator is served by a seperate processor and is therefor independent of priorities stated in a central processor. This has the advantage, that the operators are independent from each other, the systems reliability is high, there will never be a loss of data due to priority problems and the development can easily be phase-financed and in the case of later hardware replacements it is easier to change to a different system. In the system concept scetched above it will be clear, that the plotting table is no longer part of the stereo restitution system. At the moment there are seven stereo restitution instruments equipped with a digital station.

The experiences obtained in the last years show an increase of the production of approximately 25% with respect to the analogue procedure using semi-automatic plotting tables. With respect to further developments - namely analytical plotters and superimposition - should be stated, that they are not contradicting the chosen solution.

2. Points of investigation and experiments

At the start of the project the following points for investigation were formulated:

- Principle of digitization. Blind digitization versus support by plotting table or graphic screen. When and how editing should be done.
- On line or off line. What is the place of the computer in the configuration? Next to the instrument giving the possibility of interactive working or a central computer and use of mag-tape for data registration.
- Model matching. Where and how models should be matched.
- Input of codes. How, by which means and which kind of codification should be done.
- Hardware/sofware. Which hardware and software is needed for the different alternatives.
- Ergonomic aspects. What are good positions of systemcomponents, illumination, furniture.
- Personel and organisatoric consequences. Which influence has this new technology onto personel and organisation?
- Financial situation. Which constraints must be set from the financial side to make digital mapping feasible.

To investigate above points three experiments have been conducted such, that the three users (operators) in the project group had to digitize a number of models. These experiments were structured such, that as many aspects as possible were considered. As a result of the different experiments and investigations the solution described under the heading Configuration and procedure has been chosen. In the following chapters the remaining aspects will be treated.

Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

3. CONFIGURATION AND PROCEDURE

a. Configuration

Besides the stereo restitution instrument the following equipment is present:
- an interface to transform the encoder signals into model coördinates;
- a function key board to add point number or code to the model coördinates;
- one IGOS system with two graphic screens with 1024 x 1024 lines resolution, an internal processor and two hard disks;
- a simple printer to output the results of the absolute orientation.

b. Procedure

The work procedure is subdivided into preparation, capture and post processing. This three steps can also be found in fig.1 indicated as rectangulars (dotted). These rectangulars indicate also the operating system (OS) under which the work is to be done. The IGOS hardware operates with two OS: RSX for all non-graphic applications and IGOS for the graphic ones. Since preparations and post processing are non-graphic operation they are carried out under RSX. Digitizing and editing is done under IGOS. Also the two hard disks show this distribution of tasks. The software and data used under RSX are contained on one disk, while the other disk holds the software and data used under IGOS. The diagram shown in fig.1 should be interpreted as follows:
- rectangulars indicate processes;
- "bent" rectangulars indicate data;
- the central process line, shown as bold line, indicates the processes the operator has to activate.

* Blockadjustment

In the present conception the blockadjustment must be carried out prior to the digital mapping. The computation of the blockadjustment is done on the central VAX computer. The result of the blockadjustment is a file with terrain coördinates of all control points.

* Enter "RSX"

Operating system RSX must be started, because the preparation is a non-graphic activity.

* Data transmission

Data transmission means the transmission of the file of terrain coördinates, computed in the blockadjustment, from the central VAX to the RSX-harddisk of the IGOS system. This transmission is only required for the first model of the project. All following models can make use of the same data, which are then allready present on the RSX-harddisk.

* Absolute orientation

For the absolute orientation all control points, marked points as well as signalized ones, must be measured. The terrain coördinate of the same points are found in the file of terrain coördinates. When all points are measured, their model coördinates are known as well as their terrain coördinates. The residuals after a conformal transformation are checked. According to the result obtained points can be remeasured, omitted or added. When the residuals are acceptable, two data sets will be produced, namely:
- a data set with the transformation parameters. This set is copied to the IGOS disk after the absolute orientation. The data will be used during digitization to transform the model-coördination of the detail points into the terrain coördinate system.
- a data set with the smallest and larges X- and Y-coördinates in the terrain system. This four coördinates define a rectangular.

* Selection from database

The rectangular as defined by the absolute orientation is used to select the data

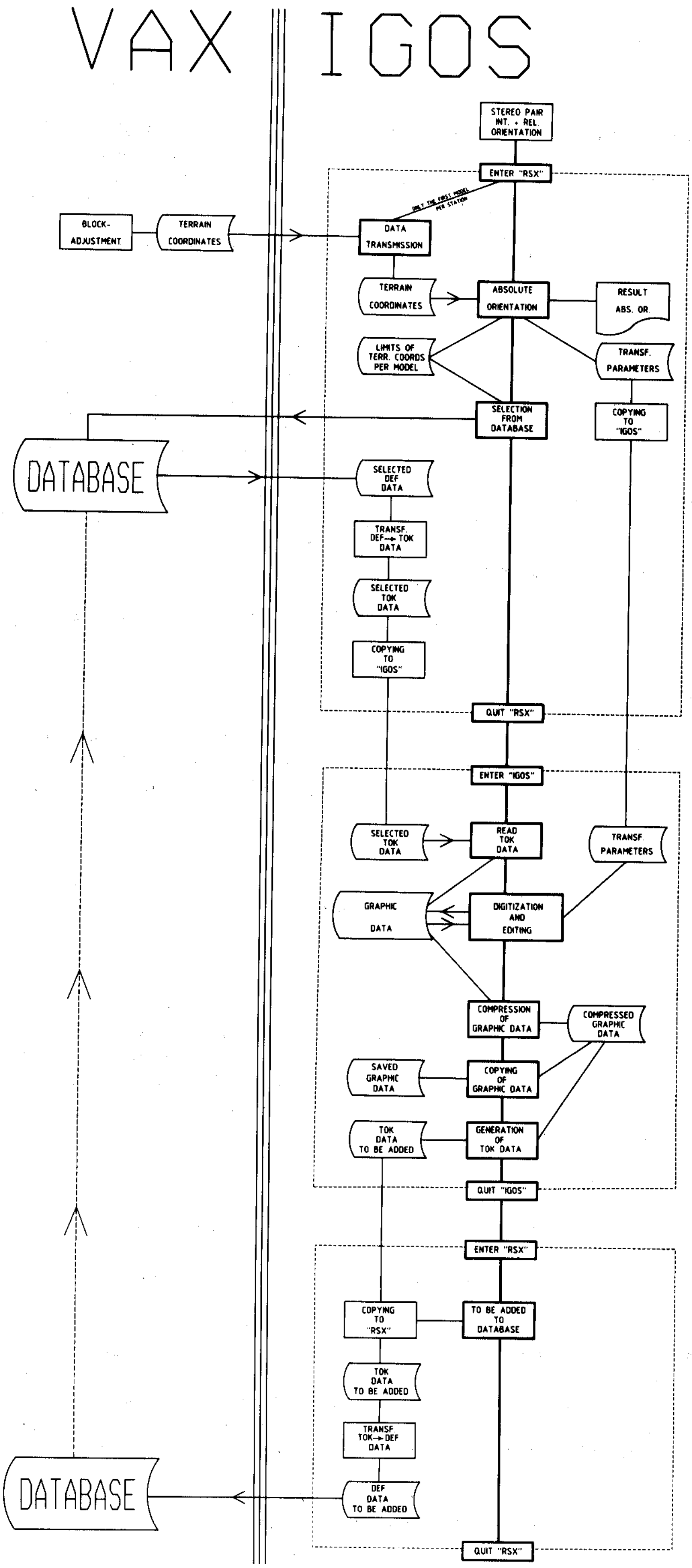

Fig. 1 The scheme of the Photogrammetic Digital Mapping System

from the master database, which is stored on the central VAX. Fig. 2 shows the rectangular with respect to the (dashed) model boundaries. The minimum coördinates are rounded to the nearest lower multiple of 100 meters, while for the maximum coördinates the nearest higher multiple of 100 meters is used.

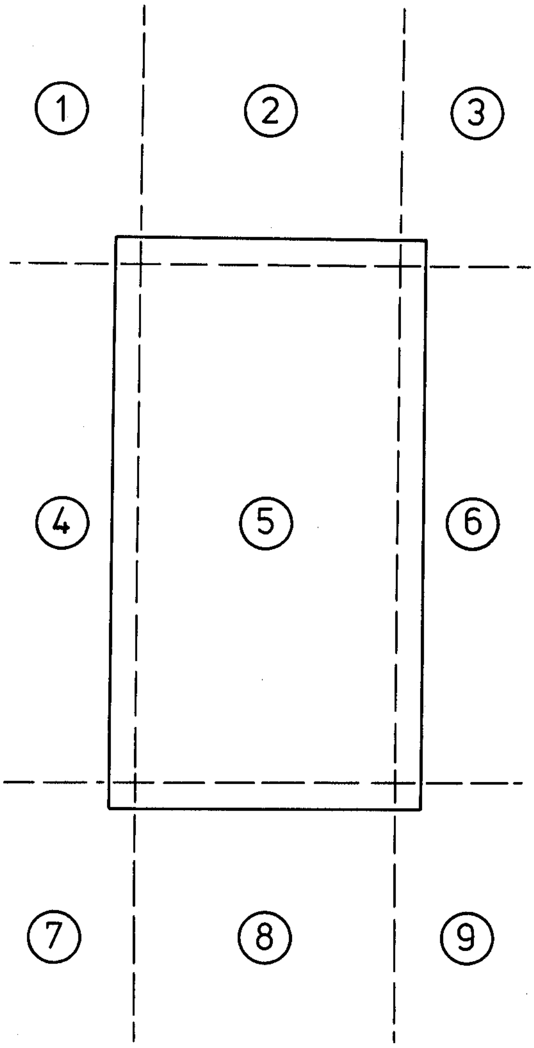

fig. 2: The computed rectangular versus the model

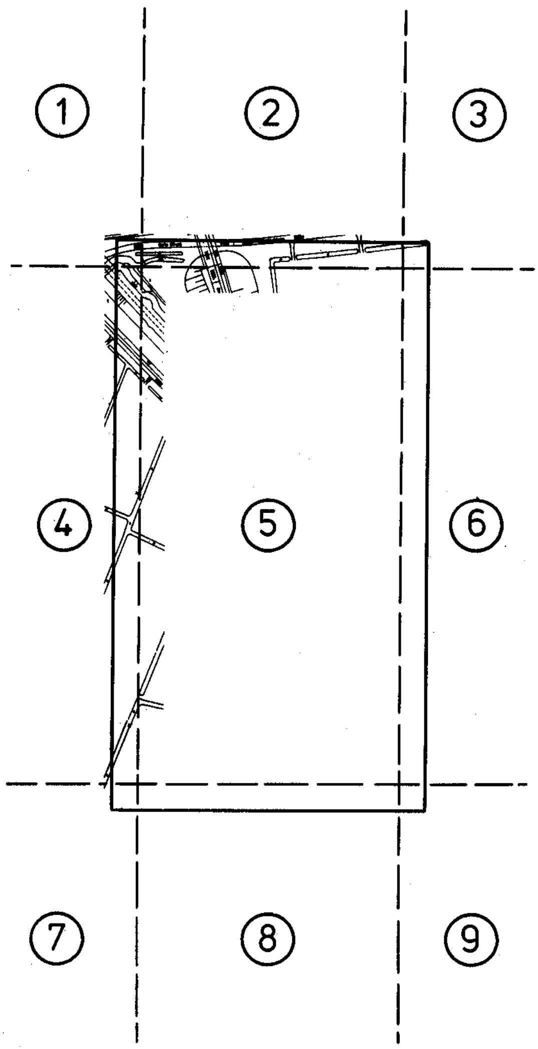

fig. 3: The rectangular with the selected topography

This makes the rectangular somewhat larger than the net model. As there was a rectangular defined similarly for the adjacent previous model, those rectangulars partly overlap each other. This overlap is used to select parts of the topography from the previous model.
Fig. 3 shows an example of a selection from the database, for the case, that the upper strip and the adjacent model to the left are maped allready. This selection forms the work set which has to be completed by digitization.

* Background processes

In the background the work set in Database Exchange Format (DEF-data) is converted to the hardware dependent TOKEN format (TOK-data), then stored on the RSX disk and copied to the IGOS disk.

* QUIT "RSX" and enter "IGOS"

To allow graphical work the IGOS operating system must be used.

* Read TOK-data

The TOK-data can not directly be shown on the screen. They must first be converted to GRAPHIC format. After this conversion the GRAPHIC data can be shown on one of the two screens. The selected rectangular indicated in fig. 3 is shown on the screen. Now topography can be added or edited in the GRAPHIC data set.

* Digitization

All topographic details listed in the GBKN- or Workplan II-mapping guide have to be measured. To each registration a one-side code is added. The code depends on the priorities stated in the mapping guide. The one-sided coding, which gives clear restrictions for the later selection, is only done for topographic detail. The code consist of four parts, namely:

1. Photoscale number devided by 1000.
2. Classification model; this indicates whether the fourth position refers to LKI-topograpby or to additional topography.
3. Good or bad interpretation or text or symbol; this defines, whether the classification in the fourth position refers to a line element (different for good and poor interpretibility) or to text or to a symbol.
4. Classification of the topographic element.

Only straight lines are digitized. Curved lines are represented by consecutive short pieces of straight lines. Constructions like squaring of objects are not done, exept for those mentioned below.
The operator uses the foot switches to trigger registrations. The same dual footswitch is used and in the same manner as earlier with the semi automatic plotting tables. On the function-keyboard the observer types in the code.
The code goes together with the modelcoördinates to the IGOS-system, where the coördinates are transformed directly into the terrestrial system. After transormation the digitised element is made visible on the graphical screen. This way the observer can directly see if the measurement has been done complete and correct.
Besides digitising the observer at the instrument has several different functions at his disposal by introducing special codes in the function-keyboard and the coördinates of that registration are used or not, depending on the function used. Internal functions which can be executed directly are:

- circle
- perpendicular with houses
- construction of the 4th point of a high tension pole
- connection of topography, see special chapter
- screen-scale, with specific codes for the screenscales 1:5, 1:500, 1000 and 1 : 2000
- removing last polygone
- removing last linefragment

  The circle, the perpendicular and the linefragments to the 4th constructed point are considered als linefragments which cannot be well interpreted.

The internal functions, mentioned above, are available during digitizing. External functions can only be executed when we go out of the digitizing-program.
External functions are:

- (partly)removal of a line fragment
- removal of a polygone
- placing texts
- (T)intersection
- changing the code
- systemfunctions

The user has no cartographic functions at his disposal, except those which are necessary to finish the photogrammetric product. In case of a product without fieldcheck, the product will be finalized elsewhere in the organisation.

* Connections of the topography

Before the connection of the topography of 2 models can be done, a number of proces-steps have been taken before:

1. blockadjustment. This adjustment takes care that the terrestrial coördinates of the controlpoints are well determined.
2. absolute orientation, by which the model will be well connected to the controlpoints.
3. reference-points. In the absolute orientation the corrections between the computed coördinates of the blockadjustment and the transformed model-coördinates are computed. As the same points also are in one or more other models there will be no check after the absolute orientation on the discrepancies between the transformed modelcoördinates of corresponding points in different models. To have a check on this part of the proces and to control it, the following procedure has been developed: the computed terrestrial coördinates of the blockadjustment are put as a triangular, graphical symbol (with sides of about 1 cm) in the database.
   During the selection these symbols are selected. Before the operator starts digitizing, the controlpoints are measured as so called reference-point. The controlpoints are given the symbol of 3 concentric circles with a radius of 10, 20 and 30 cm respectively. On the screen, with screenscale 1:5, the left square above model 1 of fig. 4 is visible.
   The difference between the triangle and the center of the circles are about equal to the corrections as they were already known in the absolute orientation. "About", as the point has been measured again. The whole model will be digitized and the rectangular of the next model is selected. In the selection both symbols come again from the database. The same reference-point is measured in model 2. Then we get the image of the righthand square of fig. 4. The differences of the 2 groups of concentric circles indicate the difference between the transformed controlpoints.
   When the difference between the transformed control-points in different models and the computed point of the blockadjustment are within a certain limit, it will be accepted.

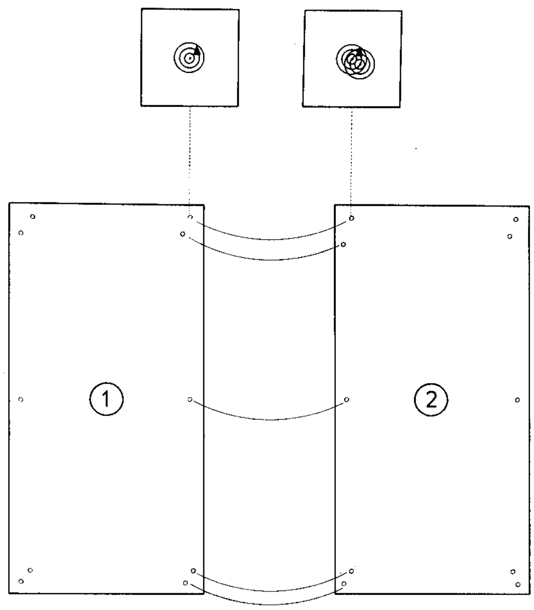

Fig. 4. The graphical representation of the reference-points.

Photogrammetrische Woche 1987
Institut für Photogrammetrie
Schriftenreihe, Heft 12, 1987

4. Connection of topography. When the reference-points fulfil the conditions mentioned before there can only occur differences due to differences in interpretation.
   The connection of topography happens as described below. The remark has to be made that this method might not be perfect theoretically but in practice works out very well.

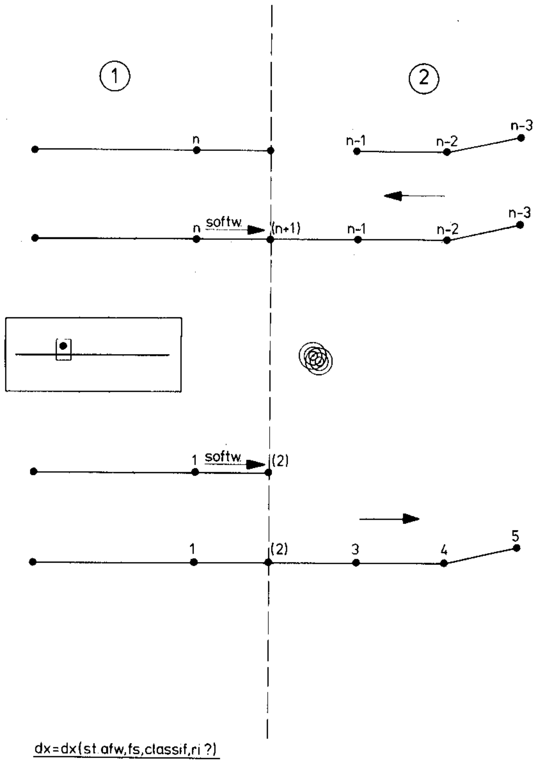

Fig. 5. The principle of the connection of topography.

Explanation of fig. 5:

It is assumed that model 1 has been digitized and the 4 lines in model 1 have been selected again with the rectangular of model 2.

a. Assume the measurement of the points (n-3), (n-2) an (n-1) has been done.
b. The operator moves the measuring mark now to a part that has already been digitized and indicates on the keyboard with a specific code that a line-fragment has to be located by the rectangular. This rectangular is very small in size. When the line-fragment is found the system will indicate which code belongs to this line-fragment. When this code corresponds with the introduced one the line-fragment (n-1) - (n+1) will be drawn after confirmation of the operator.
   In the file the separationline of the 2 models will now no longer be visible. When the operator wishes to continue the already digitized line-fragment then a similar procedure has to be followed.

* Changing graphical data

Changes can be made directly during digitizing or separately. The different internal and external functions have been described earlier in the chapter "digitizing".

* Reduction GRAPHIC-file

As all changes during digitizing give empty blocks of data it is necessary to reduce the size of the file to a minimum.

* Copying GRAPHIC-file

For safety a copy is made of the original measurement.

* Making TOK-file

To get the GRAPHIC-file again in the database it is necessary to execute the conversions mentioned earlier in reverse order.

* From "IGOS" and to "RSX"

To send the contents of the file it is necessary to go to the RSX Operating System again.

* To be added to the database

The workingfile, being the rectangular (including the selected data) are put back into the database. As the workingfile still was in TOK-size it will be converted to the background to DUF-size which is independent from application and hardware.

The measurement of the model is finished and the next model can be taken by which the procedure is repeated.

4. GEODETIC ASPECTS

It is known that the precision of coördinates of details is higher with digital mapping than with analogue mapping. The most important reasons are that there are no mapsheets, the difference between analogue and digital orientation and that plotting lines is avoided. Digital mapping entails an improvement of the precision by a factor 2. This means that keeping the same criteria, we can make the photogrammetric proces "less good". The problem is in which part of the proces this should be done. Many prefer reducing the photoscale as this gives also advantages in costs. It is however forgotten that the photoscale is not only determined by the precision but also the visibility of the topography. One could say that, on the contrary, the photoscale has to be increased. That gives the advantage that the precision will be increased and the visibility of the topographic elements improved. With good visibility and the two-fold increase in precision it should be possible to make much terrestrial work superfluous which compensate the extra costs of the larger photoscale. Another advantage is that possible "bad" photography still can be used.

5. BUSINESS ASPECTS

Digital mapping has the advantage that the processes of triangulation and mapping can be changed in sequence. This brings the advantage of proces-optimisation as seen from the managing point of view. Changing the sequence of the processes is not yet operational.
By the many numerical checks in the process it can be better controlled by the operator and the department.
As no mapsheets have to be prepared for the absolute orientation the photography, specially for the GBKN, can be made at any scale and in a for the object ideal flightdirection. It has to be investigated what relation exists between photoscale and terrain.

As in the introduction was described, an increase in production of 25% compared with analogue mapping with half-automatic drawing tables has been found.

It is said: "Automization does not give the expected increase in efficiency. Only when more attention is paid to the training this increase in efficiency can be expected". One part of the training is a good manual. By giving much attention to the training most operators were in a couple of weeks at their usual productionlevel in our case.
Equipment is somewhat more expensive than the present drawingtables and has to be written off over an shorter period of time.

6. PERSONAL AND MANAGING ASPECTS

From the managing side can be said that the organisation-units have not been changed due to this development. Regarding the function can be said that the quality requirements have increased. The extra equipment gives more possibilities and has to be mastered. A special problem is the training of the supervising staff. When not enough attention is paid to that, they will not be able to function properly in future.

7. ERGONOMICAL ASPECTS

Ergonomical aspects are important as the type of work requires a lot of concentration, especially in the beginning.
The extra equipment gives many more possibilities and the files are not "tangible" as analogue maps are.
The attention must be contineously fixed on what files one has and which ones not. A different problem when working with graphical screens is the illumination.

8. FINAL REMARKS

The experience of a couple of years with digital photogrammetry can be called very positive. The system has to be evaluated continuously. Another option is the implementation of the procedure "digital mapping-triangulation-blockadjustment-finalize transformation.

ABSTRACT

This paper describes in general the concepts for a countrywide Land Surveying and Cartographic Information System (in dutch LKI) for the Dutch Cadastre and in particular the Photogrammenie Digital Mapping. From this system several aspects will be discussed, such as research issues and experiments, configuration and procedures, geodetic, organizational and ergonomic aspects.

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