Data Base Acquisition and Revision with INFOCAM and LEICA Photogrammetric Systems

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ABSTRACT

This paper introduces some concepts of data collection and revisioning using photogrammetry with a GIS. The realization of these concepts will help photogrammetrists to utilize the advantages of GIS data structures. It will give the GIS community the means to keep the databases up-to-date with methods that can cover large areas accurately within a short time. Leica offers on-line data collection and revision with its product range of analytical stereo plotters and the INFOCAM GIS with the system MAPIT.

INTRODUCTION

During the last 15 years digital geographic databases have been created worldwide. National and local governments as well as private industry have established multi-million dollar mapping programs tò gather information about the land, store it and use it for resource management. Geographical Information Systems (GIS) are mostly used for processing the digital data.

In the last years we have seen a definite change in the products delivered by the photogrammetric restitution process, from only graphical information to digital information. With the progress made in the GIS area the importance of the photogrammetric data capturing become more apparent and an extraordinary migration from graphical products towards digital data has happened already. We are at the beginning of a boom in the usage of photogrammetry for collecting LIS data and that will ever increase due to the fact that it is also ideally suited for data base revision.

Photogrammetry covers large areas and is therefore a cost effective instrument to establish the databases. Most photogrammetric operations use feature oriented mapping software to collect and edit their data. This data has then to be translated into the topologically structured database of a GIS. This structure is necessary to perform data analysis operations subsequently. It also provides for the verification of data completeness and consistency. Unfortunately, a lot of information is lost in the translation process. The data processing machine is far away from the data gathering machine and verification procedures cannot be handled on-line. The solution to this problem is the collection of data directly into the GIS database.

Leica offers the on-line data collection with its product range of analytical stereo plotters and the INFOCAM GIS with the system MAPIT. Leica photogrammetry has provided excellent tools to gather digital data for years. With INFOCAM, Leica offers the solution for a fully topological geographic database system based on the relational model. Data gathered with analytical plotters of the DSR or SD2000 series are directly introduced and structured in the INFOCAM data model.

The INFOCAM user interface is menu driven and very flexible. Users can customize the interface to their own needs by editing a menu file and combining functions in macros. All functions can be assigned to function keys of the keyboard or an auxilliary keypad. Photogrammetric operators proceed not - different from the ways they used to. Background processes check the topological consistency of the data and notify the operator if any problems occur. These problems can then be dealt with program driven in the same environment.

Establishing a digital map database is a time consuming and expensive task. After the data is collected, it must be constantly maintained. The information in a database is valuable to the user only if it is up-to-date. Mapping organizations are therefore confronted with the task of database revision after the original data collection phase has been completed. The revisioning process is again often carried out by photogrammetric methods. These methods must work directly on the GIS database to make this process efficient and cost effective. Most of the information kept in the sophisticated GIS data structure would be lost in the translation process to the simple, feature oriented structure of a mapping system.

We are at the beginning of "intelligent data capturing" and "data base revision" is on the horizon.

1. GIS - GEOGRAPHICAL DATABASE SYSTEMS

Geographical information systems (GIS) have been developed since the late 1960s. These systems are designed to handle spatial data, i.e. data which directly or indirectly refer to locations on the earth's surface. Spatial data, in general, has a locational and a textual aspect. It is one of the most important features of GIS that they can handle geometrical and 1 textual data of the same objects in an integrated environment. Typical areas of GIS applications are (Molenaar, 1989):

- SPATIAL MANAGEMENT, e. g. land registry or environmental monitoring
- SPATIAL ANALYSIS, to obtain information about phenomena and processes on the earth
- SPATIAL PLANNING, e.g. land use or infrastructure design based on knowledge from spatial analysis

Information systems store data over a long period of time. It can be generally assumed that the data has a lifetime of up to 50 years, while software systems last about 10 years and the hardware is even exchanged every 5 years (Spaeni and Bartelme, 1988). It is therefore essential for GIS to store their data in a secure and consistent environment. The type of data handled by GIS and the way of storage methods marks a significant difference to graphics oriented mapping systems used in todays photogrammetric operations.

Most GIS manage the different kinds of data in two databases. In general there is one database dedicated for handling the geometry of the data. In a second database attribute data describing the spatial objects are contained. Relational database management systems (RDBMS) are commonly used to store attribute data. Both databases are usually connected using a common object identifier.

Geometrical information in a GIS has two aspects:

- the METRICS describe spatial objects in terms of coordinates of a local or global coordinate sysem. Metric data are also contained in conventional mapping systems.
- the TOPOLOGY describe spatial objects in terms of their relationships to other objects. Topological data are not - contained in conventional mapping systems.

Storing topology explicitly gives GIS a significant advantage: the consistency of the database objects can be checked upon data entry. Having in mind not only the current object but also adjacent elements, one can avoid e.g. digitizing lines twice or overlapping regions.

2. LEICA PHOTOGRAMMETRIC SYSTEMS

Most GIS support active data collection with 2-D digitizers. From the GIS point of view photogrammetric systems like analytical plotters and digital stereo plotters can be seen as 3-D digitizers. They can be easily linked to a GIS if the data capturing module of the GIS is able to handle 3-D coordinates and if the photogrammetric system has a modular architecture with strict separation between applications and real-time controlling of the system.

In the following, the concept of Leica photogrammetric systems like the analytical plotters of the DSR series and the SD2000 are introduced in detail. It will be demonstrated that Leica photogrammetric systems are particularly suited to be interfaced to GIS as 3-D digitizers because of their distributed processing architecture and the modular software design.

2.1 Hardware Concept

In 1980 Kern presented the DSR1 analytical stereoplotter. One of its most important features was its distributed processor architecture:

- The P1 main processor is a general purpose host computer. It executes application programs such as model orientation or data collection and output graphic peripherals.
- The P2 plate processor executes the real-time loop program, which maintains the stereo model. Communication between P1 and P2 is over a serial line. P1 downloads orientation parameters, sends commands to move the plates and requests plate position or other informatin from P2.
- The P3 processor handles input from footpedals and keypads and sends the signals over a second serial line to P1.

The advantages of this architecture are being retained in all models of the DSR series and the new SD2000, presented at the ISPRS meeting in Baltimore 1991. Supplementary modules such as image superimposition, correlators and interactive graphics can be added to all DSR models, increasing the functionality and performance.

2.1.1 Analytical plotters DSR

The concept of distributed processing allowed the DSR to be linked with different host computers to suit the standard of performance required by the user.

- Kern D5R-14: The DSR-14 works with either IBM-AT compatible or 80386 based Personal Computers as host.
- Kern D5R-15: The host computer of the DSR-15 is a DEC MicroVAX or VAXstation. One host is suited to support one or more DSRs. Networks can be extended to include the photogrammetric workstation. A special version, the DSR 15-18 is equipped with larger plate carriers of 25 x 50 cm.

2.1.2 The Kern Raster Image Superimposition System (KRISS)

The development of graphic superimposition systems has been initiated by the needs to analyze existing digital map data for revisioning requirements and/or to check the completeness of the new captured data without looking away from the eyepiece to a map sheet and/or the on-line plot. In the past few years various graphic superimposition systems have been developed. The Kern Raster Image Superimposition System (KRISS) is an optional peripheral designed specifically for the DSR-15 analytical plotter. The modular design makes installation and/or upgrading easy. According to Kern's concept of distributed processing both the DSR-15 and KRISS act as intelligent slave devices of the host processor.

The main advantages of KRISS in comparison to other existing systems are:

- Updating of the overlayed graphics according to the movements of the photo carriers is done in real time and is independent of both the amount of available data and the amount of data to be displayed. Since KRISS maintains a raster image of the total graphic overlay in its own physical memory (8 or 16 Mbytes depending on the configuration), there is no need for repeated data manipulation and/or elaborate faceting techniques. A subset of the image memory is bitmapped into the display memory and a region of 1 024 x 1024 pixels is used as a viewport for the high resolution flat monochrome monitor(s).
- The successful integration in the hard - and software design of the photogrammetric workstation allows operation with minimal operator intervention. After writing special device libraries, KRISS could be easily integrated as an additional output device into popular application software packages such as MAPS-200 and PLOTR. It has been utilitzed even more with the new MAPIT software allowing e.g. the superimpositioning of menu pages.

2.1.3 Stereo Digitizer SD2000 and Leica Mapping Terminal

The new photogrammetric workstation SD2000 is a true desktop system, which performs effectively at almost any photogrammetric task, from general mapping, GIS data collection, close range photogrammetry to interpretation and education. This fully software controlled analytical plotter combines most advanced mechoptronics with proven design principles of the previous WILD BC and KERN DSR series.

The Leica Mapping Terminal (L.M.T.) provides a new standard for flexibility. In the SD2000, distributed processing has been further developed: a powerful PC-based system processor now also handles basic photogrammetric tasks, such as calibration, model orientation and the computation of object coordinates X, Y, Z. The SD2000 is virtually independent of the host computer's hardware and application software. Whether the user's operating system be UNIX, MS-DOS or VMS, the software from Leica or third parties, the SD2000 user-interface, i.e. the "touch and feel" of the user's working environment will not be affected. The icon-based graphical user interface facilitates the software controlled adjustment - of optics (zoom), floating marks, illumination and speed of - the stage plates. Preferred settings and key assignments may be programmed and stored. The equipment can be further customized for routine tasks by defining macros and allocating them to "hot keys". The versatile and operator friendly user interface thus considerably enhances the operator's comfort and system efficiency.

The L.M.T. can be retrofitted to all existing DSRs, enabling 1 the user to work with state-of-the-art hardware and software. 1 Thus the SD2000 not only reflects the power

of innovation but proven continuity and upgrade mobility, as it has been characteristic for Leica photogrammetric systems for years.
Leica offers a wide choice of powerful mapping software such as PC-PRO 600/MicroStation (MS-DOS) or MAPCE (UNIX). For GIS data collection and revision MAPIT and INFOCAM are available under VMS.

3. LEICA INFOCAM GIS/LIS

With the introduction of the INFOCAM V.5 in the summer of 1989, Leica offers the solution for a fully topological geographical database system. INFOCAM stores its entire data in a global database using an RDBMS. Interactive work is carried out on an extract from this database. This concept allows the use of INFOCAM in a multi-user environment.

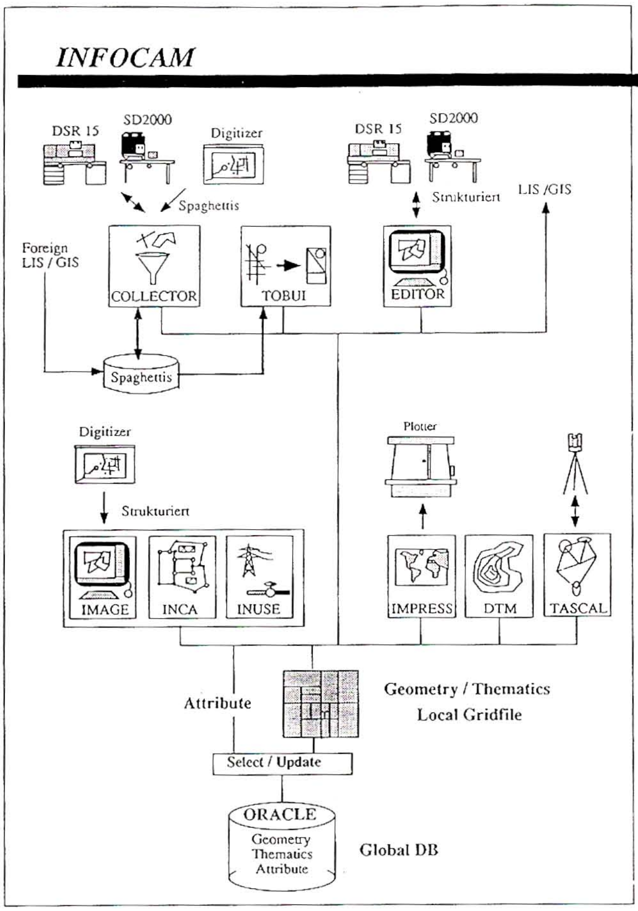
INFOCAM uses a flexible, menu driven interface. Users can customize the interface to their own needs by simply editing the menu file and combining functions into macros. A "learn" function is also provided to store working sequences which can later be retrieved and re-executed.

The spatial, topological database is the central element of INFOCAM. Points (nodes) and edges are the basic elements of this vector-oriented database. The thematic elements symbols, lines and regions comprise the objects which are manipulated by the user. Attributes can be associated with any database object. Attribute values can be displayed as text; any modifications of attribute data cause an automatic update in the graphic display.

INFOCAM stores its geometry for interactive work in a spatial database environment called a gridfile (Hinrichs and Nievergelt, 1983). A special sort algorithm guarantees quick access to data independent of the data volume. The objects and database elements are managed in structured layers. INFOCAM provides a virtually unlimited number of such layers which are defined by the user. These layers can be displayed, evaluated, and plotted in arbitrary combinations.

The project manager can define logical constraints on geometry and attributes. Consistency checks are carried out based on these constraints to maintain the data integrity. For the thematics it can for instance be prevented to connect gas - pipes with water hydrants or character input for numeric attributes.

INFOCAM provides several application modules based on its geographical database, among others IMAGE for general editing and inquiry purposes, INUSE for utility management or IMPRESS for map production. The module INCOME has been designed to be used in photogrammetric operations. It has been newly introduced in 1991 under the name MAPIT and will be described in the next chapter.



The figure shows the INFOCAM modules with a special emphasis on the INCOME (MAPIT) software.

4. INTEGRATING INFOCAM WITH LEICA PHOTOGRAMMETRIC SYSTEMS

Generally speaking there are two requirements for integrating GIS and photogrammetric workstations: A) the digitization of areas that have not been covered previously and B) the revision, accuracy and completeness checking of an existing database. INFOCAM provides the means to fulfill both requirements in a modern photogrammetric workstation environment with its module INCOME.
In order to establish a topologically consistent LIS database the data have to be checked before they are put into the system. This check can be carried out on-line at the time of data collection. This method is particularly

suited for collecting or revising a limited amount of data. The checking mechanism, however, requires some overhead which is not desirable when digitizing large amounts of data. INCOME therefore offers data input capabilities in two of its modules, the INCOME-COLLECTOR and the INCOME-EDITOR.

4.1 INCOME-COLLECTOR and TOPOLOGY BUILDER (PG-INCOME)

INCOME allows unstructured database input from 2-D digitizer tables and the 3-D analytical plotters DSR and SD2000 in the INCOME COLLECTOR. No topological and/or thematic consistency checks are carried out during digitization. This is done in a second step when the data are transferred into the complex INFOCAM data structure using the INCOME BUILDER and inconsistencies are recorded in a logfile. Consistency problems are then corrected in the INCOME (LOGFILE) EDITOR.

Using the INCOME COLLECTOR an operator digitizes lines (spaghetti) and symbols as it is done in conventional mapping systems. During this process even the most experienced operator will introduce some errors into the database, e.g. the non-closure of a region as well as overshoots and undershoots at line intersections. These data errors are of no concern in a standard mapping system. In a topologically structured GIS database, however, such inconsistencies cannot be tolerated.

The TOPOLOGY BUILDER detects data errors and problems by comparing the collected data with the INFOCAM data model. First the digitized spaghetti are cut at their intersections and transformed into a node/edge structure. Based on the data model INFOCAM elements symbols, lines and regions are built in a second step.

Data errors are detected by the system and automatically corrected. They are usually associated with a tolerance factor, such as the shortest possible edge, the minimal distance between two points, or the smallest region elements. Errors within certain tolerances are corrected by deleting overshoots or very small (sliver) regions, by merging points and edges, or by snapping undershoots to the appropriate edges. INCOME provides default tolerance factors, which have been derived empirically. The tolerances can be adjusted to fit the needs of individual projects by simply editing a topology rule file.

Data problems are detected and flagged for interactive correction in the LOGFILE EDITOR. These problems can represent topological errors but they can also be valid database elements. Examples are islands (regions within regions) or bridges (edges with the same region on both sides). The LOGFILE EDITOR takes the INCOME operator to the elements in question, higlights the problem and asks the operator for appropriate action, e.g. delete or accept.

The INCOME COLLECTOR offers an optimized compromise between the requirements of photogrammetric operation and data collection for GIS data acquisition and revision. The operator digitizes directly into a GIS data model without being overburdened by checking mechanisms which are essential to establish a consistent database. There is no loss of - information in translation processes between mapping system and GIS since both are based on the same model and operate in an integrated environment.

4.2 INCOME - EDITOR (PG-EDITOR)

INFOCAM offers an excellent tool for interactive structuring and manipulation of objects and elements with its module IMAGE. Many of these functions are available in the INCOME EDITOR. All functions for inserting new elements can be carried out by mouse, digitizer table or the analytical plotter depending on the hardware configuration. Working with DSR and KRISS allows the operator a direct comparison of existing data and the stereo model. Besides the data the following information can also be superimposed in KRISS:

- Menus: The operator can choose different functions without loosing his focus on the stereo image.
- Prompts: If a function requires operator input, an appropriate prompt can be superimposed.
- Messages: The operator can be warned of problems and errors when digitizing.

Data digitized with the EDITOR are directly stored in the topological database. They must therefore fulfill certain requirements concerning data consistency and integrity. To insure a consistent database several checks are carried out on-line. These consistency checks include among others:

- loop check for lines and regions
- automatic closing of regions
- check for line and region overlap
- check for attribute uniqueness (if defined)

As mentioned earlier these functions are available for all input devices. Additional functionality is available in an integrated INFOCAM - DSR - KRISS environment:

- permanent comparison of digitized data with the reality (database and photographs)
- permanent control of manipulations
- special functions to control digitized data, among others:
  - * identification of database elements with the DSR cursor; the operator does not have to move from digitizer to a screen to edit the database
  - * move cursor to existing points; a point can be identified by its name or coordinates. The cursor is placed at the location of its coordinates. The operator can then check the 3-dimensional database against the reality. More than one point can be selected and then all points checked sequentially resulting in an easier work process for the operator.
  - * move cursor to existing element; elements on the graphic screen can be identified using mouse or attribute input. IMAGE moves the DSR cursor to the identified element in the stereo image.

The examples mentioned above show the usefulness of combining a geographical database system with photogrammetric workstations. INCOME in a combination with Leica analytical plotters is ideally suited to digitize, manipulate and control data to establish and maintain digital land information systems.

SUMMARY AND CONCLUSION

Data acquisition and revision of geographical databases is becoming an increasingly important task for photogrammetric operations. Conventionally used mapping systems require expensive translation processes between the photogrammetric and the GIS environment. Different data models cause the loss of information during these processes. This information loss is not acceptable for organizations maintaining large geo-databases for manifold purposes. GIS and photogrammetric workstation must therefore be integrated to utilize all - advantages of the different environments.

Leica INFOCAM bridges the gap between photogrammetry and GIS. Photogrammetric and GIS data models become one and allow for direct data input using Leica analytical plotters. Stereo superimpositioning makes it possible to verify the accuracy and completeness of a geographical database against the reality as it is show in a stereo image. INCOME offer the user friendly interface of a modern photogrammetric workstation.

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