Extracting Vector Data and Attributes from Stereo Images with PHOCUS

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INTRODUCTION

Computer-assisted photogrammetric plotting systems have changed fundamentally since their introduction in the early seventies.
The beginning of this development was marked by the separate acquisition, computation and output of data with analog instruments and AD converters. Plotting had to be done quasi blindly, i.e. without graphical feedback.
The introduction of analytical instruments in the middle of seventies and the integration of graphical output devices and geographical superimposition improved working conditions decisively. However, up to a few years ago, photogrammetric plotting systems were purely graphical mapping systems. Only in the second half of the eighties did the notion appear that the collected data might be used for more than map production only. The data base concept was introduced in photogrammetry. The Carl Zeiss company acknowledged this development in 1987 by introducing the PHOCUS system.
In the nineties, the following major trends may be expected in the field of photogrammetric plotting systems:

- Transition from geometrically oriented acquisition systems to integrated spatial information systems
- Transition from the analytical to the digital concept
- Transition from harware-oriented to method-oriented systems

This paper illustrates the current state of the art in photogrammetric systems using the PHOCUS system from Carl Zeiss as an example, and provides some information on the future development of PHOCUS.

1. THE RELEVANCE OF PHOTOGRAMMETRY AND REMOTE SENSING FOR GIS

A geographical information system can be described as a system of hardware, software and procedural components that supports the acquisition, management, manipulation, analysis, modelling and representation of spatial data and allows solving complex planning and administrative tasks [Bill, Fritsch, 1991]. To simplify, a GIS consists of three main components, i.e. data acquisition, data analysis and data output.

If one considers the methods of photogrammetry and remote sensing on the basis of these three components, the main aspect is surely data acquisition.
The starting point of every photogrammetric task is pictorial information which, especially in the case of stereo images, has considerable advantages over the types of data regarding integration in a GIS:

- High information content (an aerial photo, for example, contains about 500 MB of grey scale information)
- High topicality
- "Reality-oriented" data (quasi-3D continuum)
- Automation-friendly data type (especially in the case of remote sensing data)

A basic requirement for the propagation of geographical information systems is the availability of spatial basic information in digital form. This is why one of the major tasks in the next years will be the acquisition of this basic information. Among comparable methods, photogrammetry is best suited to measuring vast amounts of data because it permits measuring not only point but also line and area information. Advanced analytical systems support data acquisition as much as possible (e.g. prepositioning of points).
Large-area acquisition of elevation information is best done by establishing area-covering digital terrain models. In this field, photogrammetry has been offering practical algorithms for many years. The use of CCD cameras for automatic image correlation will soon enable greater automation in this field.

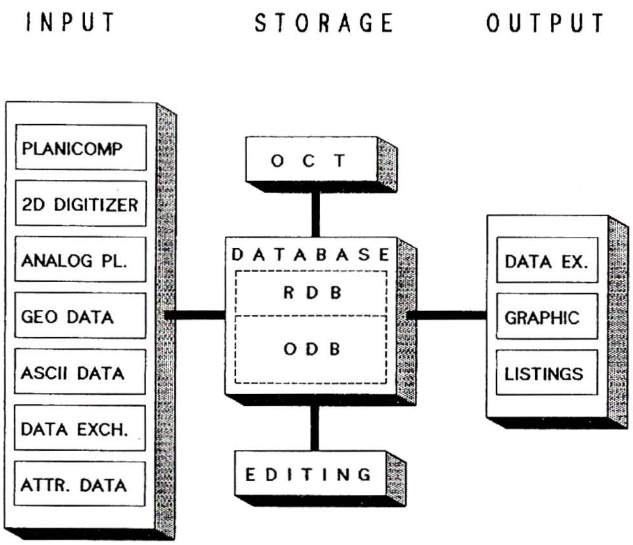
But photogrammetry and remote sensing are not only

suited to collecting geometrical information. Especially remote sensing pictures taken in several frequency ranges contribute decisively to the attributing of geographical data.
Multispectral classification methods (e.g. maximum likelihood method) can be used to automate the attribute data acquisition and to support the data analysis process.

The main task and remote sensing in the GIS field is surely the provision and editing of data. However, advanced photogrammetric systems also support data analysis and data visualization.
A typical example is stereo superimposition of data onto a model e.g. with VIDEOMAP in the Planicomp.
In addition to data verification, planning tasks can be solved in an elegant way.

Data output and visualization have been tasks for photogrammetric plotting systems for more than 20 years. The experience gained in these years can and should be used in the geographical information system field.

The above statement shows that the long-term experience of photogrammetry and remote sensing in the area of spatial data is a valuable aid for the creation of methods and algorithms in the GIS field. Therefore, photogrammetry is much more than a data acquisition method.



List of abbreviations :

GEO DATA	:	geodetical data
DATA EXCH. DATA EX.	:	data exchange to or from foreign systems
ATTR. DATA	:	attribute data
OCT	:	object code table
RDB	:	relational data base
ODB	:	object data base

Fig. 1 - PHOCUS System-Structure.

2. PHOCUS - THE UNIVERSAL PHOTOGRAM METRIC AND CARTOGRAPHIC SYSTEM

PHOCUS serves to collect, edit, store, output, analyze and transfer geometric and alphanumeric data by interactive means.
Since its introduction about 4 years ago, PHOCUS has become one of the leading photogrammetric plotting systems in the world.
Right from the beginning, emphasis has been placed on an open architecture in the implementation and improvement of PHOCUS. This means that PHOCUS is a modular system that can envolve from a photogrammetric acquisition system through a photogrammetric and cartographic acquisition and plotting system to a geographical information system in clear steps. The user thus benefits from continually expanded capabilities on a sound basis.

2.1 Survey of the Major PHOCUS Components

Fig. 1 serves to briefly describe the PHOCUS system. For data acquisition, the following general options are available:

- Photogrammetric data acquisition with P-Series Planicomp analytical plotters and with analog instruments.
  Apart from conventional photogrammetric photos, satellite images (e.g. SPOT models) are available for analytical plotting. To allow for central perspective and the SPOT geometry, the measured coordinates are corrected online by means of correction matrices.
- 2D digitizers (e.g. for map digitization).
- Input of geodetically measured data (e.g. from a field check).
- Input of mass data (e.g. from a geodetic survey or from other systems).

All of this input data is collected by a central module and entered in the PHOCUS object data base (ODB). It can be edited (interactively or in the batch mode) both during acquisition and at a later time.

The PHOCUS data base features:

- Object structure based on a user-defined object code table.
- Strict separation of geometry and object meaning.
- Allowance for topological relationships and no-redundancy storage of edges and nodes.
- Management of 3D-coordinates.
- Transaction concept with local and global UNDO functions and a recovery mechanism that recovers not only up to the last COMMIT (in the SQL sense of the word) but uses a log file to recover all actions up to the system crash.
- Optional connection of a relational data base for extended attribute data management.
- Flexible access optionally with SQL.

Not only interactive graphics terminals and geographical superimposition with VIDEOMAP are available for graphical output, but also vector and bitmap plotters.
The graphical representation of an object can be defined freely by means of graphics tables. Therefore the same data can be output easily in different ways depending on the task and the scale.

Work data bases can be established by means of the standard output interface so that the same data selection options as for the graphical output are available. Complex cartographic generalization procedures can be performed in between.
Since PHOCUS is an advanced acquisition system for GIS, special emphasis has to be placed on data interchange with other systems. This is why PHOCUS translators are available for data interchange with systems such as ARC/INFO, AutoCAD or MicroStation. An interface for the EDBS format (uniform data base interface of the Federal Republic of Germany) will be available soon.

After this data flow-oriented survey of PHOCUS, some general information may be added that characterizes the system [Menke, 1989]:

- Supported computers and operating systems: VAX/VMS, HP 1000/RTE-A, UNIX workstations as of 1992
- Multi-user system with networking capability or cluster environments (server-client concept)
- Flexible creation of project environments and data security mechanism
- Operating system-like surface ensuring a uniform appearance on different computers
- Command or menu input with macros and transfer files (command sequences allowing interactive intervention)
- User support in any situations by means of help texts and tutorials

2.2 Some GIS-Relevant Aspects of PHOCUS

2.2.1 Topology

A major feature of geographical information systems is the capability to store and manage topological relationships.
There are two reasons for this: first, allowing for the topology prevents redundant data storage, and second: only a topologically structured data base effords complex analyses (e.g. neighborhood relationships).

For establishing the topology in a GIS, there are two basically different approaches:

- Realtime topology creation during acquisition
- Later topology creation by means of spaghetti data

PHOCUS supports both approaches, but places special emphasis on the realtime topology. The operator is supported by the system in such a way that a negligibly small number of additional function calls is required and acquisition is not slowed down significantly.
The complete establishment of topological relationships from spaghetti data is currently the subject of numerous research activities. The basic component of such an automatic topology builder, i.e. the establishment of a node network, has already been implemented in PHOCUS. This enables semiautomatic area formation from the meshes of a node network.

2.2.2 Attribute data

One of the major differences between mapping and CAD systems on the one hand and a GIS on the other hand is the capability of managing attribute data within a GIS. The PHOCUS concept provides two expansion stages in this sector: in the standard version, each object, object item and coordinate can be assigned a specific set of attributes that differ in type and number, e.g. an alphanumeric string and several numeric values.
In addition, a relational data base (RDB) can be linked with the PHOCUS object data base (ODB).
This affords attribute management of any complexity.
This gives rise to the question why the geometrical data and the associated attribute data should be managed in two separate data bases. A major reason for this is the fact that

the struscutre of RDBs is not ideally situated to the management of geometrical data, which leads to unfavorable response times for geometrical queries.
Therefore the PHOCUS concept allows the user to decide if he wants to use an RDB or not.

ODB

Object	Nr.
Building	101
Street	102
Drain	103
Building	104
Building	105
Street	106
.	.
.	.
.	.
.	.
.	.

R D B

Building			Owner		
Nr.	Year of Construction	Owner-ID	Owner-ID	Name	Address
101	1960	1	1	Maier	Carl Zeiss Str. 1
104	1965	1	2	Müller	Schillerstr. 5
105	1980	2	.	.	.
.	.	.	.	.	.

Street		
Nr.	Type	State of Surface
102	1	good
106	2	bad
.	.	.

Fig. 2 - Linking of Geometric and Attributive Data.

How can an RDB be integrated in PHOCUS? The relationship between the ODB and the RDB can be established on the one hand by means of the PHOCUS object code table and by means of internal RDB tables on the other hand. For every object code in the object code table, a table can be defined in the TDB. The columns of this table represent the different attributes of the associated object code.

Example 1:

Object code 5200 Public building
RDB table: BUILDINGS
with the columns: construction date, number of floors, building condition, type of roof, function etc.

object code: 3100 HIGH WAY
RDB table: STREETS
with the columns: state of surface, width, etc.

The user can define these columns by number, name and data type within the scope of functions offered by the RDB.
The lines of such a table form separate attribute records for every object in the ODB. A unique relationship is established by internal pointers both in the ODB and the RDB.

Since the subdivision in object codes on the one hand the specification of attributes on the other hand do not necessary match uniquely, a 1 to n relationship can be established in addition between the object codes and the RDB tables.

Example 2:

Object code 5100: residential building
Object code 5200: Public building
Associated RDB table: BUILDINGS

Attribute data collection can begin after the required attribute data tables have been established. Here again a two-tier concept has been implemented. For every object code, defaults can be assigned to the attributes. This presents the advantage that during geometry acquisition already, attribute data is entered automatically without the work at the Planicomp, for example, being adversely affected.
Modification of these default values can be done at every time during the acquisition process.
On the second level, convenient input masks can be used to enter attribute data e.g. at another alphanumeric terminal in parallel with geometric data acquisition.
The flexibility of relational data bases results mainly from the ability to link the exisitng table by means of common columns and thus to create a complex network of relations. The tables mentioned up to now are linked directly with the ODB. Linking these "linked tables" with tables that are independent of the ODB ("free tables") increases the attribute assignment capabilities considerably.

2.2.3 Cartographic Generalization

In the GIS field and especially in Germany, the terms "digital landscape model" and "digital cartographic model" are being used ever more widely. Somewhat simplified they refer to the separation of the object stored in the data base from the scale - and theme - related presentations of the objects. Only the capability of deriving the largest possible number of digital cartographic models from a digital landscape model really justifies the enormous data acquisition work for a GIS. To implement this, not only strict separation of geometry and graphical presentation is required, but also the use of automated generalization methods.

PHOCUS is the first system that implements significant subareas of automatic generalization in a commercial product. This has been achieved by cooperation between the Carl Zeiss company and the Cartographic Institute of the University of Hannover.

A step-by-step approach has been used in this field. Already implemented are:

- Building generalization on the basis of the methods developed by Stauffenbiel [Staufenbiel, 1973]. This involves:
  * Data verification and automatic correction
  * Typing and selection
  * Outline simplification
  * Combination

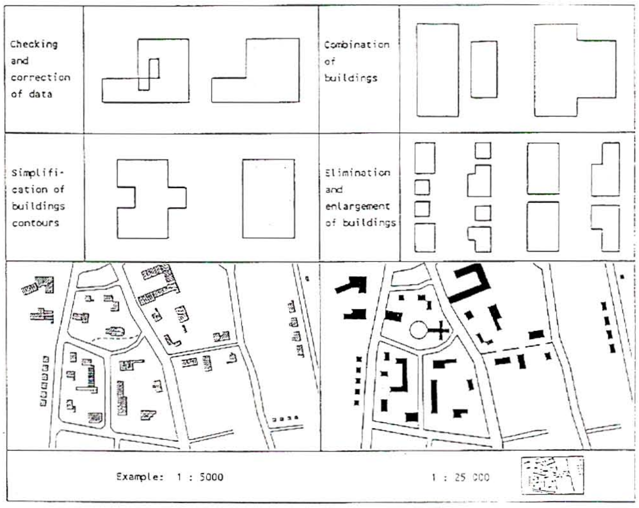


Fig. 3 - Generalization of Buildings.

- Traffic route generalization by means of methods developed by Menke and Powitz [Menke, 1983], [Powitz, 1988].
  Major substeps are:
  * Typing and selection
  * Determination of the traffic route axes and of the network topology
  * Simplification
  * Widening
  * Editing of road junctions

Traffic route widening involves one of the most critical generalization procedures in automation, namely displacement.

At the moment, a module is being implemented in PHOCUS that allows determining critical areas where displacement is required and interactively supports the user in this work.

Apart from these procedures developed in cooperation with the University of Hannover, PHOCUS offers a whole

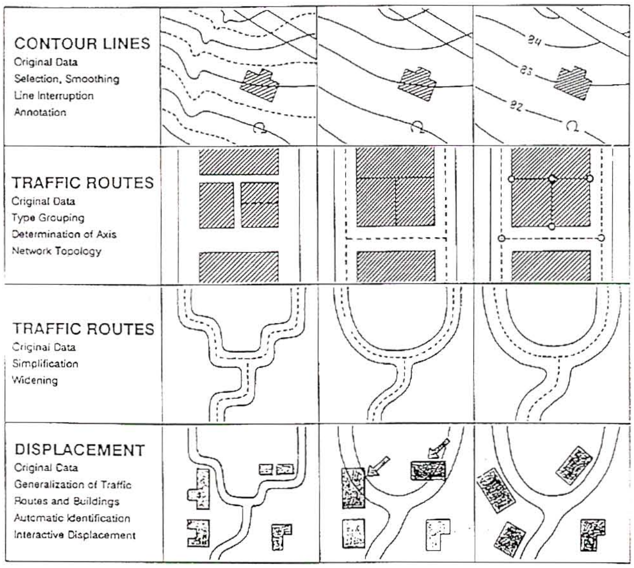


Fig. 4 - Generalization of Contour Lines and Traffic Routes.

range of functions for cartographic revision of scale-independently measured data. A brief presentation follows:

- Smoothing of linear objects
- Selection of objects according to their relevance
- Automatic space reservations e.g. for contour lines in buildings
- Automatic annotation of contour lines

CONCLUSIONS

The above exposition shows that photogrammetry can contribute considerably to GIS. Already now PHOCUS from Carl Zeiss affords convenient data acquisition for GIS systems and flexible creation of virtually any topographic maps. In the future it will be enhanced by data analysis functions also with respect to the photogrammetric component and by capabilities for thematic mapping.

In addition, the considerable differences that today exist between GIS workstations and photogrammetric plotting systems can be expected to disappear eventually.

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