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Photogrammetry and geographic information systems - evolution instead of revolution

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ABSTRACT

Photogrammetry and geographic information systems (GIS) habe been evolved in history isolated from each other. Both disciplines were strongly influenced by the rapid progress in information technology in particular by computers, sensors,and output devices. Since the midst of the eighties the relations of both in form of import and export of data and informations was acknowledged, soon after photogrammetry investigated and adopted digital image processing tools for automized data acquisition. Today there can be seen a bidirectional link of photogrammetry and GIS, both disciplines need each other. Complex tasks such as relational image matching, the setup of generic models need the help of GIS, on the other hand, a GIS without image data cannot present the actual data content, and a GIS without digital terrain models is restricted to a flat surface. The paper introduces with some historical remarks on the development of both disciplines. It is shown, that photogrammetry will help to improve the current lack in geographic information theory, which concentrates on vectorial data structures and corresponding attributes. This theory starts with well-defined geographic objects, and is currently investigating the methods of object oriented programming to come out with concepts for networked databases open for object definitions not yet known at this moment. In the contrary, photogrammetry will profit from these considerations to supplement its top-down procedures for image interpretation and image understanding.

1. INTRODUCTION

The rapid progress in information technology (IT) has influence not only on disciplines directly related to IT such as electric and electronic engineering, computer science, and physics, but also on further engineering disciplines and classic geo-related disciplines. Concepts of computer science have been adopted by scientists solving geo-related problems and practitioners because of economy and efficiency reasons. Nowadays, it is generally acknowledged that working digitally will be the future in domains which for a long time were dominated by analogue and analytical techniques.
This holds for photogrammetry in the same manner as for geographic information systems (GIS): both disciplines have a long tradition although the latter one was reborn by the use of computers for storage of geo-referenced data. At the first glance geographic information systems seem for most people to be tools to archive and retrieve, analyse and present data collected by photogrammetry and other disciplines - a more detailed view shows that a new discipline is emerging. Therefore, it is the wrong strategy to merge photogrammetry in GIS or vice versa as it was proposed by recent contributions.
Photogrammetry as science of image metrology concentrates on the extraction of geometric features from images; furthermore it is able to reconstruct the object by analytical and heuristic models. A by-product of photogrammetry is an orthoimage which can be used as backdrop in GIS. Most recent efforts deal with image understanding techniques to extract besides geometry semantic features (M. Sester, 1991, H.P. Pan/W. Förstner, 1992). A vision for photogrammetry in near future is an automated data flow from image recording to image products and vector data to be used in geographic information systems and local information environments. It seems today that this vision becomes reality towards the end of this millenium; the contributions to the 44. Photogrammetric Week indicate clear signs of further progress in digital photogrammetric systems.

Geographic information systems can be defined as collectors for spatially referenced data. They are computer based systems to capture and update, store and retrieve, analyse and present geometric and semantic data (R. Bill/D. Fritsch, 1991). Their main advantage is the link of different semantic data sets with each other via its geo-reference. Thus, we get comprehensive data sets for models which could not be solved before. Although there is a big gap between reality and desire some GIS of today are able to estimate and predict environmental goodness-of-fit of man-made constructions, or to protect for natural desasters (R. Bill/D. Fritsch, 1993). A vision for GIS in near future is its use for all spatial affairs. From this point of view we are far away, but the trend shows increasing efforts to set up sectoral GIS to be used in different fields of applications. Furthermore, these sectoral GIS will serve as nodes for meta GIS to solve regional and global problems.

1.1 Developments in photogrammetry

In history photogrammetry was a discipline to avoid computing. We can remember on very efficient analogue evaluation equipment such as E. von Orel's Stereoautograph or the family of W. Bauersfeld's Stereoplanigraphs to name only two developments which were dominating in photogrammetry for about 60 years (K. Schwidefsky/F. Ackermann, 1976). With the introduction of computers in the engineering sciences in the mid 1950's the ' analytical age ' in photogrammetry was opened. The first concepts of the analytical plotter go back to U.V. Helava (1958), but about 20 years later commercial analytical instruments were offered. The principle of analogue image recording is unchanged sind the 1920's: today very capable aerial cameras can be used which are computer controlled to adjust high frequency movements of the airplane, and can be positioned using NAVSTAR's Global Positioning System (GPS). To summarize we can state that analogue aerial imagery is nearly perfect, the same holds for analytical plotters.
Main breakthroughs in photogrammetry have been started in the 1980's, when digital imagery was seen as information source for photogrammetric evaluations. Simultaneosly with the introduction of digital image processing in photogrammetry first investigations in surveying were made using GPS for network densifications. Very soon it became clear in photogrammetry that GPS could be used for aerial camera positioning, and to measure ground control points.
Parallel to the use of GPS and image processing techniques in photogrammetry new architectures for digital image recording were proposed. Contrary to close range photogrammetry in which charge coupled device (CCD) arrays could contribute to fast progress in digital image acquisition it became evident that large formats can not be simply substituted by commercial CCD arrays. Experiments were made with two and three CCD lines; one line consisting of 6000 or 9000 picture elements (pixels). One result is the Modular Optoelectronic Multispectral Scanner of 2nd generation (MOMS02, F. Ackermann, 1993) which flew most recently onboard of the Space Shuttle during the 2nd German Spacelab Mission (D2). This new aerial camera is capable to record digital images in the whole band of visible and nonvisible spectral bands.
Although the MOMS02/D2 experiment seems to be successful a hybrid data handling is necessary for the next years to come: to use sophisticated analogue aerial camera systems and to transform the aerial images afterwards in digital format by means of high resolution scanners. The evaluations are then performed on digital photogrammetric workstations what leads to softcopy photogrammetry (F. Leberl, 1991) - a term not as stringent and powerful as the strategies behind.

1.2 Developments in GIS

Geographic information systems have been set up and used in different disciplines in form of analogue maps and analogue alphanumeric data sets. In most cases it was the descriptive part of the discipline and served for more than 100 years for science and daily services. Their regeneration and

from then on interdisciplinary link began in the 1960's when R.F. Tomlinson (1972) set up the Canadian Geographic Information System (CGIS) for forrestry purposes, in which vector data of scales 1:10000 - 1:250000 represented the georeference for semantic data of forrestry.
From this date - about 30 years ago from today - GIS has emerged to a discipline which is very dynamic and fast growing. Developments take place in data storage and retrieval, data analysis and presentation. With relation to photogrammetry important developments are the integration of height data and image data. We know that GIS has evolved from putting analogue maps and books in the computer. One main disadvantage of GIS is the ' map thinking strategy ' in GIS which means the data models developed were oriented on two-dimensional map contents. Until now this data model in geometry is still valid for vector data.
The integration of height data in GIS is under resarch with regard to three integration strategies: (i) height data as additional attributes, (ii) interfacing a DTM with GIS, and (iii) three-dimensional data structures with corresponding functionalities. Whilst strategies (i) and (ii) are applied in some GIS on the market the total integration step is still missing (D. Fritsch, 1991). Although a total unification of terrain and situation data is desired, recent investigations have shown that separate data sets will give optimum system response. This leads to conflicts with requirements for data handling in GIS which should be non-redundant and as compact as possible.
The integration of image data in GIS was necessary as soon as products of remote sensing had to be interpreted interactively. For that reason hybrid GIS have been proposed and are under development since the mid 1980's. Until now this integration step is concentrated on separate data management and data processing techniques. The first common strategy to be observed is using an extra data layer for image data, but this approach can not be seen as very efficient. It still contributes for better orientation on screen or paper of the vector data.
The lack of integration steps for height and image data in GIS is to explain by the complexitity of data handling. At present, GIS data bases are standardized by the integration of relational data base management systems (RDBMS) such as ORACLE, INGRES, INFORMIX etc. This conversion automatically ensures security mechanisms such as transactions, recovery, concurrency etc. which are necessities for distributed GIS environments. Furthermore, the query languages of RDBMS can be used to answer questions like a view: *Find all owners of parcels located at street x* or a join *Find all building sites of owners living not in the city y.* Until now these query languages are restricted on views and joins of semantic data, but recent developments are expanding SQL's on geometric queries leading to Geo-SQL.

1.3 Synergy of photogrammetry and GIS

When bringing together photogrammetry and geographic information systems the question is not to merge both disciplines with each other but how to make the most profit of this link. This profit is called *synergy* because of using the positiv energies of both disciplines. First of all photogrammetry serves as data source for GIS. Photogrammetry with its high potential for automated data acquisition for vector data on the one hand, and providing highly refined image products on the other hand is able to fill GIS with very actual geometric data. We all know, a GIS without data is a car without fuel. But we also know, that data acquisition is the dominant investment of GIS: there is a rule which differentiates the costs in GIS according to

hardware : software : data = 1 : 10 : 100

Therefore when photogrammetry is used for GIS it is located in a very heavy GIS investment sector. Here we can see a good chance for photogrammetry because of its automation efforts.

These automation efforts need on the contrary additional knowledge which is to be imported from other data sources. One of these data sources might be the geographic information system because here data are stored according to geometric-topological and semantic models. For example when working on relational matching problems, we need the geometric-topological model of vector data to set up search trees (G. Vosselman, 1992). Quite another aspect is generic modelling (M. Sester, 1991). Generic models can be of quantitative and qualitative nature: the information for these models is also contained in the GIS data model. Therefore the import of GIS semantics in generic modelling may contribute to more comprehensive descriptions than we had before.
The synergy of photogrammetry and GIS is also to be seen from a software development point of view. As it was indicated before, GIS is a very dynamic discipline and attracts people of different education: computer science specialists, geographers, surveyors, photogrammetrists, cartographers, physicists, electrical engineers and so on. For this reason it is very important in the field of geographic information systems to consider standards in programming techniques, user interfaces, and data base systems. These standards have to be fulfilled from closely related disciplines when modules for data acquisition, data handling, and data analyses are integrated.

2. COMMON PROCEDURES FOR PHOTOGRAMMETRY AND GIS

Observing the trend in photogrammetry and GIS it can be observed that powerful graphic workstations (CISC, RISC, ARC, Alpha) and Personal Computers based on 80486, 68040 processors in about 95 % off all applications represent the hardware platform. The operating system is UNIX, therefore it makes sense to develop software modules in the C programming language. This can be seen from the necessity that the operating system and the application software are coded in a homogeneous enviroment. Recent proposals in particular in computer science recommend object oriented programming techniques which are able to reuse and to alter locally programming code by inheritance mechanisms. These recommendations are also valid for photogrammetric software developments as can be concluded from the following.

2.1 Object oriented programming techniques

Object oriented programming techniques started already its progress in 1966, when SIMULA as an ALGOL-based programming language (S. Alagic, 1989) was introduced. Already the first version of SIMULA, called SIMULA-67, contained the most recently highly acknowledged mechanisms of objects, values, methods, classes, and interitance. In the meantime further object oriented programming languages are available, such as Eifel, Ada, C++, Objective-C, Object-Pascal, Turbo Pascal, and the LISP family (Flavors, Loops, CLOS etc.).
The first applications of object oriented programming techniques dealt with the design of integrated circuits. Its object definition is given as a set of data and a set of rules (knowledge), which have access to this data. Two kinds of knowledge form the basis of object oriented programming techniques. These are

- structure knowledge, obtained by *classes, interitance, attributes, and relations (is-a, is-part-of)*, and
- pattern knowledge, obtained by *methods, interitance*

In figure 1 the object relations for topographic mapping are indicated. As it can be seen, *m:n* relations between classes and subclasses are realized leading to a very flexible data model. The advantages of the object oriented approach can be differentiated according to:

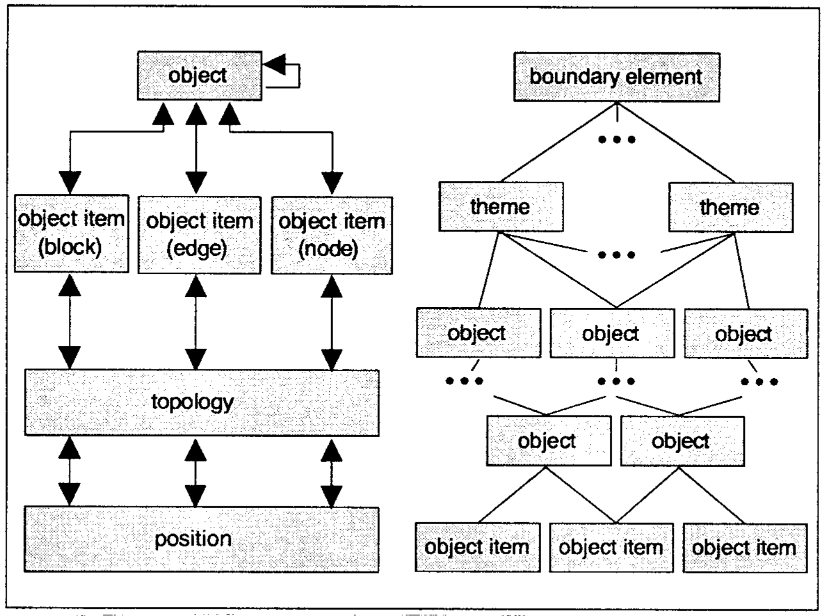

Figure 1: Object relations of object oriented programming for topographic mapping.

1. modeling of the real world
2. structured complex objects
3. methods
4. abstract data types
5. software code reuse
6. local code alterations

These advantages are in competition with the following disadvantages:

1. no standardized concepts are vailable
2. no deductive capabilities

The concepts of object oriented programming techniques can directly be derived from the advantages given above. They include complex object building, object identities, classes and subclasses, methods, abstract data types, interitance, overloading etc. In the following some items will be characterized.

Object identity: Every object has a name. The objects can be referenced by their names, what leads to the construction of very complex objects. An example:

```
OID1 <--> house (parcel: OID2, utilization: multiple dwelling)
OID2 <--> parcel (real estate register: OID3, land cover: yard)
OID3 <--> real estate register (owner:OID4)
```

Object identities (OID) carry no additional information. A comparison can be done via real names, bar codes, and alphanumeric figures.

Abstract data types: Objects with the same characteristics are collected in classes. For every class it exist a set of methods. Objects are queried and manipulated by methods. The implementation of methods is unimportant for the user. An example: manipulate a window user interface.

```
Class:
  window (graphical user interface)
```

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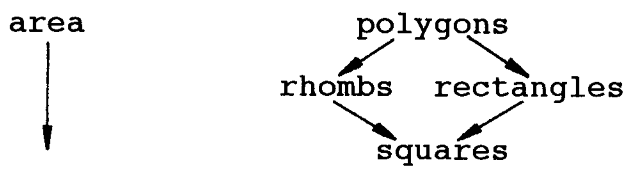
```
Methods:
  generate window, delete window
  shift window, enlarge window, generate window icon
```

Inheritance: This feature presupposes classes and subclasses. The classes contain objects with similar characteristics (attributes), subclasses contain objects with further attributes. The inheritance mechanism inherits the class attributes to the subclasses. An example: compute the area of polygons.

```
Method:               Classes:
```



Overloading: This enables the specialisation of attributes and methods in subclasses. Its advantage is obvious: we can alter locally any software, and we can reuse the software. An example:

```
Polygon              Area:
                     < low programming code >
Square               Area:
                     < fast programming code >
```

The computation of the area of a square is more efficient than using formulas for the polygon.

2.2 Software generation

The future software to be developed for photogrammetry and GIS, respectively,should be oriented on the mechanisms given before. The first problem is to choose the adequate programming language from the class of objected oriented languages. As indicated by recent trends it seems that C++ as a compromise will win the race. C++ with all its characteristics of object oriented mechanisms and an improved C language is equally suited for coding algorithms and to develop object oriented databases.

When considering object oriented programming techniques the efforts for the integration of photogrammetric modules in GIS and vice versa should be kept minimum. This leads to well-structured software, which can be reused indifferent applications. An example: very often the drawing of contour lines is necessary. These contour lines represent any phenomenon $z=z(x,y)=const.$ Contour line drawing is needed in DTM representations as well as in the visualization of attributes. Therefore the same code can be used if the object class *contour line* will be defined.

Further examples in image understanding can be cited. At first, the photogrammetric image is to be oriented with regard to the inner orientation. The measurement process of measuring fiducial marks can be automated by using template matching techniques. Template matching itself belongs to the class of matching where a standard affine transformation with simultaneous radiometric correction is realized. The next step is relative orientation. Relative orientation can be seen as special case of automatic DTM generation, in which the iconic and feature pyramids are used. The coarse-to-fine strategy in DTM generation inherits some features to the strategies for automatic relative orientation.

In this way new concepts for software development are valid. It is dependent on the developer's point of view and also, how fast object programming techniques will be generally acknowledged by the engineering disciplines. When using these techniques it is the author's belief, that investments during software development in photogrammetry and GIS will be kept minimum with output of very efficient software.

3. CONCLUSIONS AND OUTLOOK

In this paper it was shown that photogrammetry and geographic information systems need each other, the more the higher the expectations are on image understanding techniques and time and space dimensions in GIS. A further result is the acknowledgement that both terms characterize highly dynamic disciplines. Common efforts in both disciplines is software development. This software development should be carried out according the tools and rules given by object oriented programming techniques.

Photogrammetry is evolving in a discipline with strong efforts in automization. This automization needs different sensor systems to overcome lacks in exterior orientation of the images, and the inadequate boundary representations of parts of the earth' surface. Furthermore without any knowledge on the semantic contents of images progress in image understanding is not possible. Therefore, it is dependent not only on the import of different sensors but also on knowledge and data import from GIS.

Geographic information systems need automized data acquisition techniques the more the fact of data update is concerned. Further, the flat surface of vectorial map data is not the real reference surface of the earth; the integration of digital terrain models becomes a necessity. Image data will serve more and more as data source in GIS not only for orientation of vector data, but to check the geometric quality of GIS data, to apply monoplotting techniques, or simply to represent the actual real world image. Therefore, GIS is dependent on the import not only on photogrammetric images and products but also on photogrammetric knowledge.

The data import and export between photogrammetry and GIS should control and constrain the developments in both disciplines. As we know by experience geographic information systems are the leaders adapting recent techniques of computer science. Thus, it will help photogrammetry to orientate its modelling and programming efforts on new GIS tools. Thinking in this way it should be possible to integrate photogrammetric data acquisition and manipulation modules in an easy manner in GIS. It is the author's belief that photogrammetry will have much influence in particular in the development of hybrid geographic information systems, in which raster data have the same value as vector data. This will help photogrammetry to be the ' driving force ' not only in topographic mapping but also in environmental control, a task to be solved at present and in the future.

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