INTEGRATION OF GIS AND METHODS FOR DIGITAL IMAGE MAP PRODUCTION

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ABSTRACT:

During the last few years new techniques and methods in digital graphic data processing have been developed as well as in digital image processing. Also the requirements of different map users for integration of raster data, like satellite images, in Geographic Information Systems (GIS) have grown more and more.

In context to this at first some methods of digital image map production are described, including mosaicking of satellite images and image enhancement techniques. Then the basic structure of an hybrid GIS including raster, vector and also non graphic data is described. Finally the integration of the map production methods is introduced with especially aspects on hard- and software-realizations.

KEY WORDS: Hybrid GIS Design, Satellite Image Maps, Image Matching, Image Quality, System Integration.

1. INTRODUCTION

Nowadays Geographic Information Systems (GIS) have to fulfill an increasing number of new requirements announced by many map users during the last few years. Most of so defined tasks only can be solved, if raster techniques are used in GIS as well as vector data processing. Raster data, especially digital image data, offer an enormous information quantity, so that the usage for GIS purposes is really helpful. In some cases of course, satellite images represent the only available geoinformation. And finally, using existing topographic maps for building up GIS, scanning these maps is a quick possibility to produce GIS levels with topographic information.

Because of all these reasons not only future GIS should be composed of hybrid data. But the user requirements nowadays as well need raster-, vector- and non graphic data in actual geographic informaton systems. In the following the question of integration of such data will be discussed including the integration of methods for digital image map production and also techniques for digital image enhancement into hybrid systems.

2. DIGITAL IMAGE MAP PRODUCTION

A modern GIS fulfilling all demands of vector- and rasterprocessing needs not only the administration of digital data but also reliable software tools for the optimal preparation of map products. In this context the processing of airborne and satellite images is of increasing importance. Such data are in use for many purposes, e. g. for the combined representation of raster and vector data or even for updating existing maps.

In the next years new remote sensing satellite sensors with higher geometrical and spectral resolution will be developed allowing the use of image data for mapping at greater scales. Today mostly the following sensor types are in use for mapping in different scales:

Sensor	Resolution	Appropriate Scale
Landsat-MSS	80 m	1: 250 000
Landsat-TM	30 m	1: 100 000
SPOT-XS	20 m	1: 100 000
SPOT-P	10 m	1: 50 000
KFA-1000	5 - 10 m	1: 25 000 - 1: 50 000

If greater scales are concerned the integration of aerial images or aerial scanner data is required. In order to use these data in a GIS with high flexibility it is necessary to offer a software system which allows the processing of satellite data from delivering the data on magnetic tape until the final product is integrated in a GIS layer structure.

2.1 System overview

The concept of the integration of satellite image data has to be digitally. Only this way guarantees a high flexibility of handling remote sensing data independent of the used sensor type (satellite scanner, scanned photographs, aerial images). The described methods of digital image map production are realized as a software package mainly developed at the Technical University of Berlin, Department for Photogrammetry and Cartography (ALBERTZ et al. 1987 and ALBERTZ et al. 1990). The software system is now used by FPK for its duties with great success.

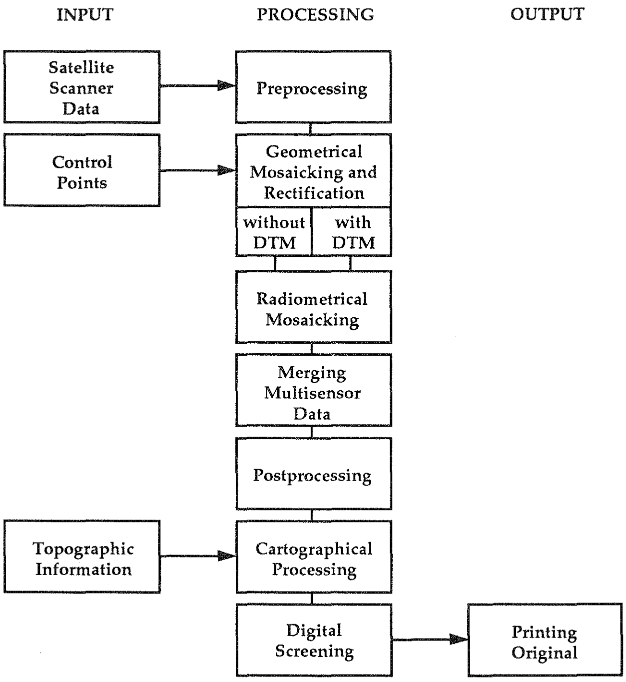

Fig. 1: System overview for digital image map production

The production line for the preparation of image maps can be subdivided into several processing steps. The main topics of each subsystem will be described in the following chapters.

2.2 Preprocessing

The preprocessing of the raw satellite image data is a prerequisite for all following processing steps and influences the quality of the final results remarkable. The preprocessing of the data depends on the used sensor system. Therefore a wide range of reliable algorithms must be available to enhance the sensor depending effects in digital images:

- In the first step all data have to be treated by simple histogram stretching in order to make full use of the available gray value interval. In the most cases the parameters have to be determined for each scene individually because they are influenced by specific illumination and athmospheric conditions.

- Sometimes bad pixels or lines caused e.g. by transmitting errors may arise in digital image data. Those errors can be detected and eliminated with a method based on thresholding and filtering.

- All operational satellite scanners show more or less typical striping effects depending on the sensor construction. If this striping effect is systematically it can be eliminated easily by adjusting each line integral histogram onto an artificial median integral histogram of all lines considered.

- Especially in dark areas of SPOT data noise influences the image quality. This effect can be eliminated by filtering techniques in the frequeny domain.

- Clouds or dust (particulary in industrial zones) can reduce the image quality essentially. This effect can be reduced by the treatment of data with partial substitution (KÄHLER 1989).

- From analogue photographs the effect of the illuminance fall-off is known. This effect can be observed in KFA-1000 images also. Therefore in the used software system a module is integrated which allows the elimination of illuminance fall-off in scanned photographs.

2.3 Geometrical Mosaicking and Rectification

It is essential for the integration of image data into a GIS to mosaic several scenes in order to fit the requirement of free map sheet administration of the data. The mosaicking must be carried out in a way that geometrical and radiometrical differences between the images disappear.

For this purpose a method is used which takes advantage of the double informations of adjacent scenes. The input information is achieved by measuring a few ground control points (GCP) in all scenens and tie points in overlapping regions. All transformation parameters for all scenes of the mosaic are then calculated simultaneously in a least squares adjustment.

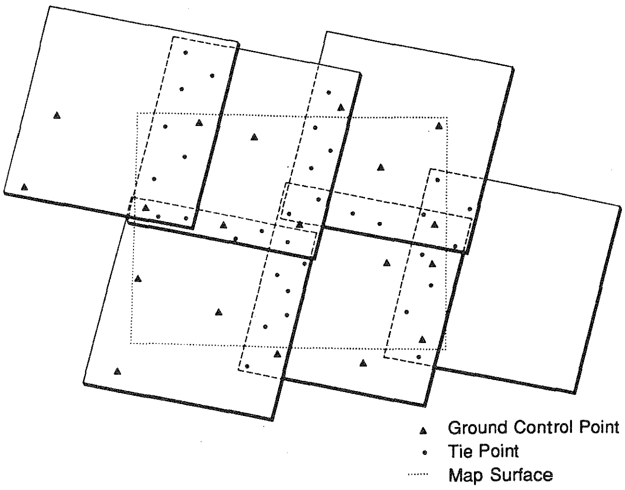

Fig. 2: Arrangement of ground control points and tie points in a satellite image mosaick

The usage of tie points has also the advantage to reduce the number of GCP´s. This is very useful because it is often very time-consuming to measure GCP´s in difficult areas (deserts, mountaineous regions, etc.) The identification of tie points is done by digital image correlation.

The rectification needs the process of resampling. For this different methods can be used. It has to be chosen that algorithm which guarantees good preserving of the image quality at reasonable computer processing time.

In mountaineous regions the influences of topographical relief causes displacements of the pixels during rectification. Therefore the polynomials applied for rectification has to be extended by using an actual DTM (ALBERTZ et al. 1990).

It must be considered that scanners have another geometrical model than aerial images. In this cases the relief displacements mainly occur in the direction of the scan lines.

The influence of the relief to rectification and mosaicking can be described as follows:

- The coordinates of the measured GCP´s in the image data are not correct. This means the calculation of the transformation parameter is based on incorrect input data.
- The positions of the input data for the resampling process are influenced by the actual terrain hights.

Both effects accumulate so that depending on the scanner and the relief differences the displacements cannot be without consideration. In this case the measured GCP´s must be corrected by actual terrain heights. This is not possible for tie points, because the absolute reference coordinates of tie points is not known. Therefore the final coordinates of tie points are calculated in an iterative process.

In the final rectification for each pixel a correction Δs can be calculated by using the DTM. This correction will be considered for the correct image position of the resampled gray value. It must be emphasized that a precise rectification needs a DTM with high accuracy.

2.4 DTM-Generation from Satellite data

It is obvious that a DTM is one necessary layer in a GIS. However, particulary in developing countries the availibility of DTM´s cannot be assumed. In this case the generation of a DTM with stereo-images takes place. Especially stereo-SPOT data play an important role in this context. With the capabilities of SPOT-satellite DTM´s with height accuracies better than 10 m can be achieved.

The photogrammetric evaluation of stereo image data is usually divided into three steps: interior, relative and absolute orientation. These procedure has to be adapted to the geometrical properties of SPOT data. The algorithm used in this software package is described in ALBERTZ et al. 1990.

However, the basic tasks of automatic DTM production is the determination of homologue points using special computer algorithms and hardware. For image matching the combination of two methods is in use: the normalized cross correlation for the calculation of approximation values and the least-squares matching for final results with subpixel accuracy. Experimental results with SPOT stereo-pairs have shown that accuracies better than 10 m can be achieved. The elevation of DTM´s from SPOT satellite have provided height data with sufficient accuracy - reliable for the rectification of satellite data and the integration into GIS. Furthermore KFA-1000 data offer also the possibility of evaluation of stereo-data. Due to the slight better resolution and a smaller base-height ratio at least similiar results can be expected.

2.5 Radiometrical Mosaicking

The result of the geometrical processing is a data set of several rectified images with high accuracy but which are single files. These scenes can differ significantly in radiometry due to different acquisition dates, atmospheric effects, etc. Hence it is necessary to compose one image within a common gray scale system. In order to acquire a homogeneous mosaic the information content in overlapping regions of adjacent scenes is used again (KÄHLER 1989).

The procedure starts with the definition of the overlapping regions which have to be used for the algorithm. After this step median integral histograms are calculated for each double information. The result is used to calculate correction tables for each scene in an iterative process. Afterwards a data set is available, which presents all scenes in an homogeneous gray scale system. The last step is the elimination of the double information in order to achieve just a single file. For this purpose special transition algorithms can be defined. Practical experiences have shown that a square transition related to a defined separation line between two scenes yields the best results. However, sometimes remaining effects can occur if regions with very different gray values be adjacent. In this cases some interactive corrections have to be applied. The method has been used very often in the last years and yields excellent results.

2.6 Combination of multisensor data sets

In order to make available the full information content of satellite image data it is often very useful to merge the advantages of different sensor image data. In particular the combination of panchromatic SPOT-data with multispectral Thematic Mapper (TM) data provides high geometrical resolution merged with a lot of possibilities in spectral band combination. This offers wide application possibilities for various map- and GIS-users.

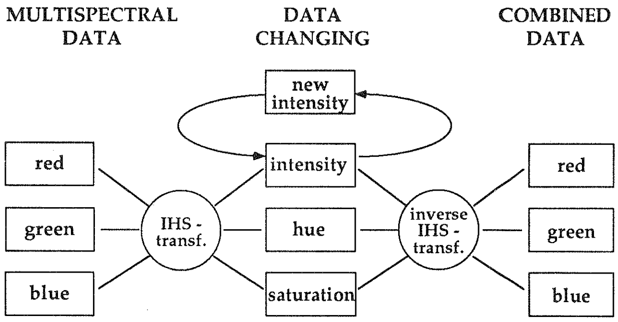

Fig. 3: Principle of combination multisensor data

The best results for the combination of multisensor image data can be achieved by using the IHS color transformation (TAUCH & KÄHLER 1988). The principle of this method is explained in figure 3. After the transformation of the original multispectral data set (RGB) the intensity, hue and saturation components (IHS) are provided. Now the substitution of the intensity from the original data with the data of high geometrical resolution takes place. If the radiometrical difference between the exchange files is too large a radiometrical adjustment of the new data onto the intensity is necessary. In the next step the retransformation into the RGB-color domain is performed. The result is a merged set of data preserving the most of the spectral quality of the original data and contains the high resolution from SPOT data.

2.7 Postprocessing

The final processing steps of the preparation of satellite image maps concerns the optimal radiometrical contrast. For this purpose in most cases simple histogram modifications are sufficient. Furthermore special filters are used to enhance the edge elements in order to improve the visibility of details in the final product (TAUCH & KÄHLER 1988).

The result of all described processing steps is a satellite image database which now can be used as a layer in a GIS or which can be completed with cartographic elements used as map.

3. BASIC DATA STRUCTURE OF AN HYBRID GIS

In order to the needs of scientists, planners and other GIS users for actual information, the above described methods have to be integrated into GIS. For this purpose the graphic database must include vector data as well as raster graphics in a so called hybrid system. The basic data structure of an hybrid GIS will be introduced in the following.

The actual situation in development of GIS technology represents differences between the user requirements and the available GIS hardware and software. Problems occure for example in building a relatively large scaled hybrid GIS for a complete country. For the territory of the Federal Republic of Germany e.g. a digital vector mapping system called *ATKIS* (*Common Topographic-Cartographic Information System*) will be established. For this purpose nowadays it looks unlikely that a digital vector database can be build up by hand-digitizing or raster to vector conversion of scanned topographic maps. Hand-digitizing - the best way today to collect logical structured data - takes an enormous amount of time and on the other hand suitable cartographic pattern recognition methods are not available yet. Even for this task (*ATKIS*) an hybrid GIS represents a good solution, where large format scanners will be used for creating digital raster data as input for the GIS, and for map revision vector data are used as well.

3.1 Data Types

Generally the input data for hybrid systems vary in a large field (see figure 4). Besides scanned topographic maps different types of data are expected, like: satellite image data, digital orthophotos, image data from airborne scanner systems, digital elevation models, vector data from map digitizing, from photogrammetric systems and terrestrial survey. Finally non graphic data complete the GIS input. These data are needed to support tasks like map revision, production of printing originals, data interpretation and analysis for many scientific and commercial applications, environmental protection e.g.

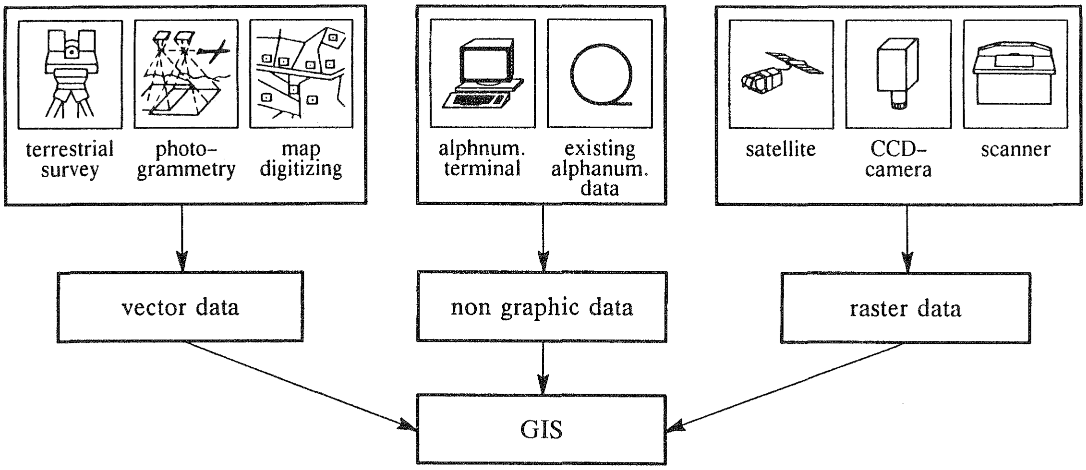

Fig.4: GIS input data

In context to the input data structure the GIS data storage works on three different data types:

- -non graphic data,
- -vector data,
- -raster data.

Non graphic data are managed like usual in standard database management systems. So also during GIS applications query languages (*SQL* e.g.) are helpful tools to solve the actual tasks. Additional connections between the non graphic data and graphic data are needed to create and represent the final result. Therefore the topological data structure of the vector data should be an object orientated model, so that special pointer can be used like object class, object number and so on. Geographic or geodetic coordinates are used as pointer as well, especially if raster graphics are needed.

Generally the data storage in hybrid GIS without concern of map sheet boundaries is referring to a fundamental homogeneous coordinate system, *UTM* or similar. In contrast to this map sheet orientated GIS are possible, in order to an easily realization if single scanned maps build the first data base, where each map is stored on a separated optical disk for example.

In such map sheet individual systems transformations between different meridian stripe coordinates need not to be performed. Each map is stored with its own geometric reference system. This leads into large problems if such single stored map archives shall be used as a database for applications in areas covering two or more map sheets. So hybrid Geographic Information Systems should be stored without concern of map sheet boundaries, especially if additional data from remote sensing systems or similar are included in the database.

But with regards to the user requirements map sheet orientated access also has to be available besides the standard access via free coordinate windows (x, y, Δx, Δy). So far map sheet numbers or names should be stored as non graphic information in the continuous GIS to enable this user access.

It is quite evident, that such a continuous GIS based on UTM e.g. is handling a large amount of data. This is the reason why a practical hybrid GIS realization without substantial degradation of retrieval performance needs a special data structure. For this purpose an internal separation of the raster database in small submatrices (128·128 pixel e.g.), using header and index management, is necessary. So any user defined window will be found in the database in a very fast manner.

3.2 Data Reduction

Another particular problem in hybrid GIS in context to the large amount of raster data represents the disk capacity. By that data compression methods have to be integrated. The worldwide available compression algorithms are divided in two main groups: *Bit level reduction methods* achieve a decreased need of bits per pixel. *Compression techniques of homogeneous data* transform the data from pixelmatrices to pixel counting structures.

Examples of bit level reduction are: binary image generation, reduction of gray levels, and calculation of gray value differences. For cartographic purposes binary images are used for most of the scanned map foils, and reduction of gray levels - from 8 bit to 6 bit e.g. - may be used for the hill shading data. Many compression techniques of homogeneous data are available, like run-length-, quad-tree-, or chain-coding to store scanned map data. Compression methods are normally not very helpful if image data from remote sensing or photogrammetric systems are included and their full information content should be preserved.

However, it must be pointed out that hybrid GIS need data compression methods. Depending on the application different compression methods have to be applicable simultaneously.

3.3 Layer Structure

Independant to the amount of geographic data another database structure principle is performed by sub layering of the continuous GIS according to the applications. Even analog topographic maps are organized in different layers respectively map foils. For example the foils of a topographic map 1:50.000 (*TK50*) of the Federal Republic of Germany include:

- planimetric,
- script level,
- vegetation,
- waters,
- contour lines,
- hill shading
- special level for hiking, cycling, touristic institutions and so on.

Such a layer concept represents the fundamental graphic data structure of an hybrid GIS in general. Like shown in figure 5 GIS layers consist of the topographic database and the application database. The topographic data include digital maps (vector data), scanned maps (raster data), digital elevation models, also digital orthophotos, and rectified satellite images. Results of image interpretation and image classification (land cover e.g.) belong to the application database as well as geological data, soil types and temperature, land use (forestry data, water quality data e.g.), population statistics, administrative data, and much more.

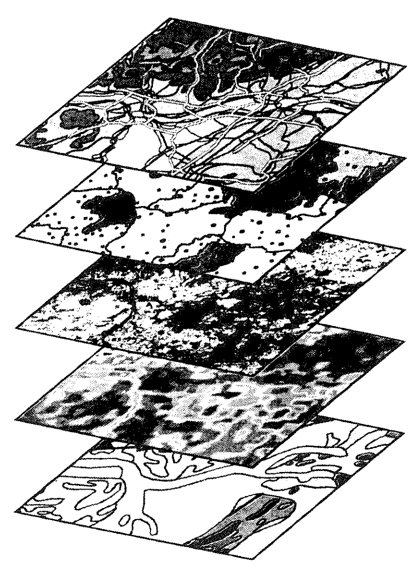

Fig.5: GIS layer structure
(GOEPFERT 1987)

4. INTEGRATED HYBRID GIS

Additionally to the introduction of the basic data structure the principle system architecture of an hybrid Geographic Information System will be discussed in the following. It is shown how the different input data are connected to the database itself and also to the output data as results of applications with GIS. The complete system is separated into five subsystems:

- input data,
- processing techniques for integration of several data types into GIS,
- hybrid GIS database,
- processing and enhancement techniques for building new GIS levels as well as output data,
- output data as results of application questions.

These subsystems contain many other second order subsystems which are connected sometimes or not. A much more detailed separation of the subsystems will not be described now, but figure 6 illustrates how the system architecture can be seen in principle.

It is shown how the different input data on the left hand side will be processed, with geometrical or radiometrical techniques e.g., before the data are integrated in several GIS levels. On the right hand side composing and enhancement methods are figured out, for creating new derived GIS levels and also for the data output as results of user requirements. The output data itself are not separated in conventional and digital results or other more detailed possibilities, these details are included in the shown resulting groups.

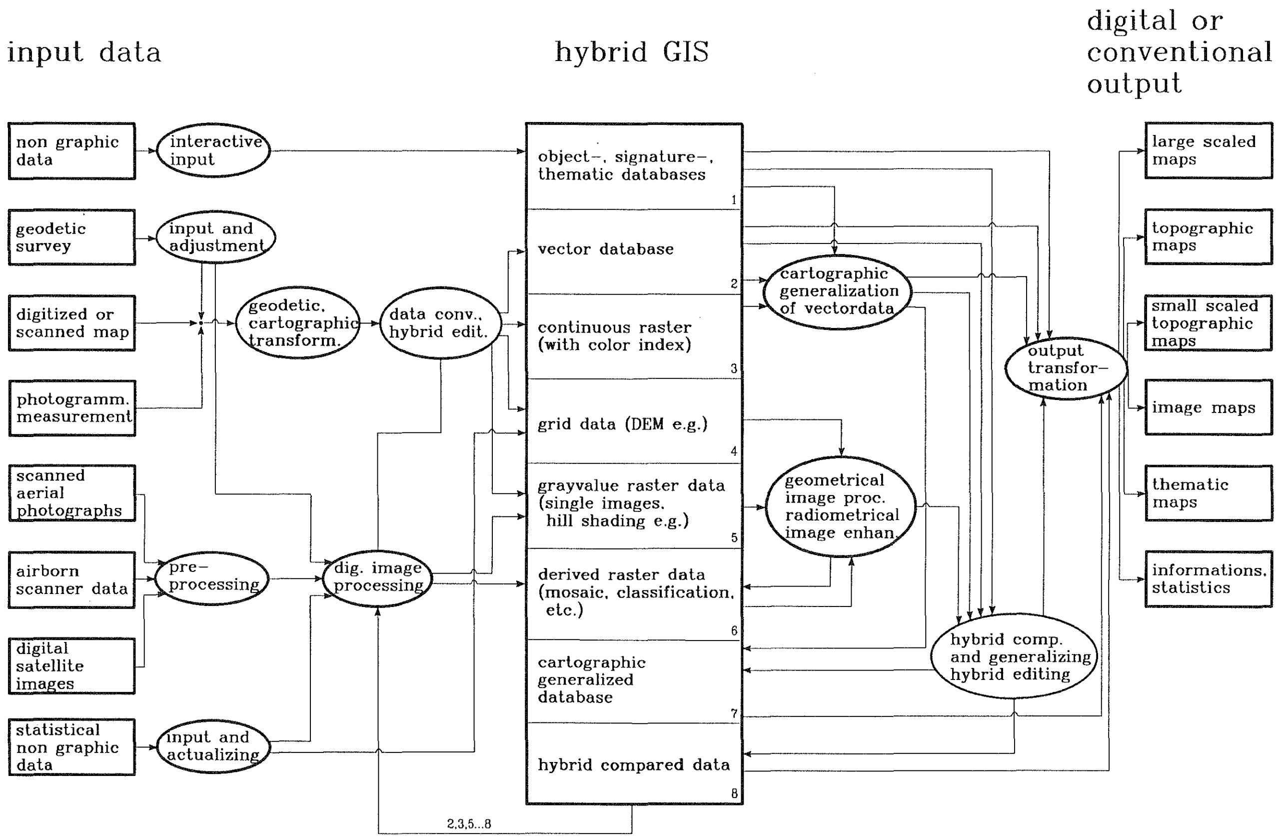

Fig.6: Hybrid GIS system architecture

In this GIS architecture the hybrid database itself includes 8 subsystem levels, where the non graphic database is not more detailed (just level 1). The graphic database is separated twice: original data (level 2...5) and derived data (level 6...8), both containing of vector-, raster- and grid data levels. Most of the original data belong to the topographic database and most of the derived data build the application database.

These both main subsystems of a GIS - topographic database and application database - often are realized in the existing applications yet. Due to the actual hard- and software limitations standard Geographic Information Systems are separated into some parallel existing GIS: a vector GIS and a raster archive representing the topographic databases, a geological and a soil information system as two application databases for example.

In order to the increasing hardware capacities (jukeboxes etc.) and the actual software development the realization of large integrated hybrid GIS seems to be possible soon. But on the other hand database sharing and transaction systems could be of special interest for GIS because of multidisciplinary users.

This leads to a decentralized concept alternative. In distributed database architectures it is possible to handle the data in different local organisations. Nevertheless the user's interface may look like in centralized systems (logical centralization). Decentralized systems give a better system structure and increase the performance due to parallel possibilities. But it must be pointed out that a complete distributed functionality is not really available in commercial decentralized systems yet.

The decentralized GIS hardware like shown in figure 7, including workstations, plotter-scanner-systems, retrieval systems and the decentralized database hardware itself will be connected via local area network (*LAN*) for example. All these workstations are necessary for interactive usage, updating, retrieval and managing the hybrid data, and most of them are available from different vendors worldwide.

5. STATE OF THE ART AND OUTLOOK

Actually excellent raster workstations of different vendors are known as well as outstanding cartographic CAD systems including database management systems. Also interesting hybrid workstations, so called live links between raster- and vector-systems e.g. and the first digital photogrammetric workstations are offered. Hence many of the requirements to GIS workstations are realized nowadays in the existing cartographic GIS and CAD-systems.

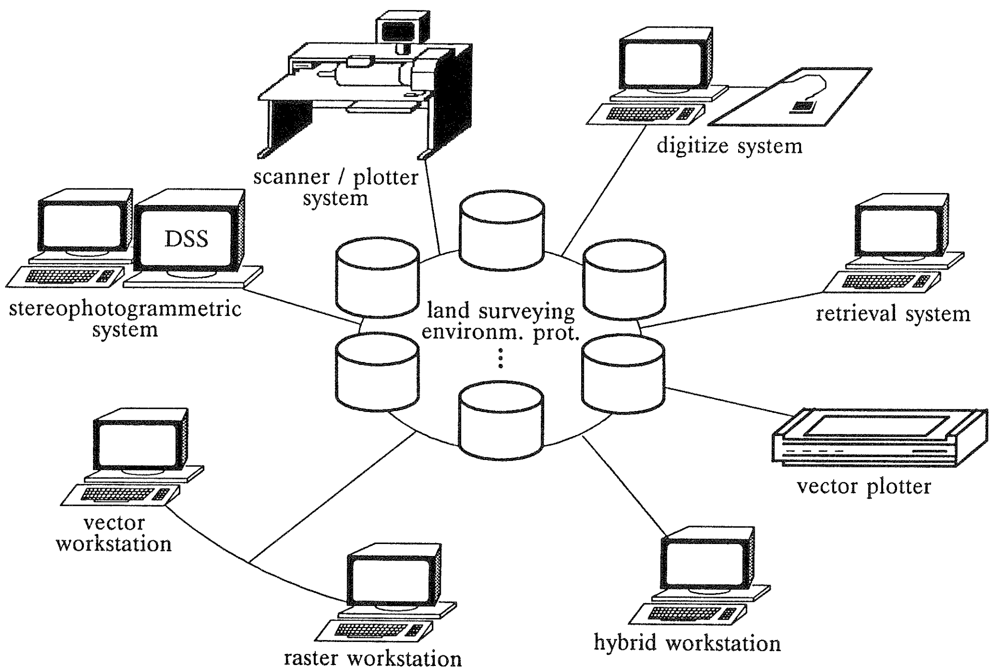

Fig.7: Decentralized hardware architecture including workstations

Just one example with particular application in context to the realization of the *Common Topographic Cartographic Information System* (*ATKIS*) in Germany will be introduced in detail: The topographic maps of the Federal Republic of Germany have to be converted into a digital information system during the next years. According to some additional user requirements the topographic map 1:25.000 (*TK25*) is needed as a digital database very early. These maps are scanned and a digital raster archive is build, in the area of Niedersachsen for example. In this context the digital raster archive is used also to increase the speed of map revision. For this purpose a special hybrid software component (*SICAD-MAP REVISOR*) is used containing a standard CAD software which is extended for enhancement of raster data. The **hybrid data structure** of this system includes pixels, pixel areas, continuous pencil elements, all for painting as well as for deleting of information. Copy elements for free defined raster area *copy and paste* are also part of the data structure additional to all the standard vector graphic elements. All editing functions may work directly in each of the scanned map foils in a *wysiwyg*-modus (what you see is what you get) with free windowing and combined raster- and vector-zoom. The cartographic line symbols for the topographic maps are able to be defined like the user needs.

This software for example, installed in a UNIX workstation represents one of the important tools which are needed for hybrid GIS applications. Other tools like raster to vector conversion for topographic maps or cartographic pattern recognition algorithms are still under development as well as distributed hybrid database management systems. For the development of such software the consideration of international software standards or quasi standards (UNIX, X-WINDOWS, MOTIF etc.) is very important. Also the database formats for non graphic data, the vector data format and of course the raster data format need to be standardized vendor independant. For the integration of methods and data of satellite image map production into hybrid Geographic Information Systems such standardization problems must be solved immediately.

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