A DIGITAL STEREOPHOTOGRAMMETRIC SYSTEM IN A GIS ENVIRONMENT

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ABSTRACT:

Geographic Information Systems (GIS) have become widely used tools for handling geographic and spatial data. Processed with digital stereophotogrammetric instruments, remote sensing or aerial imagery can be used to define new layers containing the whole 3-D potential of the landscape. Information like orthophotos, DEM data and linear features derived from digital plotters form a geometrically precise database for spatial measurements and operations. Moreover, existing GIS vector data may serve as knowledge base for plotting, supporting the automatic correlation process. Simultaneous display with the raster data on the stereo monitor is a prerequisite for an interactive or semi-automatic update of the vector data. This paper discusses first experiences combining the Advanced Digital Stereophotogrammetric System of the TUB and the ARC/INFO GIS.

KEYWORDS: DEM, Digital Stereophotogrammetry, GIS, Image Matching, Surface Measurement

INTRODUCTION

Geographic Information Systems are on the rise with an enormous growth rate (GANTZ 1990). GIS provide researchers, resource managers, and decision makers with powerful tools for manipulation and analysis of spatial data. They are used to facilitate measurement, mapping, monitoring, and modeling of a variety of data types. GIS offer scientifically, management, and politics orientated information, and can be used to plan and analyze spatial relationships in a geographical environment. Remote Sensing imagery and aerial photographs represent an important data basis which supports a fast investigation of large continuous areas. The development of high resolution digital sensors has lead to an excellent quality of satellite imagery and airborne scanner data, making them widely accepted and increasingly used in many applications.

GIS create a new set of requirements for image based data. At first the imagery itself has to be imported as an additional layer and as part of a GIS data base. From this imagery, information can be extracted and used in the spatial data base. Tools have to be available that allow an easy update of the data base if inconsistencies between the image and existing features are discovered. Again, GIS information can be used to support interpretation and analysis of aerial or remotely sensed data. In either case an optimal quality of the imagery is presumed, concerning image radiometry as well as geometrical accuracy. While improvement of the image radiometry is in the domain of digital image processing, the geometrical aspect is highly influenced by photogrammetric approaches. Image mosaics or orthophotos of good quality covering the region of interest become more and more important. It is the geometric accuracy achieved with photogrammetric methods which allows an advanced analysis giving reliable and certain results. The demand for three-dimensional spatial information that can be extracted from at least two images forming a stereo-pair can easily be satisfied applying stereophotogrammetric methods. In this context the development of Digital Photogrammetric Systems as completion of integrated GIS is a challenge in photogrammetric research.

STEREOPHOTOGRAMMETRIC FUNCTIONS IN A GIS ENVIRONMENT

Digital orthophotos created with photogrammetric tools are accepted as an additional GIS layer, since aerial photography has been an excellent data base for many geoscientific applications at any time (BAEHR, WIESEL 1991). This information is improved by use of stereo imagery. Especially in urban areas with their man-made objects, stereo images are the only help to extract accurate 3-D information. Hence it is necessary to combine conventional GIS systems with a stereoscopic visualization and measuring option as available in a stereophotogrammetric workstation. Thus, stereo imagery can be processed by use of a three-dimensional floating mark which allows collection of 3-D features. While automatic feature extraction is a main topic of research today, it can not be expected that this task will be solved within the next few years. A realistic way in measuring 3-D objects is to extend the GIS workstation with the functionality and algorithms of a digital stereophotogrammetric instrument. This gives the workstation the advantage of an integrated system, combining the flexibility of the GIS system with the accuracy of a photogrammetric instrument. Meanwhile, tasks such as orientation, triangulation, epipolar resampling, feature and DEM collection, derivation and superimposition of contour lines, ortho-resampling, and generation of perspective views are solved in photogrammetric workstations. An example of the realization of this digital approach is the development of the TU Berlin (fig. 1).

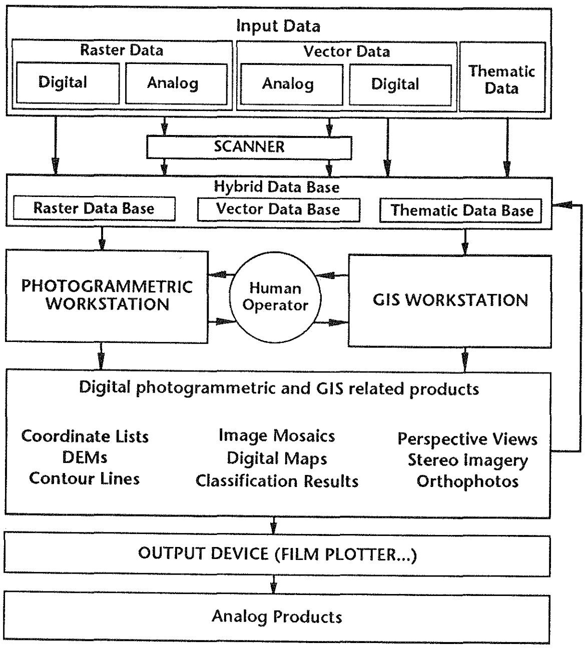

Fig. 1: Data flow in a distributed system

ADSS - THE ADVANCED DIGITAL STEREOPHOTOGRAMMETRIC SYSTEM OF THE TU BERLIN

Today's digital photogrammetric systems mainly are PC or workstation based. A clear tendency can be observed to employ commercial off-the-shelf Unix workstations in a modular approach (Gruen 1990), thus software can easily be transferred between systems of different manufacturers. But with increasing workstation power high resolution data acquisition systems produce more and more gigabytes of image data. To overcome the problem of processing the huge quantity of image data in reasonable time, additional processor hardware is required to achieve the performance level needed. High performance systems require open parallel architectures where data and algorithms are distributed over many processors. Scalable architectures, for example transputer based systems, are appropriate, particularly for heavy offline processing and when immediate results are needed.

In order to be prepared for these increasing requirements related to a digital photogrammetric system the working group at the Technical University Berlin decided to develop parallel algorithms for its Advanced Digital Stereophotogrammetric System (ADSS) on a workstation basis (Koenig et al. 1990). It is designed around a SUN 4/330 complemented with a PARSYTEC MultiCluster1 consisting of 14 INMOS T800 transputers. This is a very flexible approach where additional system performance could be achieved simply by adding new transputer boards.

The transputer network at the TUB is managed by a distributed operating system called HELIOS. HELIOS is designed after the Communicating Sequential Processes model of parallel programming (Hoare 1985). Applications are subdivided into single processes communicating over Unix-style pipes. These tasks are developed and tested on the workstation in a common programming language (e.g. C) and then are ported to the transputer network. Porting efforts are highly justified by significant performance gains. The most time consuming algorithms, i.e. epipolar image transformation and automatic stereo matching, are implemented on the transputer system. The matching algorithm runs 10 times faster than on the VAX based system (fig. 2).

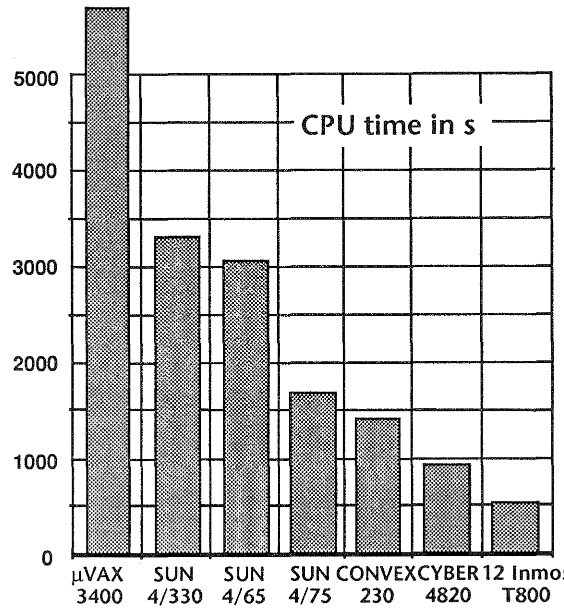

Fig. 2 Performance comparison of different systems

At present ADSS includes the following topics (Albertz, Koenig (1991):

- Preprocessing
  Common algorithms for image enhancement are implemented that are necessary to improve the information content of the imagery.
- Creation of epipolar imagery
  After an operator assisted orientation process, a stereopair is resampled to normal case imagery. This allows a stereoscopic view on the system's Tektronix stereomonitor and reduces computational time in the correlation process.
- Generation of a DEM
  Image matching techniques based on pyramids starting in reduced imagery for collection of approximate values and calculating the accurate position of homologuos points in the original data set are applied in order to obtain a DEM for surface reconstruction, analysis and display.

The ADSS is part of a heterogenous LAN consisting of SUN workstations, a µVAX3400 and several PCs, mainly Macintosh systems (fig. 3). These different hardware platforms are connected via Ethernet and TCP/IP, allowing a standardized and reliable communication concept. File access between this systems is handled by SUN's Network File System (NFS) which is responsible for comfortable data sharing. This is particularly important since it guarantees transparent access to various GIS data bases available on ERDAS and ARC/INFO workstations. Moreover, systems at the department of photogrammetry are integrated in the campus net of the Technical University, thus services of other institutions can be used. Exchange of results between those users engaged in geoscientific research can easily be managed. Also available are efficient compute servers (Cyber, Convex) and a peripheral server managing I/O devices (e.g. plotters) that form a cost effective infrastructure.

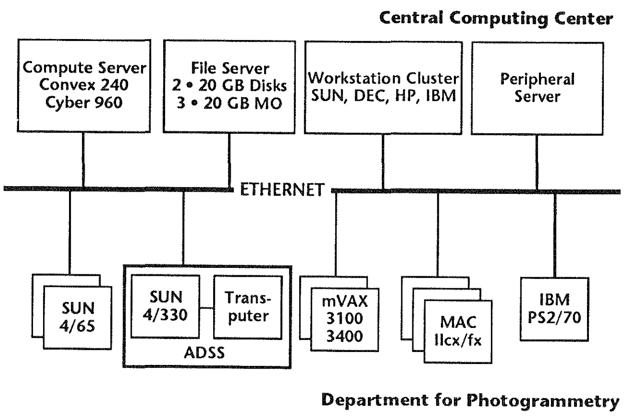

Fig. 3: ADSS in the FPK network

ARC/INFO - A VECTOR STRUCTURED RELATIONAL GIS

ARC/INFO software developed by ESRI is a vector structured relational GIS. Available for several platforms, it is one of the oldest data base-oriented GIS and worldwide probably the system with the most installations. As ARC/INFO is well known it is not necessary to describe its concepts in detail, so only a short sketch of its functionality will be given here. ARC/INFO provides a modular approach, with several useful and necessary components for

- generation and management of geographic data
- geographic analysis
- geographic data base manipulation
- data base queries
- graphic display and report generation
- surface modelling

For the distributed use of ARC/INFO in combination with the ADSS two modules are of main importance, i.e. the Image Integrator and TIN, a module for surface modeling and analysis.

With help of the Image Integrator module, raster images (B/W up to color) can be displayed as background simultaneously with ARC/INFO vector data. Several image file formats are supported, i.e. formats that are common in the Remote Sensing community, such as BIL, BIP or ERDAS, and TIFF which is mainly used in the DTP world, just to name a few. Since ARC/INFO coverages are stored in a map coordinate system the image coordinates of raster data sets must be transformed to that map coordinates for simultaneous display. For that purpose the system offers a registration tool for georeferencing the imagery to a real-world coordinate system. Moreover the Image Integrator allows the creation of an image catalog which contains images covering the area of interest.

TIN (Triangulated Irregular Network) allows the storage of topological relationships between triangles and their adjacent neighbours. Two models describing a surface are available, i.e. tins and lattices. Tins are based on irregularly spaced point, line, or polygon data which represent either mass points or breaklines. Lattices are arrays of regularly spaced grid points. These surface models can be created by different sources describing height information such as ARC/INFO coverages, stereo plotter data, or DEMs. Once the model has been generated, several calculations for surface analysis can be performed. The system allows the generation of profiles, contour lines and bands, the calculation of slope and aspect values. Volume and visibility analysis is possible as well as interpolation of surface data and derivation of surface shading based on reflectance values. Of course the system offers 2-D surface display and tools for a user controlled surface view (ESRI 1991).

In general ARC/INFO with its mighty functions competes with algorithms available in photogrammetric systems. But, as in most GIS, 3-D information is projected to the 2-D space, thus naturally much information is lost. At present no stereo-plotting tools are available. To support the GIS data base with accurate 3-D information the results obtained by digital stereophotogrammetric systems like the ADSS must be used.

EXCHANGING ADSS RESULTS WITH ARC/INFO VECTOR INFORMATION

First efforts concerning a joint use of raster data handled from the ADSS and vector based features derived by ARC/INFO had been made with data sets from the test area Remscheid, located in western Germany. Aerial photos of this region (fig. 4) are used in training courses where students of geodesy learn to handle photogrammetric instruments. Photographs of different flights are available so that the change of landscape and the influence of human activity can be studied over many years.

First, aerial photos covering the region of interest are scanned on a HELL Chromagraph DC 360 drum scanner with a resolution of 25µm (400 lines/cm). These data are the input to the photogrammetric workstation and are processed in the previously described manner, i.e. they are orientated and resampled to the normal case of stereophotogrammetry. The transformation parameters needed for overlaying the image with the coverages in the GIS environment are stored in an ARC/INFO readable world file. Since the ADSS image format meets the BIL or TIFF requirements, import is handled whitout problems. If a Digital Terrain Model (DTM) is desired in the GIS it can be calculated with transputer support in the ADSS. Detected 3-D points are displayed for stereoscopic view on the monitor to give the operator

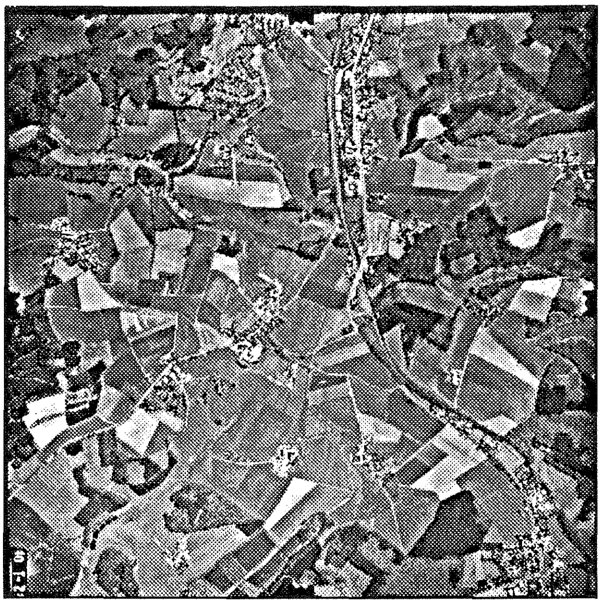

Fig. 4 Test Region Remscheid

the chance of a last check on gross errors and to correct some points interactively. Stereoscopic view of the terrain allows an easy definition of breaklines, which has to be done interactively too. The revised DTM and additional surface information are used as accurate layers to the ARC/INFO data base and serve as data input to the TIN module for performing surface analysis. In addition to the DTM, digital orthophotos can be derived and integrated as 2-D layer. Fig. 5 represents a wireframe of the test area Remscheid.

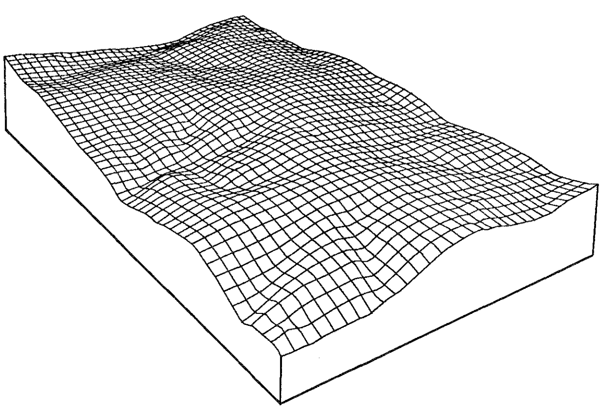

Fig. 5 Wireframe model Remscheid

On an ARC/INFO station features of interest such as roads, railway lines, forest boundaries, housing estates, etc. have been digitized on the basis of topographical maps in scale 1:25,000. These features are stored in different coverages in a vector data base. Once registered, the different information levels can be accessed on demand by operators working on any workstation of the network and especially are available as input data for the ADSS. This information can be used for example in DTM generation, where uncertain regions such as forests or water areas can be excluded from the correlation process.

FUTURE RESEARCH AND OUTLOOK

At present the most accurate method to collect logically structured data is to digitize them interactively. Raster scanning will play a more significant role for updating existing data bases. To improve and speed up the operator guided extraction of features, a knowledge-based approach is necessary. The data basis for this procedure is the information stored in a GIS, where the location of the features of interest can be extracted. In a semi-automatic process the a-priori knowledge of the feature location can be used for identification in the images. If the automatic process of linear feature tracking fails, operator assistance is possible to avoid failures in updating GIS layers.

As the world changes more and more rapidly, up-to-date spatial information can only be obtained if GIS are capable of handling the broad spectrum of different input data. This includes both vector and raster data. Attribute information about land has to be combined with its cartographic representation in order to perform spatial analysis. Raster data such as scanned air photographs and imagery recorded by opto-mechanical scanners, electro-optical systems, radar imaging devices and high resolution spectrometers must be integrated to the vector object data in order to form a hybrid GIS. The information potential of stereoscopic imagery allows a more accurate extraction of features of interest, thus photogrammetric tools for visualization and analysis of these 3-D data sets are essential.

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