A Digital Image Mapping System

presented at the ISPRS Congress in Kyoto 1988 by G. Konecny, P. Lohmann, University of Hannover and L. Skog, Teragon Context AB

0. ABSTRACT

A software and hardware solution for the various mapping tasks is being developed in a joint project of research institutes and Teragon Context AB.

The basic image processing system (**ContextMapper**) supports various I/O devices for images, DEM and map data as well as interfaces to GIS. Different software modules, like a map revision system (MONOPLOTTING), an orthophoto system (IMAGE RECTIFICATION) and a stereoscopic photogrammetric work station (STEREOPLOTTING) are part of the development. Together with the advanced package of feature extraction, contextual classification and correlation this new work station will have performance exceeding the present generation of analytical plotters.

1. INTRODUCTION

In August 1986 a cooperation between ContextVision AB and the Institute for Photogrammetry at the University of Hannover was agreed upon. The scope of the cooperation was to jointly develop an integrated mapping system for remote sensing, photogrammetry, cartography and GIS (**ref no 1**). This cooperation was rapidly extended to the International Institute for Earth Sciences (ITC) at Enschede in the Netherlands, the Norwegian Computing Centre in Oslo in Norway, the Royal Institute of Technology (the Institute for Photogrammetry) in Stockholm and the University of Stockholm (Dep. of Physical Geography). At a later stage the Institute for Image Processing and Computer Graphics in Graz, Austria joined the group. This paper gives a general overview of the system now being presented under the name **ContextMapper**. It also describes who did what and how it all was realized. More detailed descriptions of the contributions of each of the participants are given in many other papers referred to and presented at the ISPRS congress in Kyoto.

ContextVision AB emerged out of a group of image processing specialists from the Technical University of Linköping, Sweden in 1983 heavily supported by Swedish industry. The heart of the image processing systems from ContextVision is the contextual image processing (developed by Prof. Gösta Granlund and his group in Linköping), whereby a point in an image is represented not only as a function of its grey scale value, but also of the context (e.g. a line) it is part of (**ref no 2**). ContextVision has been active in three main markets; mapping, microscopy and radiology. To strengthen its market position the company recently (May 1988) merged with its main competitor on the Scandinavian image processing market, Teragon Systems AB, incidently also from Linköping. Teragon is mainly active in mapping and the graphic arts industry (pre press). The new company, **Teragon Context AB**, will be market leader in Europe and one of the biggest image processing companies world wide. Technically the strong image analysis of ContextVision is ideally combined with the outstanding image handling techniques of Teragon including a high speed flat bed scanner. Some of the achievements with the Teragon system are presented by the Swedish Space Corporation at the Kyoto congress.

The **ContextMapper** in its present version is a modularized multiprocessor system built around an industry standard 32 bit VME™-bus and a Sun-3™ UNIX™-based host processor. A hardware overview of the **ContextMapper** is realized in diagram 1.

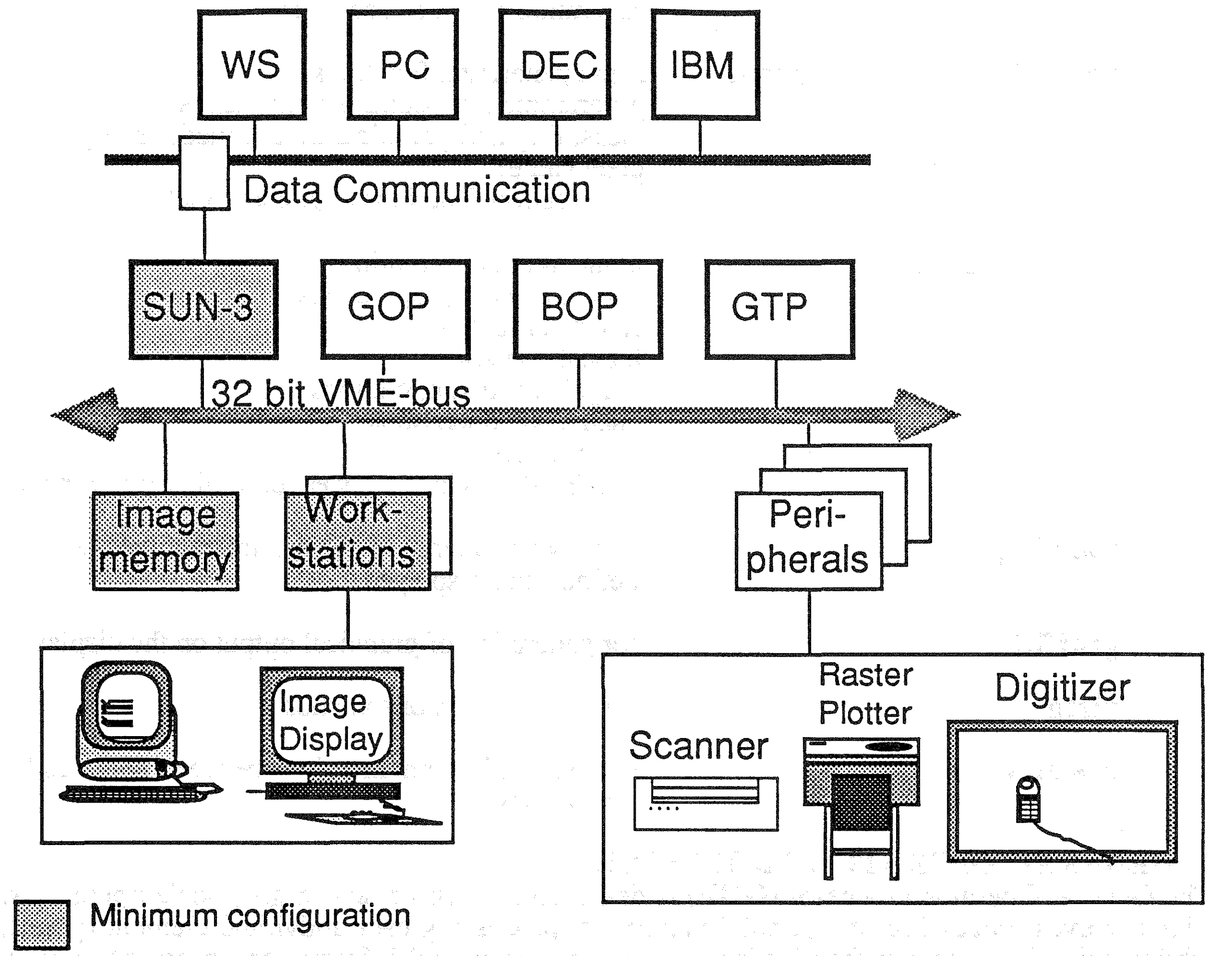

Diagram 1

2. HOST AND DISPLAY PROCESSORS

The open system configuration of the 3 MIPS **Sun-3 host processor** enables easy communication to and from other computers and peripherals. Ethernet, NFS and VME are some of the key words. The main purpose of the Sun host processor in the ContextMapper is to administrate the optional processors for image analysis. However in combination with the display control processor there is an increasing number of image processing routines available. These routines include:

display functions	display and colour manipulation measurement and statistical functions image manipulation and graphic functions logical operations on or between planes

general control language	flexible allocation of image registers flexible copying to and from images/files/display automatic resampling choice of display window configuration of display memory generation of image sequences
menu description language	menu generation functions programme flow control from menus measuring and graphical input functions (e.g read pixel value) menu action functions (e.g. zoom factor)
binary package	input and output routines feature detecting operations statistical routines logical operations neighbourhood operations chain code operations test routines (the BOP provides a faster set of binary routines)
roaming	windows in a large image can interactively be defined and displayed
graffiti	for generation of graphical output on the display
vista	for visualisation of statistics
raster/vector	conversion in both directions between raster and vector files

3. GENERAL OPERATOR PROCESSOR

The General Operator Processor (**GOP**) is designed for fast advanced grey scale operations. This involves processing of a parallel nature, i.e. processing each indvidual element (pixel), whilst taking into account the pixel's neighbourhood (context) information. In order to obtain acceptable processsing rates the GOP has a high-throughput parallel architecture. The GOP consists of a pipe lined filter processor and a floating point processor.

It is sometimes claimed that image processing should be carried out only on standard computer hardware rather than on special purpose processors as the software developed then would be compatible with future models of e.g. technical work stations, assumingly many times faster than the present generation. As quite a number of complex operations are performed in the pipeline, a direct comparison of computing power is difficult. However, to achieve the same throughput a floating point array processor would have to run at 110 to 120 MFlops to match one double pipeline of the system. As future versions of the GOP will make use of newer technology the relations in terms of speed and performance will be maintained. A VLSI-GOP is currently being developed in cooperation with a French Philips subsidiary, TRT all under the framework of the EUREKA project.

The **filter processor** is mainly used to perform image filtering operations (convolutions) between images and operators (kernels). The input images are held in the image segment memory, represented as complex valued 16+16 bit words. Computations are performed in parallel in "pipeline" units, in order to produce the complex valued products. The compound results are in the form of complex valued 40+40 bit words, which are converted into floating point numbers for transfer into the **floating point processor**. This processor is normally used for further computations of the convolution outputs from the filter processor, taking e.g. contextual rule modifiers into account. This two-stage architecture is programmable in a PASCAL-like language.

The software running on the GOP gives a completely new approach to image analysis. It assumes that the interpretation of each point in an image is dependent on the context in which it occurs rather than only its grey value. In a small neighbourhood (e.g. 15x15 pixels) around the image point the computer looks for fine details at high resolution. The system then detects somewhat courser details in a larger neighbourhood (e.g. 50x50 pixels) at lower resolution and so on. By combining results from each level in this hierarchy we get a clear description of the type of structure each image point belongs to. This makes it possible to sharpen edges, lines and other structures and at the same time reduce noise (**texture controlled adaptive filtering**).

The GOP concept is based on a polar representation of images, where the magnitude (radius) as well as the argument (angle) gives information about the image. The GOP image analysis operations library includes a large number of operations that may be related to different levels of image processing, depending on the complexity.

In the basic level operations (**feature extraction**) results from several convolutions of grey level images are combined to produce a final vector image. Examples of these operations are:

Orientation estimating
Frequency estimating
Vectorial averaging
Gravity estimating
Consistency
Phase detecting

In the high level operations (**context controlled operations**) context images from above form a guiding model for the controlled grey scale operation. Such operations are:

Line consistency
Enhancement (context controlled)
Relief and etch

There is a wide range of kernel sets with varying characteristics that may be chosen for each operation.

There are also **serial operations** preceeding parallel filtering operations. Common for this category of operations is that they all estimate a path in an image according to different rules. There are a number of different algorithms included, ranging from simple contour following and minimum cost tree approaches to complex dynamic programming algorithms. These operations are well suited to reestablish contours of very weak structures.

A typical operation is to find the "least cost" path between two points in an image, where the cost image could be for example the output from an edge detecting operation or a slope map generated from a digital elevation model.

The **image calculator** can perform almost any conceivable arithmetic operation or function on one or more images of different data types and formats. This function can also be used to generate test images, kernel functions and to display images. All calculations are carried out in a floating point format.

For **image conversion and transformation** there are tools for convenient management of incompatible images. The package includes straight and inverse FFT transforms, conversion between different colour representation e.g. RGB to IHS and a number of image data format conversion routines, such as polar to cartesian and compact packing of colour images. How colour transformations and texture information can be used to differentiate between sealed and vegetated areas is discussed in a paper by Lohmann and Altrogge (**ref no 3**).

The **GOP classifier** package offers the unique possibility to combine spectral features with texture features. GOP classification thus becomes a useful tool when spectral classification cannot produce reliable results (**ref no 4**). Basically there are three main classification algorithms included in the package:

A **clustering** algorithm that serves as an unsupervised classifier.The results from this classification may be further enhanced and edited interactively, using any of the supervised classifiers.

A **minimum distance** classifier (MD), that minimizes the sum of the distances between each pixel and the corresponding class centre. Any of the class centres may be edited.

A **maximum likelihood** classifier (ML), that assumes a certain probability distribution and performs the classification according to this. Also this classifier permits supervision in the same manner as the MD classifier, using the **multidimensional visualization** package. Up to 16 projections may be studied at a time. The interactive editing and training facilities make a stepwise training of the classifier possible in order to successively improve results.

A number of **geometric transformations** can be run on the GOP. An extended set of transformations with higher performance mainly in terms of speed is found in the GTP software. The following functions are available on the GOP:

Registration of images according to **first order polynomials.**

Perspective transformation of images including scaling, rotation and translation.

Warping using a displacement image that gives the displacement vector for every pixel.

By using a digital elevation model **perspective views** taking also height variations into account can be generated. Consecutive views can be produced for visualization.

3-D reconstruction of a number of section images (slices) to reconstruct a three dimensional volume. The reconstruction can be rotated and viewed from different angles.

The **image coder** is controlled by a set of parameters that makes it possible to combine algorithms and adapt the coder to the type of image data to be compressed. By varying these parameters the tradeoff between average bit density and image quality can easily be studied. Included in the package are coding tools such as FCDT, threshold coding, runlength coding, zonal coding and Huffman coding.

Various **high level programming tools** are available to the GOP user. The operations definition language (**ODL**) is used to define an image processing operation to be performed in the filter and floating point processors of the GOP. For programming of the floating point processor a high level PASCAL-like (extended with vector operations and complex numbers) language (**GPL**) is available. The source code can be written as a standard UNIX™ file and compiled with a call to the GPL-compiler. In most cases however the GPL-programme is produced by the ODL. **Kerngen** permits filter design in both the spatial and the frequency domain. Filter coefficients may easily be determined by editing a text file or by selection of a part of an image. This image could also be an artificial image generated in the image calculator. For visualization of the resulting kernel or kernel sets different 3-D display and plot modes may be used.

The **GOP micro programming** package contains tools for optimal use and full control of the GOP when designing user defined operations on microcode level. Among the tools included is an interactive assembler, UMA.

4. GEOMETRIC TRANSFORM PROCESSOR

The geometric transform processor (**GTP**) is primarily designed for geometric image transformations. It consists of a 32 bit floating point processor and a closely coupled integer memory interface processor. The GTP is used mainly for resampling of images where the transformation is described either by a precalculated matrix or calculated directly with polynomials of arbitrary degree or described by an analytical function. It is also well suited for applications like FFT and matrix manipulations. Any transformation of a 512x512 image is performed in a couple of seconds. The GTP plays an important part of orthophoto generation. The registration software handles up to third order polynomials. For pixel value interpolation nearest neighbour, bilinear interpolation or cubic convolution can be selected.

5. BIT ORIENTED PROCESSOR

The bit oriented processor (**BOP**) is designed for high speed processing of binary images. Communication with the BOP is made via a C routine package. Calls to these programmes can be made directly from application programmes or interactively by using the BOP monitor programme (BOPMON). A universal micro assembler (UMA) is also included. The subroutine library contains a large number of binary operations for feature estimation and image manipulation. At the ITC the BOP has been extensively used for the implementation of rank order filtering (**ref no 5**). Of special interest for GIS applications is the logic function that performs Boolean expressions on up to four bitplanes. Also for cartographic applications such as raster to vector transformation a vast set of software tools is available.

6. CONTEXTMAPPER SOFTWARE DEVELOPMENT PROJECT

The above described hardware and software environment has been the base for the development group to integrate remote sensing, photogrammetry, cartography and GIS. There are some obvious limitations in the present generation of image processing equipment but many of the essential components of a product for a large market are already there:

- **VME-bus**
- **open system concept**
- **special purpose processors for heavy and time critical operations**
- **contextual image processing**
- **consistent transportable software**

The functionality of the **ContextMapper** is best described by the following diagram.

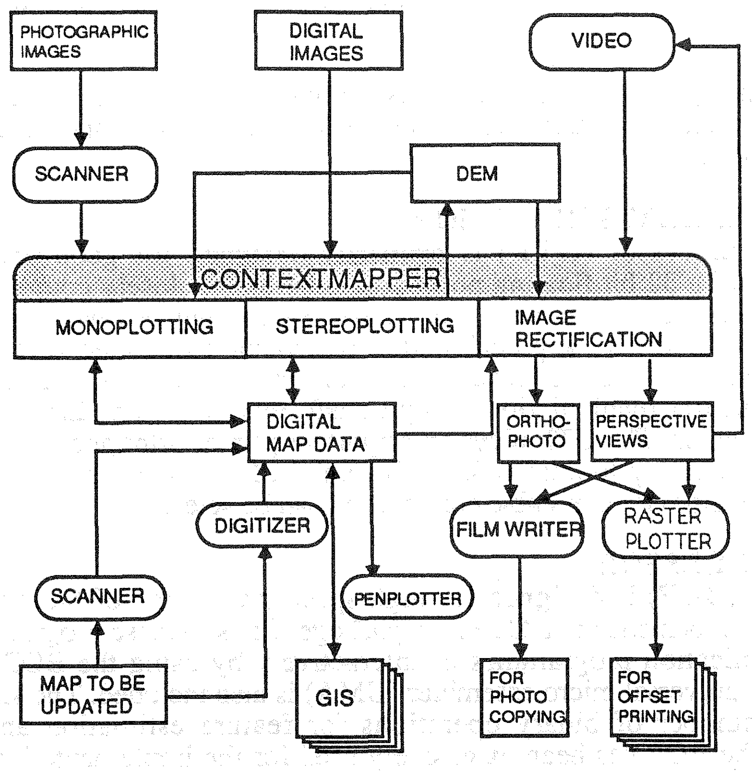

Diagram 2

The guiding principle of the development of the **ContextMapper** has been to convert various mapping tasks into software procedures that can interact in a common hardware environment. The above described hardware and system software provide such an opportunity.

One important goal for the project team has been to present a prototype version of the integrated system at the ISPRS congress in Kyoto. To meet with this goal programming efforts have to be coordinated and already existing software and algorithms must be utilized in an optimal manner. The fact that the processors are high level programmable has given the application programmers the necessary tools to quickly implement existing and new written software.

6.1 IMAGE INPUT

As one of the objectives with this project has been to develop a photogrammetric work station the conversion of analogue photography to digital format is essential. It must be possible to scan the photographs at varying resolution depending on the resolution of the imagery and the requirements on the results. The pixel size has a direct impact not only on the interpretability but also on the complexity of the evaluation and the requirements for data storage. At 25 micron pixel size a B/W 23x23 cm photograph scanned with 8 bits grey scale resolution requires close to 100 MB disk area. At the moment there is not one single system that fullfills all the different requirements for scanning. Therefore we have chosen to interface different scanners for different purposes. For high precision photogrammetric measurements a Rollei Reseau Scanner allowing for images up to 23x23 cm has been interfaced. This scanner is built on a simple but genious solution where a high precision grid engraved on a glass plate is placed over the film on the scanning table (**ref no 6**). A video camera that is placed over the movable scanning table can then transfer video signals including the high precision grid crosses via the frame grabber of the ContextMapper for identification, rectification, mosaicing and further image processing. The images can be mosaiced to reconstruct the original image. Another possibility is to use the option to store only smaller patches that due to the design principle are in perfect geometric relation to each other. The same principle can, as will be discussed below, also be used for on-line high precision photogrammetric measurements.The maximum image resolution is 50.000x50.000 pixels giving 1 micron precision corner to corner.

For colour scanning interfaces have been developed for Optronics and Joyce-Loebl. As the latter can scan colour images in one pass the registration between the colours becomes perfect. Also the **Teragon 6000 flatbed scanner** will be interfaced. This scanner uses a linear CCD-array and scans a 60x80 cm document in less than five minutes (**ref no 7**). The maximum scanning resolution for these scanners are 25 microns making them in the first place important for scanning of images where the output is supposed to be another image or map or where the requirements for geometrical quality are less pronounced.

For satellite images on a CCT (Computer Compatible Tape) special tape reading software is usually required. Such software is available for SPOT, LANDSAT (TM and MSS) and NOAA in addition to other software required for reading of radar imagery, airborne scanning systems etc. The treatment of radar imagery is especially developed at the Institute for Image Processing and Computer Graphics in Graz.

As mentioned above the storage and retrieval of digital image data is a vital problem that has to be properly addressed. Together with the Norwegian Computing Centre in Oslo an image catalogue and a raster data base has been developed to make large volume image data processing possible in a production environment. Also the storage media may be a bottleneck when fast access to a large number of data sets is required. Conventional magnetic tape is a far too limited media and even if 4x690 MBytes (unformatted) disks can be reached directly via the VME-bus it is easily understood that more is needed when single images require several hundred MBytes. The solution chosen by the Swedish Defense Staff was to interface a laser disk juke box with 20 laser disks each capable of storing 2x1 GBytes. This gives 40 GBytes on-line storage!

TV video input functions can be added to the basic version of the ContextMapper. Real time video recording and playback functions can be integrated if a video disk subsystem is attached. Using the same reseau technique as described above high precision on line photogrammetry can be used for industrial applications where photogrammetry up till now could not meet with the accuracy requirements. This will be further studied in a project for high precision photogrammetric measurements at the Technical University of Braunschweig in West Germany.

6.2 MONOPLOTTING

A map revision system where digitized aerial photography or satellite imagery is transformed to the relevant map projection system and scale taking also elevation differences into account has been developed. Geocoded data including digital elevation models are communicated to and from the monoplotter. A prototype version of the Monoplotter was developed in cooperation with the Royal Institute of Technology in Stockholm. The results are presented at the ISPRS congress by John Stokes (**ref no 8**).

The Monoplotter is a fast and accurate map revision system and used in combination with image processing routines, such as classification, line and edge detection, least cost line following, cartographic feature extraction, raster to vector and vector to raster conversion the map updating task is significantly simplified to the operator. In addition to this map data may be transformed into the image geometry, displayed as an overlay and used as a priori data for classification and feature extraction.

The use of contextual image processing for map updating is being discussed in two papers given by Gorte, Sijmons and Mulder from the ITC of Enschede, The Netherlands (**ref nos 5**

and 9). Contextual information at a higher processing level is fed back to filter parameters of a lower level. Once the maximum information has been extracted from the data a human operator will finish the updating task by line and area editing in the raster domain. An option is provided to link the raster data base of objects, attributes and topology to a classical GIS like ARC/INFO. In another paper from ITC Radwan and Mulder has carried out a correspondence analysis to identify the same or similar objects in images taken at different times and from different view points and to identify where relevant changes in maps have occured. An object oriented database is described which supports the selection of objects based on property lists and topology **(ref no 10).**

6.3 STEREOPLOTTING

A stereoscopic work station has been developed in cooperation with the Photogrammetric Institute at the University of Hannover as an option to the ContextMapper. It basically contains two image processing displays with freely movable images and fix floating marks. The operation of the work station is controlled with a mouse and pop up menus. A detailed description of the functionality of the work station is given in a paper given by Lohmann, Picht and Jacobsen from IPI, Hannover together with Skog, Teragon Context **(ref no 11).** Some of the main features of the stereo work station are:

- Stereo viewing
- Handling of arbitrary image sizes
- Real time zoom and roam
- Sub-pixel measurement accuracy
- Vast set of photogrammetric orientation, adjustment and compilation software
- Enhancement and feature extraction on line
- Automatic DEM generation
- Superimposition of graphics
- On-line editing

The stereo work station can be used for mapping from aerial photography or remote sensing data as well as for high precision industrial measurements. It is assumed that the work station will in the first place be used in combination with satellite data or other imagery already existing in digital format.

Stereoscopic satellite data can also be recorded on filmwriters for further processing in analytical plotters however with a certain loss in interpretability and geometric accuracy **(ref no 12).** The task to digitize photographs rather than to use the films directly in a conventional photogrammetric plotter may seem overambitious and inefficient. On the other hand the potential for image analysis seems so high that it may have a direct impact on how photogrammetry should be practised. This will be further explored after the congress. The techniques for feature extraction and correspondence analysis is of course also applicable to stereoplotting. Another reason for building a stereoscopic work station is the increasing number of platforms offering stereoscopic coverage in digital format.

An essential component in photogrammetric processing is to correlate homologue points within stereo image pairs. In the stereo work station several strategies for automatic correlation can be used. Many of the different methods give as low mean square errors as fractions of a pixel. The method of least square matching has successfully been used by Rosenholm at the Swedish Space Corporation **(ref no 13).** Some aspects on the correlation procedure implemented is given by Sasse in his paper to the ISPRS Congress **(ref no 14).** One spectacular feature is the automatic generation of a DEM from arbitrary sized images. By superimposing the results of the correlation in vector format on the stereoscopic model the operator has the possibility to check and also edit the results. For perfect viewing all images are resampled to epipolar geometry.

Another approach to DEM generation has been taken by Kostwinder, Mulder and Radwan from ITC, presented in their paper (**ref no 15**). In contrast with classical methods for "stereo correlation" which perform correspondence analysis at the signal processing level the authors report on the progress in correspondence analysis at the segment and object levels. Correspondence is quantified on the basis of model constraints and minimum "distance" between left hand and right hand property lists.

Digital elevation models (DEM) form an important part of many applications of the ContextMapper. To perform Monoplotting or Image Rectification from images over areas with significant variation in elevation a digital elevation model (DEM) describing the topography is required. DEMs can be stored as Z-values in equally distanced grids but also as "Z-images" pixel by pixel.

Various DEM operations like hill shading, automatic contouring, slope mapping, colour coding etc can easily be performed by using the existing software.

6.4 GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

The ContextMapper opens a new dimension for processing and presentation of geographical data. In the ContextMapper aerial photographs, remote sensing data, topographic data, geological data, statistical data, virtually any data describing our geographic environment can be combined, processed and presented to non-experts. This is accomplished through different software modules and a few peripherals to an optimized, but yet to the user standardized, hardware; the ContextMapper. Raster to vector conversion and vice versa is supported by the Basic Image Processing Package. Geo-coded map data can be transferred to and from local digital cartographic data bases via nationally standardized interchange formats. Coded vector data can also be output on penplotters.

All images and maps in raster format can be stored in a raster data base. Maps and images of interest can be searched, displayed and put into register with any coordinate system. In the standard software a set of logical Boolean operations exists for combination of different data types. Also the image calculator can be used.

Data from any vector GIS can be transferred to the ContextMapper, converted into raster format and cartographic feature extraction. As a result of the processing the resulting data can be vectorized, coded and transferred as update files to any external GIS. Some of the results from linking the Arc/Info GIS from ESRI are described in the above mentioned paper by Sijmons and Mulder (**ref no 9**). Also at IPI there is an interface between an Arc/Info system running on a VAX 11/750 and the ContextMapper. An installation of the Arc/Info on a Sun work station for direct communication is foreseen. With the internal Sun-3 Host processor 3rd party GIS software may easily be run directly in the system or in a network on any computer connected to Ethernet (or another network supported by Sun Microsystems) ranging from PCs to big main frames.

In cooperation with the Norwegian Computing Centre in Oslo a raster database has been developed for the ContextMapper (**ref no 16**). The importance of a raster data base is very much dependent on the computing speed of binary raster operations. As described above such performance is given by the BOP.

6.5 IMAGE RECTIFICATION

Any images or maps in the system may be transferred to any projection system, provided there is enough information to calculate the projective relationships. This information can be entered either as predefined values or by matching an input image with a map or an image in the desired projection system. If a digital elevation model (DEM) is introduced orthogonal projections in any coordinate system can be resampled (using the GTP) taking also height variations into consideration. The mosaicing software enables the user to produce orthophoto maps from a series of adjacing photographs or satellite scenes. The orthophoto production is described in a paper by Müller from IPI and Sauleda from Teragon Context AB (**ref no 17**). The software is able to handle digitized photographs as well as the nearly central perspective SPOT images and other special geometries.

Perspective views can easily be resampled. Consecutive perspective views can be generated for flight simulation or display of consequences of planned building and highway projects.

6.6 IMAGE OUTPUT

The ContextMapper offers unique possibilities to produce instant colour maps or screened film separations for offset printing. Rectified photographs or satellite images can be combined with digital cartographic data in raster format. In this way colour maps can easily be produced in the system. Results are inspected and corrected via the interactive colour display. Interfaces (hardware and software) have been developed for output of images or maps in raster format on different output devices

film recorder gives a photographic copy of the image displayed on screen

film writer gives a continuous tone output on film. The size of the image is determined by the size of the image on file (disk or image register), the resolution of the film and the maximum film size of the filmwriter.

raster plotter gives output on paper or film via ink jet or electrostatic techniques

laser writer post script (this format can also be used for transfer to foto type setters or to PC-based page make-up systems)

magnetic tape for transfer of image data in any format required by an off line printer (e.g. data can be transferred to Scitex plotters in 280 as well as 350 format)

video for presentation of video sequences on video tape recorders

7. CONCLUSIONS

The described system has all the essential components of a digital photogrammetric mapping system in which the techniques for digital mapping of analogue images, digital images and their combination with existing map data can be evaluated, processed and analyzed. This is the prerequisite for the new area of the GIS-technique. It has been clear to the authors that a few hardware modifications of the existing system are necessary to fullfill all possible requirements in a photogrammetric production environment. However, by this design important knowledge has been gained which has been used in the development laboratories of Teragon Context. Most important is the possibility to test how image processing can favourably be used in the mapping process. The present version of the ContextMapper is an excellent tool for resource mapping and analysis from satellite imagery. The project continues with intensified development of new hardware and software modules.

List of references

1 **A digital image mapping system** by Lars Skog, Teragon Context AB, Stockholm, Sweden

2 **Introduction to GOP computer vision** by Gösta Granlund, Linköping University, Sweden

3 **The use of SPOT and CIR aerial photography for urban planning** by P. Lohmann and G. Altrogge , University of Hannover, Institute for Photogrammetry, Hannover, West Germany

4 **Textural features useful in classification of digital images** by Knut Conradsen and Bjarne Kjær Nielsen, Technical University of Denmark, Lyngby, Denmark

5 **Cartographic feature extraction and thematic classification based on context dependent filters** by B. G. H. Gorte, N. J. Mulder, ITC Enschede, The Netherlands

6 **Photogrammetric data acquisition using the digital reseau-scanning system Rolleimetric RS1** by T. Luhmann, W. Wester-Ebbinghaus, University of Hannover, Institute for Photogrammetry, Hannover, West Germany

7 **Teragon 6000 CCD flatbed scanner,** Technical Description

8 **A photogrammetric monoplotter for digital map revision using the image processing system GOP-300** by John Stokes, The Royal Institute of Technology, Institute for Photogrammetry, Stockholm, Sweden

9 **Computer assisted map updating using SPOT data and context dependent classification methods** by K. Sijmons, N. J. Mulder, ITC Enschede, The Netherlands

10 **Correspondence analysis applied to image matching and map updating** by M. M. Radwan, N. J. Mulder, ITC Enschede, The Netherlands

11 **The design and implementation of a digital photogrammetric stereo-workstation** by P. Lohmann, G. Picht, K. Jacobsen, University of Hannover, Institute for Photogrammetry, Hannover, West Germany and L. Skog, Teragon Context AB, Stockholm, Sweden

12 **Aerial triangulation of SPOT and aerial photography** by K. Jacobsen, P. Lohmann, G. Picht, University of Hannover, Institute for Photogrammetry, Hannover, West Germany

13 **Multi-point Matching along Vertical Lines in SPOT-images** by Dan Rosenholm, The Royal Institute of Technology, Institute for Photogrammetry, Stockholm, Sweden

14 **Realisation of automatic correlation within a digital stereo plotter** by V. Sasse, University of Hannover, Institute for Photogrammetry, Hannover, West Germany

15 **DEM generation from SPOT multiple view images, using correspondence analysis on segmented data** by H. R. Kostwinder, N.J. Mulder, M. M. Radwan, ITC Enschede, The Netherlands

16 **A Database for Handling Raster Information,** BILD/19/87 by Margaret Robb, Jean-Pierre Caillot, Bo Wang, Norwegian Computing Centre, Oslo, Norway

17 **Orthophoto production in the ContextMapper System** by W. Müller, University of Hannover, Institute for Photogrammetry, Hannover, West Germany and H. Sauleda, Teragon Context AB, Linköping, Sweden