

# The design and implementation of a digital photogrammetric stereo-workstation

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## 1. Abstract

The design and implementation of a digital photogrammetric stereo-workstation based on a commercially available image processing system, the GOP 302, is presented. Aspect of theoretical background and practical implementation are discussed and first results obtained during the test phase are presented. The system includes a stereo display, measurement and orientation programs as well as a package for digital correlation and orthophoto production for aerial photography and SPOT images.

## 2. Introduction

The amount of digital photogrammetric data originating either from satellites like SPOT or by digital scanning of photographs is recently increasing. Furthermore there has been a tremendous development in the field of digital image processing in the past including the geometric processing of imagery. This led to the idea of having a complete digital mapping system including a photogrammetric workstation based on digital image processing techniques. The overall system is shown in figure 1. An overview of the total system is given in /1/. This system is the joint development of different groups including the institute for photogrammetry in Hannover, as well as the manufacturer of the image processing system CONTEXT-VISION.

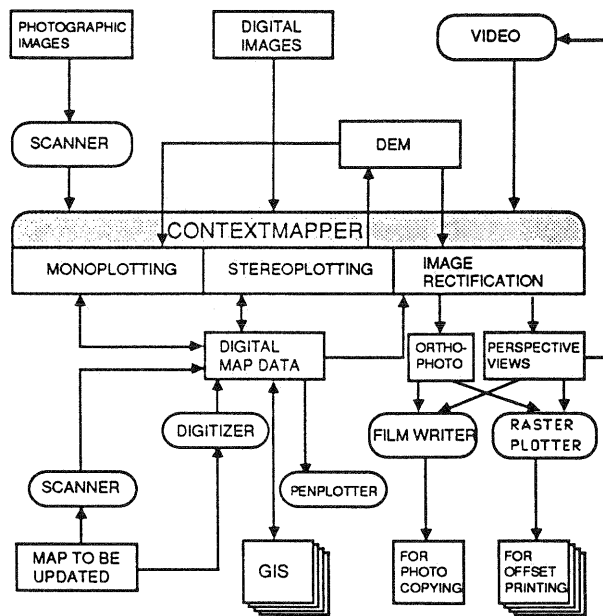


Figure 1: The CONTEXT MAPPER System

The idea of a digital stereoplotter in which analogue photographs are replaced by digital image memories is not new. A first concept was given by Sarjakoski (1981) /2/ who also stated the major advantages of such a system to be

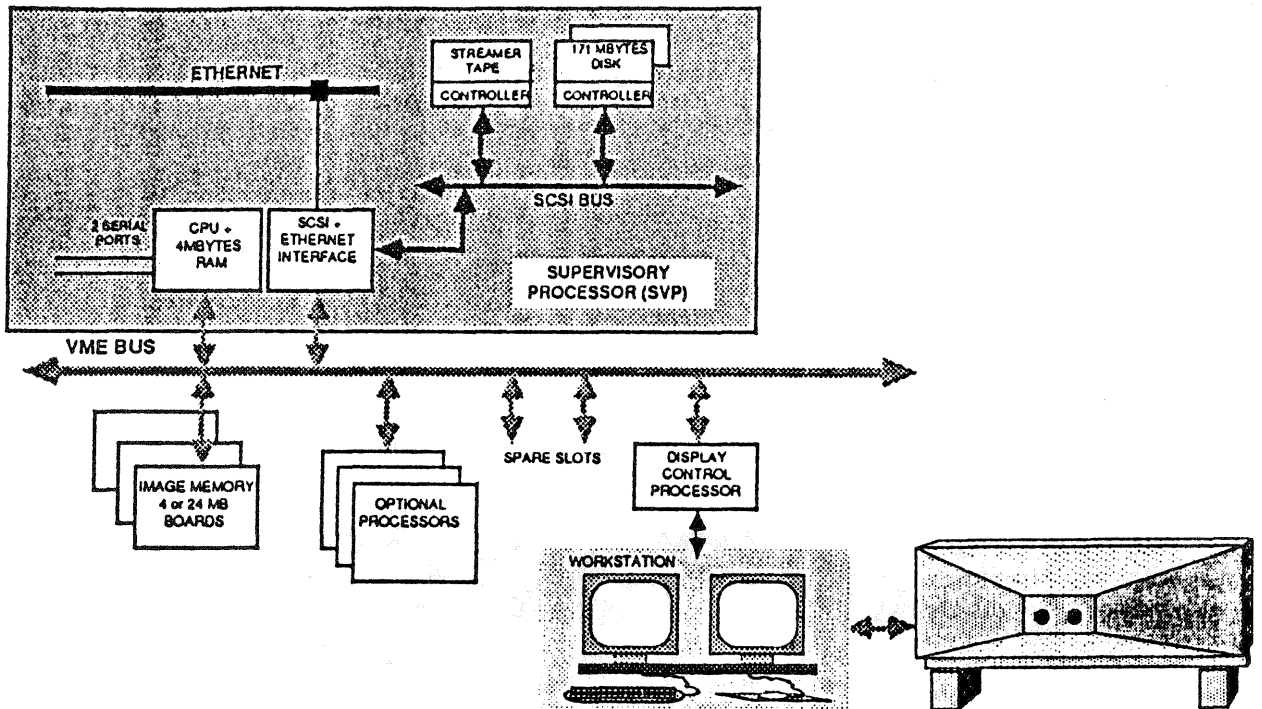
- stable geometry of digitized images
- no need for high precision mechanical components
- advantageous use of image processing techniques in addition to photogrammetric processing.

Gugan and Dowman /3/ described the main requirements for such a system to be the ability of real-time scanning of the model area, sub-pixel measurement accuracy, 3-d floating mark control and stereo viewing.

These requirements and the emphasized application of digital correlation techniques were the primary design ideas at the beginning of the system development.

### 3. Hardware used in the project

The digital photogrammetric workstation is based on a commercially available image processing system GOP 302 for CONTEXT VISION, (figure 2).



The host processor consists of a SUN-3<sup>TM</sup> supervisor processor (SVP) with 20 MHz MC 68020 CPU and 68881 floating point coprocessor running under UNIX 4.2 operating system. Special processors like the GOP (General Operator Processor) for fast complex filtering and correlation and the GTP (Geometric Transform Processor) for quick geometric transformations and resampling can be accessed via the VME bus. The digital images are stored on Winchester disks or optional optical discs. The size of the images is limited only to the size of the discs.

The basic system is equipped with one display control unit (DCU) per workstation. This DCU is based on a MC68000 display control processor (DCP) having a real time operating system written in MODULA 2. The DCP with its own local VME-bus controls the image display system and its related display functions. It communicates with the SVP VME-bus via a dual port RAM of 16 K. In addition 4 serial communication lines (TAP's) are available. Images, graphics, menus and also the cursor in its current position are stored in the Display Memory. The memory is organized in an image area of 1 Megapixel (16 Bit) and a menu area, where each of the

cursors, menu and two graphic planes occupy a full one bit plane. Using a full bit plane for the cursor allows freedom to move over the entire display without restrictions, as well as choosing an arbitrary cursor shape. The display window is 512 x 512 pixels, which may be roamed realtime over the total of 1 Mega pixel area.

Due to the limited size of the display window two DCU's have been selected each controlling one color monitor. These two monitors have been placed under a mirror stereoscope encapsulated in a viewing box (figure 3).

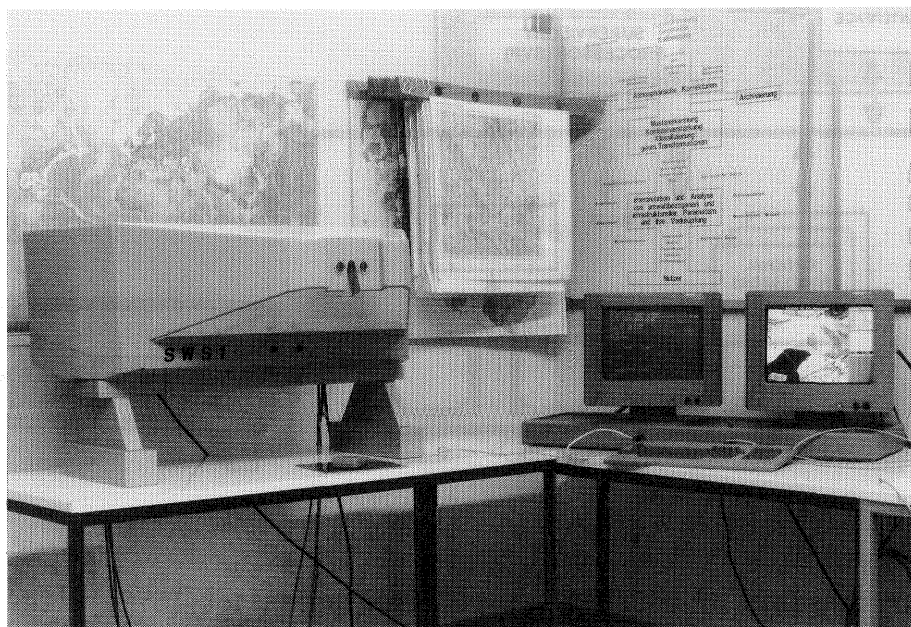


Figure 3: The CONTEXT MAPPER stereo-workstation

Split-Screen display was regarded to give a too small field of view especially for images digitized at a very high resolution.

The choice of two DCU's in addition provided full use of color image processing power in each display. However because of the use of a mirror-stereoscope and the lack of DOVE-prisms the images have to be resampled to epipolar line geometry in order to make full use of the menu technique on the display screens. This resampling is done with the GTP which has a performance of 0.1 Mpixel/sec including cubic convolution. The typical time of resampling one image at a size of 2300 x 2300 pixels to epipolar geometry is roughly 1 minute.

The use of two independent DCU's required a software layout, being able to synchronize and control both DCP's.

#### 4. Design and implementation of the stereo plotter software

##### 4.1 The stereo workstation control program

A stereo workstation control program has been developed, which communicates with both DCU's via dual ported memory DPM and message queues. This software handles all image and coordinate transfers as well as necessary data type conversions.(figure 4). This software also assures all interprocess communications and - control via 2 listener processes interfacing the workstation control program and the DCU's. These listener processes act on DCU requests. The interface between the application program and the workstation controller is handled by Remote Procedure Calls (RPC), which are realized as kind of a library both on top of the application program as well as in the workstation controller. A so called loop library serves for the transformation of the received pixel coordinates coming via coordinate taps to the required photo-, model- or object coordinate system.

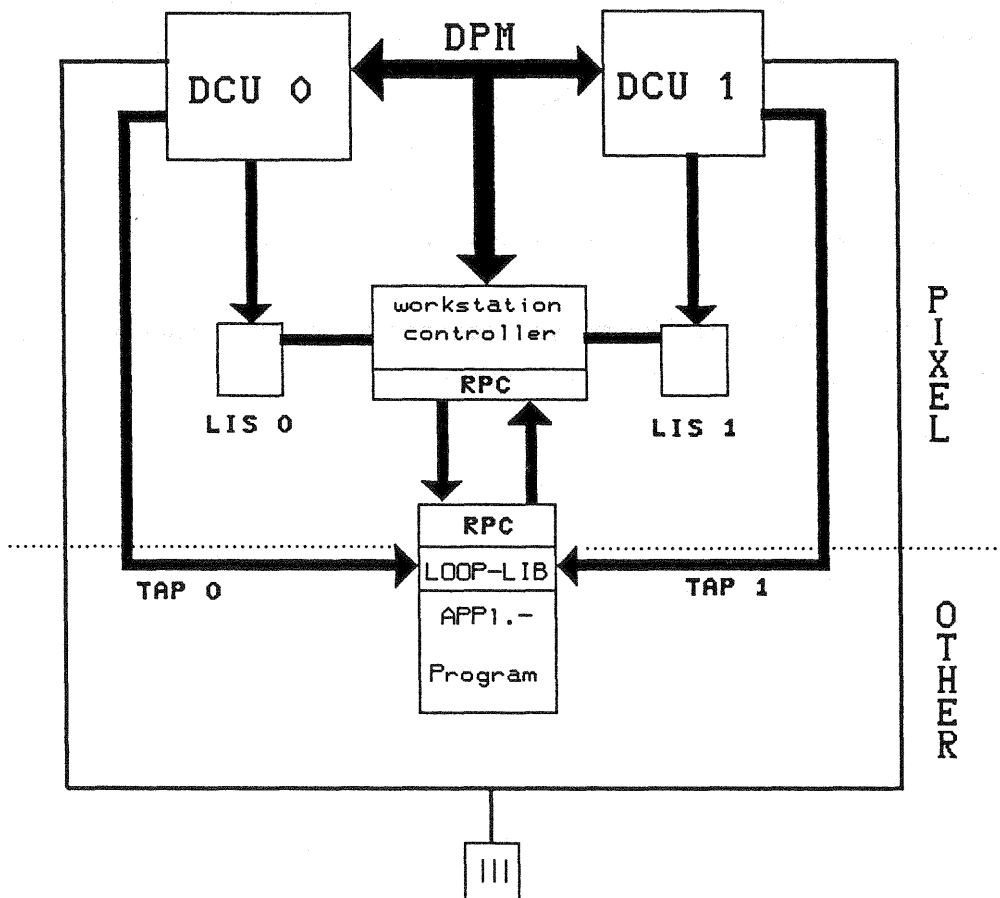


Figure 4: Control and Data flow

All interaction with the display is performed by a 3 button mouse which is linked in parallel to both DCU's. The DCU's have a real time operating system covering the display control software. This software is totally menu driven and image processing as well as measurement actions can be invoked by soft-buttons with the mouse. This menu is on the right side of each display and is user programmable. In addition the display control software contains a graphic package as a subset of GKS with some extensions.

The stereo plotter utility functions inside the DCU comprises the following tools:

- Center floating mark to display window. (The position of the floating mark is fixed)
- Roam both images simultaneously in both DCU's which means real time movement of display window relative to memory
- Fix left image relative to right image (Roam only in right image)
- Next frame. This function loads the total display memory centered at current floating mark position
- Jump (Fast Move). When this function is activated a graphic window appears in the menu area representing the total area of the left image. Within this window a box representing the display window can be moved arbitrary to any position by mouse movement. By doing so the user can select any portion of the image or model to be displayed. The display memory is reloaded at the actual position of the box.

The three buttons of the mouse together with its movement are programmed in a way that the user can select

- accept coordinates (Read)
- ignore coordinates (Reject point)
- switch to menu control
- movement in x, y, z

## 4.2 Orientation Programs

### 4.2.1 Interior Orientation

This program is necessary only for digitized photographs. The user has the option of selecting a manual or automatic mode. In either mode the image is down sampled to the display window size and the user is asked

to roughly digitize position of the fiducial marks, which for the case of the user are graphically displayed on an alphanumeric display, which is part of the workstation.

In automatic mode templates of the fiducials, which may be created by the user, are matched by digital correlation with the fiducials of the image file in the background with subpixel accuracy /4/. In case of correlation failure at any fiducial position the image is displayed at that position and the user is prompted for manual measurement, where he can make use of all display control software options like zooming (1 to 32 times) or contrast enhancement.

Similarity or affine transformations are used to compute the interior orientation according to the number of fiducials. Each measurement of a fiducial serves for correcting the pointing position for the next fiducial.

#### 4.2.2 Bundle Orientation

The traditional method of exterior orientation is separated in relative and absolute orientation. This is necessary for analog photogrammetric devices. For analytical and digital photogrammetric workstations it is not necessary, will not lead to the most accurate results and limits the possibilities. For example a relative orientation with very small angle photographs has high correlated unknowns and often not usable results are achieved. So extreme small angle reconnaissance photos and makro photos can not be handled by relative orientation, even the sowjet space photos from KFA 1000 (1 m focal length) are causing problems.

The bundle orientation program BUNOR computes approximate orientations in a very flexible manner and locates blunders in the bundle adjustment by data snooping. The orientations can be computed also with control points located not in both photos up to independent resection of both photos. Systematical image errors can be computed by self calibration with additional parameters. Standard deviations of unknowns are listed /5/.

#### 4.2.3 Measurement Program AMOC (Advanced Measurement of Coordinates)

The program serves as a acquisition tool for image coordinates on the stereo plotter, where the user has the option either to measure in monoscopic or stereoscopic images. As input a project definition file

and a camera calibration file are required in addition to the endlap for the approximation of the image coordinates of a measured point in the right image.

The measured pixel coordinates are transformed to photo coordinates by the use of the parameters out of the interior orientation. The measured image coordinates may be stored in a file for later use by bundle orientation or block adjustment. In addition to manual pointing the user may select the correlation option. This method requires the exact positioning in the left image while the correlator finds the homologues point in the right image automatically. The search window for correlation may be any rectangular window up to a size of 120 x 120 pixels, while the pattern matrix is restricted to 27 x 27 pixels. Interpolation to subpixel position is carried out by calculating the point of maximum correlation with a twodimensional polynomial.

Further options are being implemented such as the automatic positioning by means of known point coordinates which are known to the system by prior models or by predigitized positions in paper hard copies.

#### 4.2.4 DTM-generation

Measurement of DTM's can be made either manually or by automatic correlation. The latter requires that the user defines the window of the DTM in object coordinate system as well as the gridspacing in x and y. The correlation may be performed by an offline process resulting in a file of x, y, z and the correlation coefficient which may be used for editing bad points, or the user may select an interactive mode, where he has control over the correlation, because the images are displayed and he is able to follow the floating mark pointing to the terrain. The correlation may in addition be context controlled, which means that an existing classified image may be used to avoid correlation in selected areas (i.e. forest areas). Other options allow to delete spot heights which do not fit to their neighbours.

#### 4.4.5 DTM Editing

This program allows for 3 dimensional overlay of graphics to the model where good points, whose correlation coefficient is above a user definable threshold are marked in green and bad points are marked in red. The user has the option to remeasure those points or delete them totally.



#### 4.4.6 Contour Line Generation

Beside manual measurement of contour lines, they may be computed out of DTM files. In addition to the graphic representation of the contours they may be displayed in color, where the color represents the orientation of contour line element in its neighbourhood or the consistency of orientation (standard GOP operation) which might be used as information for generalizing the contour lines. Figure 5 shows a correlated DTM where the height of each point (pixel) corresponds to its intensity. Figure 6 shows the resulting contour lines computed out of figure 5. Figure 7 shows the same area as a plot of contour lines out of an existing base map.

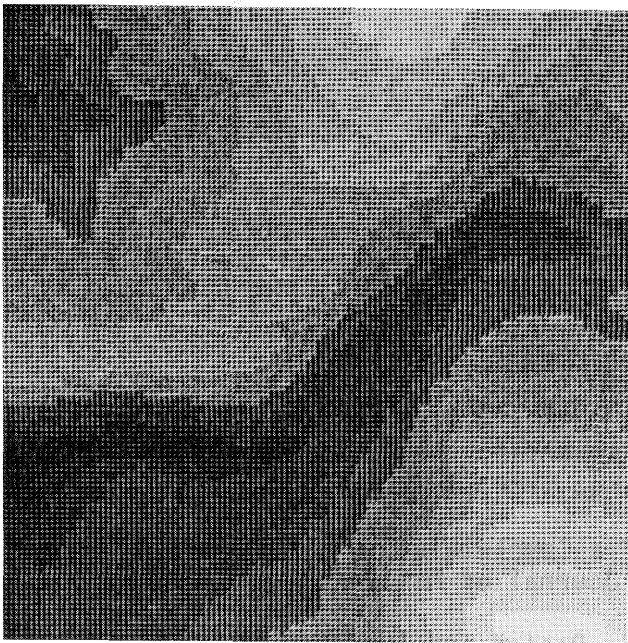


Figure 5: Correlated DTM

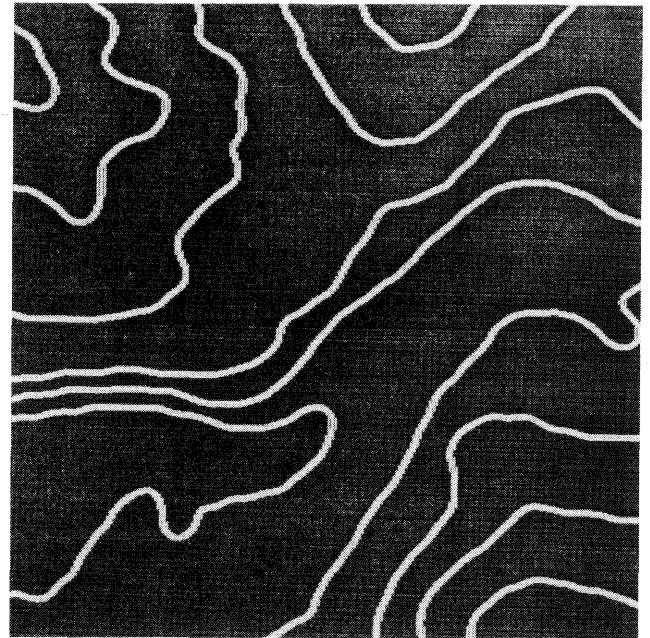


Figure 6: Contour lines computed from figure 5

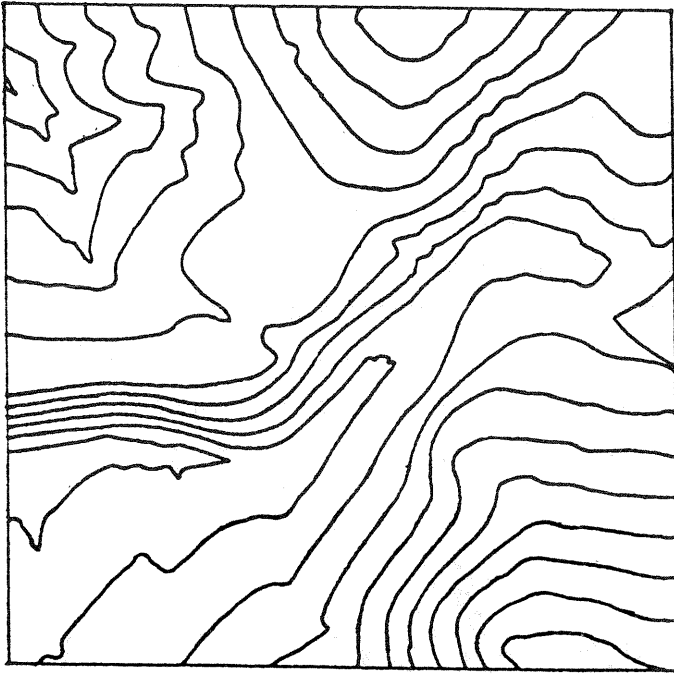


Figure 7: Contour lines from an existing base map

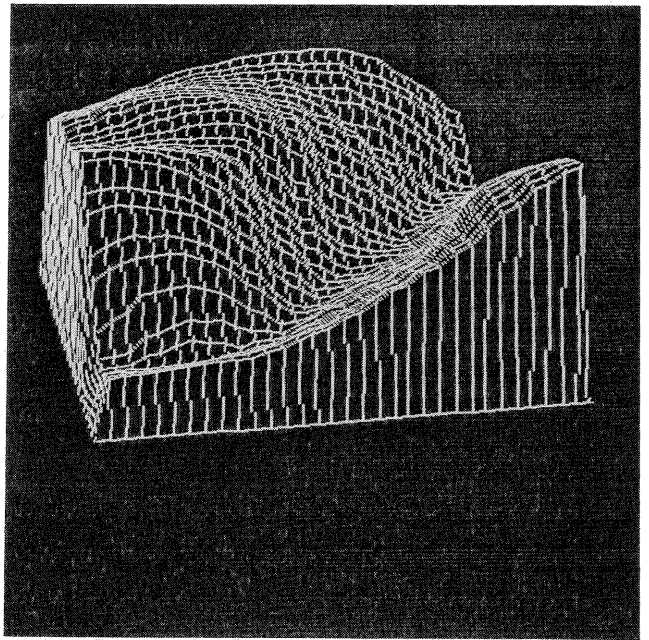


Figure 8: Optional perspective display of the DTM

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