

A DIGITAL PHOTOGRAMMETRIC WORKSTATION

FOR THE EVALUATION OF SPACE DATA

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The planned MOMS-02/D2 mission which is presently scheduled for launch in spring of 1993 on the second German Spacelab Mission D2 will deliver three-line imagery from CCD sensors. This leads to a development of a digital workstation for the evaluation and interpretation of digital data. The design and functionality of this station is explained, whereas the emphasis is laid on the interactive tasks.

Key Words: digital system, image interpretation, system design

1. INTRODUCTION

In the recent years the trend to so-called softcopy photogrammetric workstations is obviously. Mainly the rapid progress in computer technology and the incidental lower costs are responsible.

Many technical problems, that recently seem nearly unsolvable, are getting smaller. Keywords in this context are storage of large data amounts, fast access and process of data, faster and better scanning technology, satisfactory stereoscopic display and so on.

On the other hand the improvements on the field of sensor technology make digital data (SPOT2 and further developments, ERS-1 etc.) available in upward tendency.

The planned MOMS-02 (modular optoelectronic multispectral scanner) mission is another project in this context, but with special purposes and aims.

The expected huge amount of data and the related demand of computer performance led to the development of a UNIX-based digital workstation, where the complete digital flow from data acquisition to exploitation shall be realized.

This paper emphasizes the design aspects as well as the necessary interactive tools for creating and updating digital topographic maps.

2. BACKGROUND

MOMS-02 is an experimental development for digital mapping of the earth's surface from space. The electro-optical scanning device was first flown on two Space Shuttle missions in 1983 and 1984. The continuation takes into consideration the increasing requirements of the photogrammetric and thematic sciences.

The system consists of five lenses, two for multispectral recordings (with a total of four spectral bands in the visible and the near infrared range of the electromagnetic spectrum) and another three for stereoscopic images. The high resolution central lens records 8400 pixel

per line, this leads to a pixel size of $4.5 \times 4.5 \text{m}^2$ on the ground. The two other stereo lenses are inclined to $+21.9^\circ$ and -21.9° , respectively, their resolution is as three times worse. With an orbit altitude of 296 km a swath width of 37km in the stereo mode and 78 km in the other modes can be achieved. The base-height ratio is 1 : 0.81 for the stereo evaluation (see Fig. 1).

Due to limitations of other experiments the orbit inclination has been reduced to 28.5° for this one week mission. But in case of an successful flight the scanner is going to be carried on the MIR-Prroda platform of the Soviet Union in 1995 for a three year operation in a 51.6° inclination and a 350 km orbit height.

The MOMS-02 concept is different from other remote sensing systems and offers a lot of advantages. For example in contrast to SPOT along-track stereo imagery is given in four of seven recording modes. Further features are

- high geometric resolution and accuracy
- stereo capability in panchromatic mode or in combination with the multispectral channels
- specific layout of the four multispectral channels

The scientific objectives are investigated with regards to the photogrammetric and the thematic-geoscientific aspects. The photogrammetric group consists of the Universities of Stuttgart / Bonn, Munich (Technical University and University of the armed forces) and Hannover, under the leadership of the German Aerospace Research Establishment (DLR, Institute of Optoelectronics).

Their tasks are the development and realization of a concept for a complete digital photogrammetric data acquisition and evaluation from the three-line scanner.

The main topics are as follows:

- 1) point determination for the orientation of the scanner using the concept proposed by O. Hofmann (Hofmann, 1982)
- 2) automatic point recognition and automatic DEM reconstruction of large surfaces with high geome-

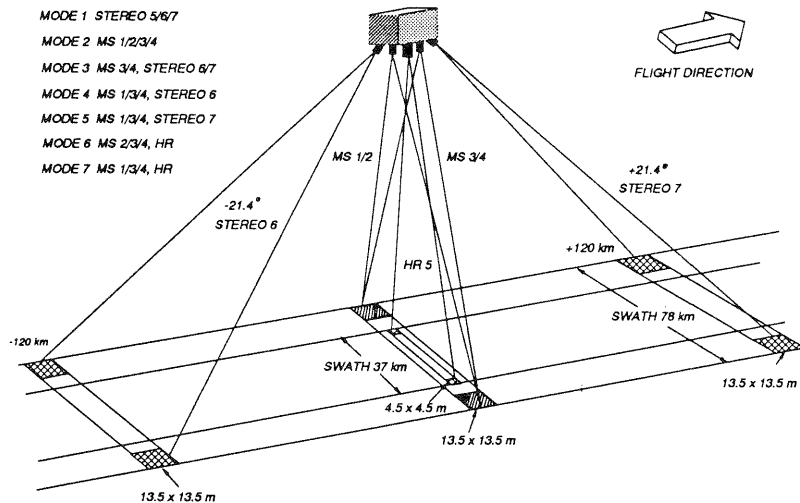


Fig. 1: MOMS-02/D2 scanner layout

try from digital stereo imagery

- 3) computation of orthoimages and orthoimage maps
- 4) the analysis of the cartographic potential of the MOMS imagery
- 5) the extraction of vector data for line maps and for a further process in geometric information systems
- 6) the design of a digital workstation for visualization, interpretation and interactive measuring
- 7) algorithm for analog evaluation of three-line imagery on analytical plotters.

3. GENERAL OBJECTIVE

The separation in assignment between the joined institutes leads to the task in Hannover to design the soft-copy workstation and to solve all problems, that are concerned with the interactive use of such a station, to investigate the expected cartographic potential and to create a link to a geographic information system for further processing.

Bad experiences with special hardware systems and the increasing progress in computer technology led to the demand to use custom-built hardware with common periphery.

The commitment to open and modular systems allows the transition to better hardware in the future without greater changes of the used software. The integration of standard software is easily possible.

Divergent from this aim a special graphic accelerator for a fast image handling is used at present, but all programming code is strictly separated in modules. An abandonment of special accelerators should be possible in the near future, if hardware progresses continuously.

The digital station is designed first of all to process three-line imagery of MOMS-02 with its special mathematical model, nevertheless other input data sources, such as SPOT satellite imagery and digitized aerial frame photographs shall be evaluated, too.

4. HARDWARE

4.1 Workstation equipment

Base of the digital workstation is a SUN SPARCstation 4/370 with a performance of 16 Mips and 2.6 MFlops. A 19" color monitor with a pixel resolution of 1152 x 900 is used as the standard monitor for the control and the management of the plotter software. The monitor is accelerated by a GX graphic accelerator.

The main memory of the system is 56 MByte at present, disk storage capacity is about 2 GByte, for local backup a 150 MByte streamer tape is used.

4.2 Stereo equipment

For stereo viewing the standard SUN hardware had to be extended. A second (multifrequency) 19" monitor is connected and the stereo solution CrystalEyes by the company Stereographics is used.

This unit consists of a controller; an infrared transmitter and wireless LCD shutter glasses.

The controller is responsible for stereo-viewing with 120 Hz or mono-viewing with 60 fields per second, respectively.

The infrared transmitter controls the synchronisation with the eyewear and the radius of emission for one or more eyewears.

The battery powered shutter glass has buttons for stereo / pseudo view and 3D / Brite view. The first button controls which image you see on the left and on the right eye, respectively. In the 3D mode the lenses switch in synchronisation with the monitor fields, in the Brite mode the lenses will transmit twice the light. The latter mode is important for looking at the standard monitor. The pulses are detected by the eyewear sensor.

The used technique for stereo viewing bases on the electric polarization of crystal planes. Both stereo partners have to be loaded in the frame buffer one after the other. In the mono mode with 60 Hz the first image appears on the upper side of the monitor, the second on

the lower one (see Fig. 2). The controller doubles the frequency for the monitor up to 120 Hz, so the images are displayed alternately (Fig. 3). The user may view either monochrome or true color images in stereo.

The electronics of the eyewear detect the infrared signal broadcast by the emitter to switch the liquid crystal lenses in synchronization with the image fields at the display. In this way it is guaranteed that by displaying the upper image the right lens is closed and by displaying the lower image the left lens is closed.

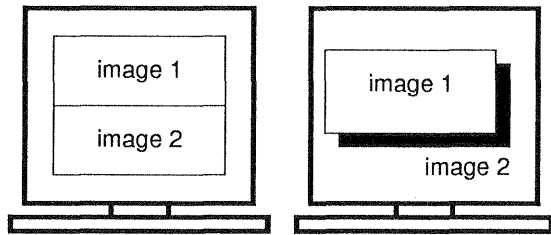


Fig. 2: mono view

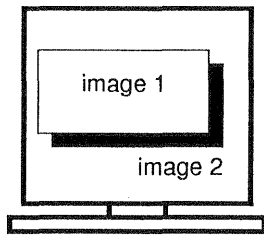


Fig. 3: stereo view

SUN supports up to now a display solution for the second monitor of 1152 x 900 pixel, in the near future a solution of 1280 x 1024 shall be available.

This active polarization technique reduces the vertical resolution by half and stretches the stereo image, however the monitor can be adjusted to compensate this.

Therefore the theoretical display size in the stereo mode is 1152 x 450 pixel at present. But the display of a zoom and an overview window however caused a smaller image view.

4.3 Graphic accelerator

For a real time image handling another extension was necessary. The graphic accelerator board SUN VX, connected to the host via the VME-bus, delivers the necessary performance and flexibility for both graphics and imaging.

The features are

- 32 bit processor (i860) with 40 Mips and 80 sp / 60 dp Mflops
- 4 Mbyte VRAM program / data memory
- dual frame buffer:

VX frame buffer with 16 MByte RAM and 32 bits per pixel

GX frame buffer with 2 MByte RAM and 8 bits per pixel

The processor is extendable by the multi-processor board SUN MVX with four parallel i860 boards. The frame buffer can also be enlarged up to 126 MBytes in the near future.

4.4 3D input device

A common disadvantage of all commercial built workstations is the lack of an appropriate device for 3D pointing and measuring.

Solutions with techniques used by the analytical instruments were rejected. Therefore two other possibilities are tested.

1.) Two commercial trackballs (Fig. 4 and Fig. 5) are connected to the host via the serial interfaces. A second process records the trackball movements and communicates with the plotter per pipe. The first trackball is responsible for the x- and y- directions, the second for the height, whereas one function is disconnected. Both trackballs get three buttons each which can be loaded with important and often used functions, for example to call the zoom and to store points.

This solution is similar to the well-known hand-wheels at the conventional analytical plotters.

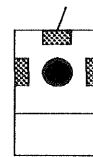


Fig. 4: trackball for x and y direction

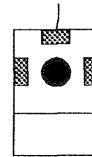


Fig. 5: trackball for z direction

2.) Instead of the second trackball a one-directional wheel (Fig. 6) can be used for the vertical movement. This wheel has been constructed at the institute and can be fixed at the trackball. In this way the operator can control all necessary movements with one hand. A disadvantage however is the loss of the three buttons of the second trackball. For lefthanders the wheel can also be fixed at the right side.

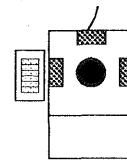


Fig. 6: trackball and z-wheel x, y and z direction

4.5 Digitizer

For the approximate positioning of points a Digitizer (18" x 24") with high precision is connected to the host also. The tablet offers 12 user programmable function keys. The sixteen button cursor can also be coded by the user. So a wide range of applications can be supported. As a special detail the above described z-wheel can be fixed at the cursor, so a complete 3D measurement is possible with the digitizer (Fig. 7). This solution is realized in dependence on the P-series analytical plotter from the ZEISS company.

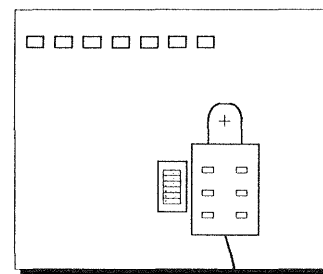


Fig. 7: digitizer tablet and z-wheel

The described possibilities have to be tested for their practical operation. Nevertheless the user can choose his own preferable equipment.

4.6 Digital Inputs / Outputs

Although getting digital input data within the MOMS project should not be the problem (successfully they will be in digital form), a scanning device is essentially necessary for a softcopy mapping system. In the institute an Optronics P1700 and a HP scanner IIc (400 dpi, 24 bit depth, 8" x 11") are available at present.

Output devices can be divided into film writers, pen and raster plotters (ink-jet, electro-static, thermal-transfer etc.). At disposal are the HP pen-plotter 7580B, the Mitsubishi thermo-sublimation printer S340-10 (150 dpi, 24 bit depth, 1184 x 1450 pixel) and a Calcomp electro-static plotter (400 dpi, 33" x 46"). For the output of reports a laser printer is connected.

Figure 8 illustrates the main components of the workstation.

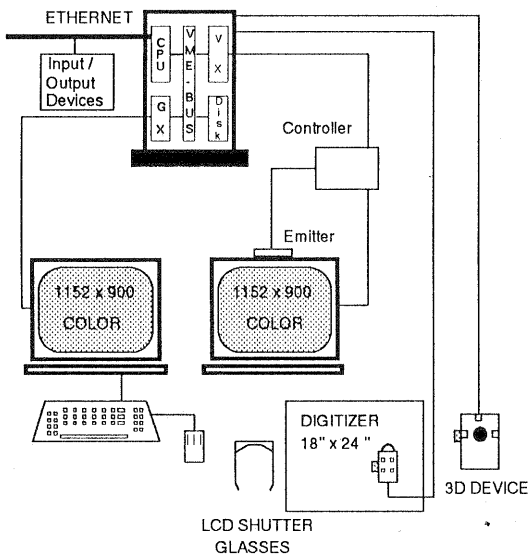


Fig. 8: workstation environment

5. SOFTWARE

5.1 General Notes

Principle of the development is the programming in standards on an open system. A vast independence of special solutions facilitates the portability to better systems in the future and reduces the costs of changing the hardware. This seems to be the only promising way under the banner of the rapid computer progress.

In consequence for example all programming code related to the special accelerator VX is strictly divided into separate modules. An exchange to other hardware should be possible with minor modifications.

A UNIX-based workstation seems to fulfil these requirements at best. The very common company SUN with its operating system SunOS is used. Programming languages are C and partly FORTRAN.

The two-display-solution is chosen for a complete separation of image data and menu display. On the SUN monitor all applications are controlled under the Open-

Look environment, the menus are designed with functions of the XView library. The solution of the second monitor can be used completely for image display.

The following software aspects emphasize the interactive interface of a digital workstation. The human operator has to meet the same possibilities as known from the analytical plotters. However the main advantage is the combination with automatic image processing methods. Orthophoto generation, automatic DEM and feature extraction, automatic point determination are some keywords. These features are tasks of the joined institutes and shall be integrated.

5.2 Image Processing and Database

For all image enhancement tasks the image processing system XDibias, developed by the DLR, is used. It consists of a wide range of applications, like histogram equalization, brightness and contrast control, filter and rotation possibilities, a tool for mono measuring and graphic overlay and so on. Part of the system is also the hierarchical database db_Vista. An interface has been created between the database and the digital plotter. Taking into account the expected large amount of digital data in the future, a powerful database is important for an effective management. The database delivers references to image data as well as to additional data (graphic overlay, sensor data, history of images, ...). For example the user can easily get information about what area is covered by how many images. So data from different sources and acquisition times can be combined.

In the beginning the user defines a project file with all information necessary for displaying and handling the digital data. It consists of image paths, paths to all related files (GCP files, orientations, vector data, ...) and so on. In this way the project file focuses the necessary informations and controls and updates their disposal; the file is stored in the database.

5.3 Image Display

The selected image (listed in a menu and given by the project file) will be loaded from the disks into the random access memory. The loadable image size depends on the available RAM.

For the real display on the second monitor a maximum of 1200 by 1200 pixel in 32 bit depth (for one image in the stereo mode) is loaded now into the VX-RAM. This procedure is repeated for the second image.

The visible part of the images depends on the monitor size. Theoretically it could be 1152 x 450 for one stereo image, because of the optionally display of zoom and overview windows, the size of 700 by 450 pixel is selected. However SUN has already announced a 21" monitor with a resolution of 1280 x 1024 pixel. Figure 9 depicts the actual usable sizes for one stereo partner.

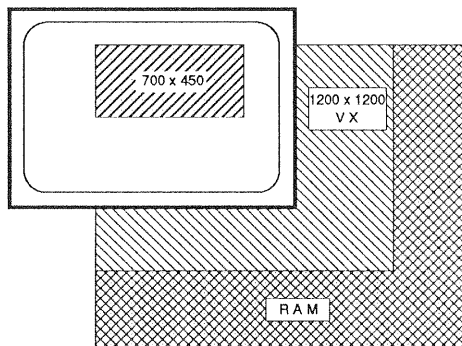


Fig. 9: displayable image size

5.4 Point Marking and Measuring

For the interactive point measuring a cursor is permanently positioned in the centre of both display windows. The images are moving "behind" the measuring marks. For the cursor three sizes and seven colors can be selected from the options menu, ensuring a good contrast with the background. The coordinates are currently displayed on the monitor.

5.4.1 Zoom To achieve comparable accuracy in comparison with analytical plotters subpixel measurement is essentially necessary.

Therefore a zoom window (with the dimension of 100 x 100 pixel) is created for each image. While moving the original images the surrounding of the cursor is enlarged by factor two or four and simultaneously displayed in the zoom windows. Because the zoom function is often used, it will be activated by pressing a button of the trackball. While the zoom is activated the moving speed is reduced for a more precise point positioning. A second press will deactivate the zoom, this accelerates the roaming velocity.

5.4.2 Overview Handling with large amount of data makes the orientation within an image often very difficult. An overview window (again 100 by 100 pixel) for each image facilitates the orientation. A cursor on a white background moves simultaneously in dependence on the original movement. With a hardcopy or an appropriate map a more detailed view is possible then. To reduce the image information makes no sense in most cases because of the too large image sizes.

5.4.3 Image Movement Fast roaming over the images is important for reasonable measuring. The images have to be loaded from the disks into the RAM, which is the bottleneck in the whole data access process. Once the data are in the memory, the time factor is not crucial any more. The processor VX is able to handle the image data in a fast way. Its restricted memory of 12 MByte (4 MByte are reserved for the display) requires fast image reload routines. If reaching the limit of the currently loaded image part, the access to the adjacent part takes only a few seconds. By menu control the user can move both images or the left and right image separately.

A fast jump to anywhere within the images is also possible. The user clicks into the overview window and the

appropriate part is loaded within seconds. For example the interactive measurement of the interior orientation of an 28 MByte image takes less than two minutes.

5.5 Orientation and Bundle Adjustment

The well-known steps of interior, relative and absolute orientation are applied. In each step the coordinates and the results can be saved on file, so if accepting the results, no further orientation measurement is necessary.

The measured pixel coordinates are transformed by an affin transformation into photo coordinates as defined by fiducial marks or reseau crosses.

Measuring homologous point pairs for performing the relative orientation is possible. Normally however the computed photo coordinates will be right used for a bundle adjustment.

With the orientation data each image of the stereo pair can be rectified to the epipolar plane, so the stereo perception is given in the whole model without further processing.

In case of scanner imagery like MOMS the special geometry has to be considered for the stereoscopic observation. The collinearity equations have to be extended (Dorrer, 1991).

5.6 Topographic Mapping

Satellite image data shall help to increase the revision cycle of maintaining currency of paper map products. These data enable a fast possibility to create up-to-date map coverage in a sufficient scale for planning and decision making. In case of MOMS it is expected to deliver maps in scale of 1 : 50 000 or better and DEM with height accuracy of 5 m. For the evaluation of MOMS data it is planned to display the third, high resolution strip simultaneously while measuring in both exterior strips. This enables the operator to identify features more accurate and to determine better map worthiness.

5.6.1 Plotting and Superimpositioning The graphic accelerator VX offers 8 bit overlay for both true color and panchromatic images in mono or stereo mode. Because of less functional support at present, drawing points and lines is just realized now. Additional to the coordinates the operator has to classify the selected feature according to the definitions of the object type catalogue from the official government system ATKIS. These classification is supported via menu. The vector data and the attributes are stored in files referring to the Arc/Info format.

This geographic information system, also running on UNIX on the SUN workstation, enables the further process of map production. The enhanced vector data can be transformed back to the appropriate format for displaying on the VX.

6. CONCLUSIONS

The progress in computer technology supplies standard workstations with high performance for more and more lower costs. The requirements are given to solve the time consuming tasks in the field of photogrammetry in considerable time. Nevertheless data storage and fast

access will remain a problem.

On the software side a digital system has to support all the interactive tasks we know from analytical plotters. The operator is still important, mainly on the field of verification and control. The automatic methods (point measuring, image matching and understanding, and others) are topics that improve the map derivation, however much research is still necessary.

The described digital plotter for the evaluation of MOMS and other space data will support both interactive and automatic techniques. This will provide savings in time for creating and updating of topographic maps and will offer a variety in data output products like orthoimage maps and 3D perspectives.

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