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Cartographical Potential of MOMS-02/D2 Image Data

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ABSTRACT

Due to a reduced pixel size of 4.5 m and an along-track stereo capability data from the space sensor MOMS-02 are exspected to be a valueable source for the generation ot orthoimage and topographical maps at medium scales. This contribution will discuss the cartographical potential regarding the coverage, the geometrical accuracy and the inherent information content in more detail. Furthermore, the methods for creating cartographical outputs like orthoimages or orthoimage maps in a GIS-environment will be outlined.

1. INTRODUCTION

The status of a world-wide and up-to-date coverage with three-dimensional spatial data like topographical maps or Digital Elevation Models is not satisfying yet. As an example, in 1993 only 65.6% of the world was covered with maps at a scale of 1 : 50 000 by having an annual progress rate of only 1.1% in the six years before. Even if one considers that for uninhabited or desert regions a full coverage at scales of these order is not necessary, it can be summarized that this status is deficient and the use of conventional surveying and mapping methods is not sufficient to satisfy the demands (Konecny, 1995).
One - if not the only one - longterm solution for this problem could be the observation from space using electro-optical scanners and the derivation of geo-coded orthoimages or line maps from these image data. In general, space scanners offer the advantages of huge covered areas, multi-temporal recordings and an ideally digital and therefore fast data flow. On the other hand there are still a couple of disadvantages in using space-borne data, like the limited ground resolution or the more complicated orientation models.
One of the latest space sensor developments in the civilian area is the MOMS-02 - the Modular Opto-electronic Multispectral Scanner in its second version - which was flown for experimental puposes on the D2-Spacelab mission in 1993 and shall be employed for an operational use onboard the Russian MIR-station from 1996 on. MOMS-02 offers a variety of advanced features like a ground pixel size down to 4.5 m or an along-track stereoscopy. These properties, which will be pointed out in more detail in chapter 2, are exspected to open a wider range for the generation of the desired cartographical outputs at medium scales.
This contribution, which is based upon the research done at the Institute for Photogrammetry and Engineering Surveys at the University of Hannover, will firstly discuss the cartographical potential of MOMS-02 regarding its coverage, its geometrical accuracies and its information content (chapter 3). Then the developed methods for producing cartographical products like orthoimage or line maps within a GIS-environment will be described (chapter 4). Finally, some statements regarding the suitabilty of MOMS-02 data for mapping at medium scales at present and in the near future can be made (chapter 5).

2. MOMS-02/D2 DATA ACQUISITION

2.1 General system layout

The MOMS-02 (Modular Opto-electronic Multispectral Scanner) was flown for experimental purposes on the German Spacelab D2-mission for 10 days between April 26th and May 6th, 1993. The system operated in a bay down position of the Space Shuttle, which had a nominal altitude of 296 kilometers and an inclination of 28.5E resulting in main test areas in Africa, Asia and South America. In contrast to opto-mechanical devices like the Landsat Thematic Mapper (TM) electro-optical scanners like the MOMS-02 or SPOT-HRV employ less and no more moving or rotating components which not only saves energy but also facilitates the data processing. The MOMS-02 camera system exists of five lenses which allow line scan recordings in seven different channels (Table 1). The four multispectral channels which are implemented into two lenses offer a ground pixel size of 13.5 m × 13.5 m and cover narrow bands in the visible and near-infrared spectrum. The other three channels operate in panchromatic mode, whereby one of them - the High Resolution (HR) channel with a ground pixel size of 4.5 m × 4.5 m - is looking in nadir direction and two of them - with a pixel size of 13.5 m × 13.5 m - are tilted about 21.4E forward and backward, respectively. This layout offers two main advantages for photogrammetrical and topographical evaluations:

- a comparable good ground resolution and
- an along-track, three-fold stereo capability in real time.

Channel	Spectral Band	Orientation	Ground pixel size	focal length	image scale	max. swath
1	440...505 nm (blue)	0°	13.5 m • 13.5 m	220.08 mm	1 : 1 345 000	78 km
2	530...575 nm (green)					
3	645...680 nm (red)					
4	770...810 nm (near IR)					
5	520...760 nm (panchr.)	0°	4.5 m • 4.5 m	660.30 mm	1 : 448 000	37 km
6	520...760 nm (panchr.)	+ 21.4°	13.5 m • 13.5 m	237.25 mm	1 : 1 345 000	78 km
7	520...760 nm (panchr.)	- 21.4°				

Table 1: Characteristics of the MOMS-02/D2 optics module.

Compared to Landsat Thematic Mapper (TM) and SPOT-HRV with ground pixel sizes of 30 m and 10 m, resp., the HR-channel of MOMS-02 offers a more than 6 resp. 2 times better resolution which will affect not only the geometrical accuracy but also the interpretability of the image data. By recording ground areas from three different viewing angles (+21.4E, 0E, -21.4E) an along-track stereo-scan can be performed (Figure 1). This principle offers some advantages compared to the across-track stereo-scan - as applied by SPOT-HRV or Landsat TM - which records the ground from two adjacent tracks. As a consequence, MOMS-02 takes corresponding stereo images within 40 seconds instead of waiting one day or even longer for reaching neighbouring orbits as in the case of SPOT or TM. So MOMS-02 guarantees that there are no major changes on the ground between the recordings due to another sun elevation, another daytime or even another season. This feature allows a better derivation of heights and increases the interpretability of topographical objects which stand out of their surroundings.

Datatakes can be made in specified combinations of up to four of the seven channels (e.g., the so-called stereo-mode I represents the combination of channels 5,6 and 7; see Table 1). The recordings were made on a high density tape onboard the Spacelab. From these raw data quicklooks with a resolution of 68 m × 68 m can offer overviews. The further data processing steps include the conversion and decompression of data (to level 0), raw radiometric corrections (level 1A) and systematic geometric corrections due to the curvature and rotation of the earth (level 1B). On the more advanced stages there are the thematically and photogrammetrically processed data (levels 2 and 3). Data can be ordered through the German Remote Sensing Data Center (DFD) at comparable low prices.

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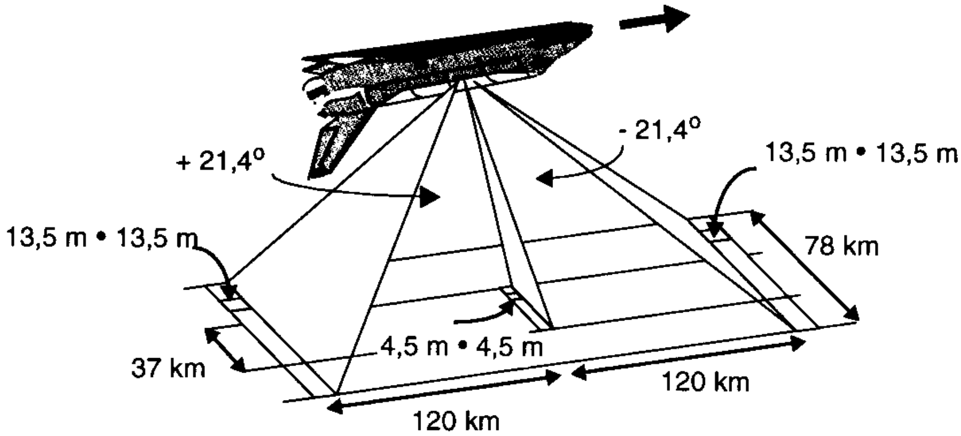

Figure 1: MOMS-02/D2 stereo imaging mode.

2.2 Test site Dubai-City

Due to the small inclination of the Space Shuttle only a limited area of the world was covered during the D2-mission. Within these regions it was very difficult to find appropriate reference material in form of ground control points and maps at medium or large scales. For a couple of test sites it turned out that the MOMS-02 data controlled the reference material instead of vice versa (Jacobsen, 1994).
The only remaining test site for the purpose of evaluating the cartographical potential and producing cartographical outputs with an interesting topography and some man-made features was the Emirat Dubai. In a first stage a 10 km by 10 km large area within Dubai-City was examined. In a close co-operation with the Dubai Municipality suitable reference material in form of topographical maps at scales of 1 : 10 000 (dated 1993), 1 : 25 000 (1984) and 1 : 50 000 (1991) as well as a Digital Elevation Model (DEM) and data from SPOT-HRV (1988, 1993) and Landsat-TM (1992) could be obtained for ground control and comparison purposes.
The corresponding MOMS-02/D2 image data were taken on April 27th, 1993 (orbit 12, scenes 42 and 43) in stereo mode I (channels 5, 6 and 7). Due to inexperiences at the beginning of the D2-mission with the setting of the gain factors channel 7 had been over-exposed and could not be used anymore for the following processing steps, for example for the derivation of a Digital Elevation Model (see section 4.1). All photogrammetrical operations described in the following are based upon level 1B data.

3. EVALUATION OF CARTOGRAPHICAL POTENTIAL

The suitability of a system for mapping purposes depends mainly on its

- coverage,
- geometrical accuracy and
- information content.

In the following the theoretical exspecations as well as numerical results from practical examinations using image data from the test site Dubai-City will be presented.

3.1 Coverage

The coverage of a system for mapping describes the area, the time and the frequency of datatakes. Due to the facts that it was only one out of 90 experiments onboard the Spacelab D2-mission and that the

goal was just to test its functionality MOMS-02 offers some disadvantages concerning this factor. The mission parameters (see section 2.1) do not fulfill the claim to complete world-wide, up-to-date and multi-temporal recordings.
An operational use is planned for the employment of MOMS-02 onboard the Russian MIR-station which shall be launched in 1996 and work for 2 years at latitudes of up to 51.6E. Furthermore, from 1998 on an independent use on an own satellite - the so-called "MOMS-Freeflyer" - is under discussion (Fritsch, 1995).

3.2 Geometrical accuracy

Mapping at certain scales demands for appropriate geometrical accuracies for the determination of positions and heights. Assuming the U.S. standard values for topographical maps of 0.3 mm at map scale for the horizontal accuracy and 0.3 times the height contour interval for the vertical accuracy one yields standard values at the ground of about 15 m (horizontally) respectively 3 to 6 m (vertically) at a map scale of 1 : 50 000 (contour interval 10 to 20 m), and 7.5 m (horizontally) respectively 2 to 6 m (vertically) at a scale of 1 : 25 000 (contour interval 5 to 20 m).
Taking only the geometrical parameters of an imaging system into acount the theoretical horizontal standard deviation is computed by

$$s_H = (h / f) s_{XY} = p P_{GROUND} \tag{1}$$

where h denominates the flying altitude (MOMS-02: 296 km), f the focal length of the objective (channel 5: 660.3 mm) and s_{XY} the pointing accuracy within the image. The last factor is very much influenced by the image contrast and the ability of the operator to identify points. In general, an empirical factor p of 0.5 to 0.9 times the CCD-pixel size is set for sXY. In the case of MOMS-02 (CCD-pixel size = 10µm) one yields theoretical values for the horizontal standard deviation of 2.3 to 4.1 m - which equals the product of p times the ground pixel size (P_{GROUND} = 4.5m). In contrast, SPOT-HRV (P_{GROUND} = 10 m) offers values in the range of 5.0 to 9.0 m, Landsat TM (P_{GROUND} = 30 m) in the range of 15.0 to 27.0 m.
The theoretical vertical standard deviation is obtained by

$$s_V = (h / f) (h / b) s_{px} \tag{2}$$

where b is the base length and spx the standard deviation for the determination of the x- parallaxes. In general, in a stereo environment the x-parallaxes can be measured with a standard deviation of 0.3 to 0.8 times the CCD-pixel size. Taking the oblique channels 6 and 7 of MOMS-02 into account (b/h = 0.78, f = 237.25 mm × cos 21.4E), one yields theoretical values for s_V of 5.2 to 13.8 m. If one oblique channel is enlarged by factor 3 and combined with the HR-channel 5 for a stereo evaluation the b/h-ratio is reduced to 0.39 but the focal length is set to 660.3 mm, so that one yields values in the range of 3.5 to 9.2 m. In contrast, SPOT with an optimal b/h-ratio of 0.75 (only at latitudes of 0E!) offers values from 4.0 to 10.7 m.
Practical examinations have the goal to determine the standard deviations for the pointing accuracy and the x-parallaxes. As already pointed out, these measures depend very much on the specific image contrast and the ability of an operator to identify objects. For the test site Dubai-City the geometrical potential was checked with the program BLASPO which is a module within the system "Bundle block adjustment University of Hannover" (BLUH) and serves for the evaluation of satellite line scanner images like SPOT or MOMS-02. Ground control points have been obtained by digitizing the positions from 1 : 10 000 - topographical maps (mainly road crossings) and interpolating the heights from 1 : 25 000 - maps. Because the mathematical model of the bundle adjustment requires an exactly orthogonal coordinate system the positions had to be converted from UTM-coordinates into a local

tangential system. The corresponding pixel coordinates have been measured using the Digital Stereo-Workstation Hannover (DISH) with sub-pixel resolution in stereo as well as in mono mode. In contrast to the bundle adjustment carried out by the Technical University of Munich (see section 4.1) nor actual and precise orbit data neither automatically matched conjugate points have been included into the adjustment. Instead of this standard orbit values as well as additional parameters for the affinity and angular affinity have been applied (Jacobsen, 1994).
The residuals coming from the orbit determination show that the pointing accuracy within the three times enlarged channel 6 is not as good as in the HR-channel 5. But on the other hand the stereo combination with the HR-channel supports the object identification within channel 6 so much that the error measure is only 1.1 to 1.5 times worse compared to the High-Resolution channel instead of an exspected factor of three.
Table 2 summarizes some important results obtained from the bundle adjustment using BLASPO. The first two rows indicate that - as exspected - the measurement of pixel coordinates in a stereo environment increases the identification of objects and enables a more precise determination of the x-parallaxes and with that more accurate Z-coordinates.

Pixel measure-ment	Ground Control Points					Indep. Control Points			
	No.	σ_0 µm	s_X m	s_Y m	s_Z m	No.	s_X m	s_Y m	s_Z m
Mono	20	9.6	3.5	3.5	9.4	-	-	-	-
Stereo	20	8.0	2.7	3.4	3.0	-	-	-	-
Stereo	13	7.8	2.6	2.4	2.8	11	3.3	3.2	4.8
Stereo	6	8.0	0.4	2.0	2.3	11	3.3	3.2	4.0

Table 2: Bundle block adjustment results obtained from BLASPO.

Furthermore, the theoretical values as outlined above have been confirmed. The horizontal standard deviations of about 3.0 to 3.5 m indicate a pointing accuracy of 0.6 to 0.7 times the pixel size. The vertical measures of up to 4.8 m show that a standard deviation of the x-parallax determination in a stereo environment amounts to 0.3 to 0.4 times the pixel size.
The less ground control points are used the better are the standard deviations of the ground control points. The presumption that these values are too optimistic is confirmed by the constant measures for the independent control points. Future research will be concerned with the determination of an optimal number of ground control points as input for the bundle adjustment.
Similar results have been obtained for the measurement of independent control points within orthoimages which have been derived from MOMS-02 data (see section 4.2). Here, uncertainties not only due to the exterior orientation but also to the interior orientation and the DEM lead to the fact that residuals of positions amount to 3.0 to 4.3 m (corresponding to 0.6 to 0.95 pixels).
One important advantage in using space images as input source for the generation of digital orthoimages is the required precision of the DEM which is significantly lower than in the case of aerial images as input. In general, the DEM-precision dh depends on the flying altitude H, the allowed relief displacement dx within the orthoimage, the radial distance x of the object point within the original image and the scales of the input image (m_{INPUT}) and of the orthoimage (m_{ORTHO}):

$$dh = H \, (dx / x) \, (m_{INPUT} / m_{ORTHO}) \tag{3}$$

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Assuming typical values for an aerial image (H = 4 km, x = 8 cm, m_{INPUT} = 1 : 12 500) one needs for an orthoimage at scale of 1 : 10 000 with an allowed relief displacement of 0.3 mm a DEM-accuracy of 12 m. On the other hand, for processing a MOMS-02 image (H = 296 km, x = 3 cm, m_{INPUT} = 1 : 450 000) the required height accuracy only amounts to 65 m.
Summarizing these results it can be stated that for the case that a sufficient number of ground control points (in the range of 5 to 20) have been used for determining the exterior orientation parameters, the horizontal deviations for points derived from the adjustment or measured within an orthoimage are in the range of 3 to 5 m which is good for mapping at scales of at least 1 : 20 000. More complications arise with the vertical accuracy of up to 4.8 m so that height contours with an interval of only 15 m can be derived which can lead to problems by mapping critical regions with varying terrain at medium scales of 1 : 25 000 or 1 : 50 000. On the other hand one should keep in mind that the above mentioned U.S. standard accuracies are very strong measures and can be reduced depending on the current area of interest and the desired application.

3.3 Information content

The suitability of a scanner system for mapping at certain scales with respect to the information content depends on a variety of ground-side factors like relief and contrast of the topography and of scanner-side factors like the spatial and spectral resolution or the capability of deriving heights. Due to this bundle of varying factors no general rules but only a variety of recommendations regarding a suitable input source can be given. One general recommendation is that the ground resolution R_{GROUND} of the input source should obey the rule

$$R_{GROUND} \ \# \ 0.2 \text{ mm} \times \text{map scale} \ \text{ AND } \ R_{GROUND} \ \# \ 5 \text{ m} \qquad (4)$$

Assuming a Kell-factor of 2.0 for the transformation of the pixel size into the ground resolution - necessary for the same ability to identify objects in digital images - MOMS-02 offers a ground resolution of 9 m which is only good for mapping at a scale of 1 : 45 000 by neglecting some objects which fall beneath the border of 5 m. From rule (4) one can conclude that the pixel size of a scanning system for mapping at scales of 1: 50 000 or 1 : 25 000 should be around 2.5 m. Similar pixel size values are given by Konecny (1995) for the identification and interpretation of specified objects:

- buildings and paths: P_{GROUND} # 2 m,
- smaller roads and rivers: P_{GROUND} # 5 m
- main roads and building blocks: P_{GROUND} # 10 m.

Practical examinations using the test site Dubai-City confirmed these theories. After enhancing the images by applying simple radiometric filter operations (e.g., a MEDIAN-filter for removing disturbancies due to sensor problems and a LAPLACE-filter for enhancing edges) the road network and building blocks larger than 15 m × 15 m could be extracted completely without any problems. On the other hand, smaller building blocks or single buildings could not be detected.
Figure 2 compares corresponding areas as taken from an aerial image (original scale 1 : 27 000), which was the basis for the official 1 : 10 000 - map, MOMS-02, SPOT-HRV and the official map 1 : 25 000. It can be seen that MOMS-02 shows some more details compared to SPOT, for example the separation of traffic lanes or more building blocks. The comparison with the topographical map 1 : 25 000 also elucidates that the above made recommendations are not important for every application because not all mentioned features are required in the map. In the case of Dubai-City a representaion of building blocks rather than of single houses is sufficient.

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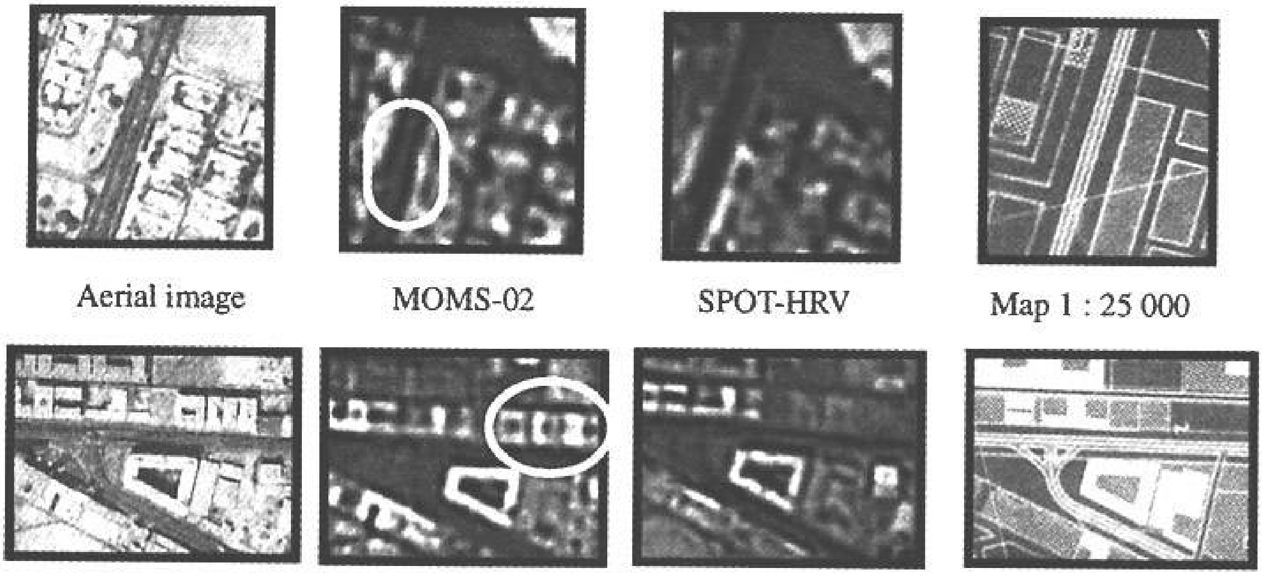

Figure 2: Comparison of the information content (brought to an unique scale).

For the generation of digital orthoimages a resolution of 10 pixels/mm in the resulting image is often claimed in order to keep all information inherent in the original image to the unaided human eye (Doyle, 1984). If the input pixel from MOMS-02 is not enlarged this would lead to an allowed scale of 1 : 45 000. On the other hand, our investigations have turned out that this resolution seems to be very pessimistic and that images with 5 pixels/mm (corresponding to an orthoimage scale around 1 : 20 000) give a relatively sharp impression with no visible disturbancies like jaggies or doubled pixels.
Summarizing these results it can be stated that by theory the pixel sizes of MOMS-02 and other civilian space sensors are not sufficient to represent all desired topographical objects in maps at medium scales, especially paths and single houses. Due to limited data transfer rates and too small CCD-arrays the demand for pixel sizes of 2.5 m and lower by having an appropriate swath width - in contrast to some military systems - could not be fulfilled yet, but developments in this direction are done at present.
Another often neglected strategy for dealing with this dilemma is a critical discussion about the actual necessary object representation which could come up with a clear reduction of the required pixel size for a certain application.

4. PRODUCTION OF CARTOGRAPHICAL OUTPUTS

4.1 General workflow

The evaluation of MOMS-02/D2 data is performed in a joined project by a couple of German universities and the German Aerospace Research Establishment (DLR). The digital photogrammetric evaluations are carried out by the Universities of Stuttgart, Munich and Hannover. Figure 3 gives an overview of the photogrammetrical data processing which ends up with the desired three-dimensional data like Digital Elevation Models (DEM), digital orthimages or other follow-up products like orthoimage maps, line maps or perspective views. The software packages of the involved institutes will be integrated into the image processing system XDibias (developed at the DLR). A more detailed overview about the data flow - especially about the work at the Universities of Stuttgart and Munich - is given by Fritsch (1995).
At the Institute for Photogrammetry and Engineering Surveys at the University of Hannover that is concerned with the evaluation of the cartographical potential as well as the production of

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cartographical outputs three main streams of hardware and software developments can be distinguished:

- Interactive stereo measurement of control points,
- generation of orthoimages and
- generation of follow-up products in a GIS-environment.

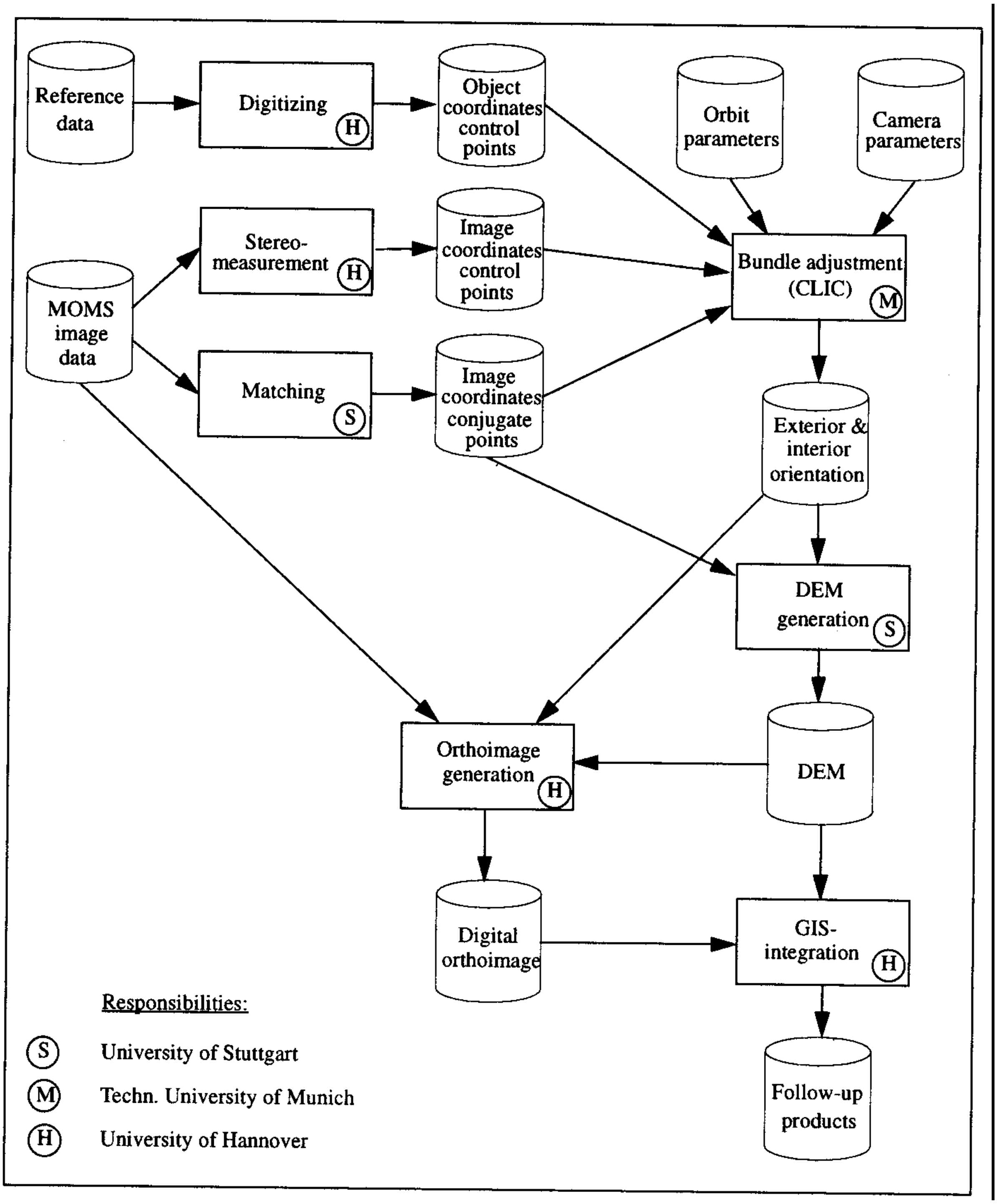

Figure 3: Digital photogrammetric data processing of MOMS-02/D2 data.

For the interactive stereo measurement the Digital Stereo Workstation Hannover (DISH) has been designed (Siebe and Schiewe, 1993). This was necessary because no suitable and open digital

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photogrammetrical system was available at the beginning of the MOMS-02-project. DISH bases on a standard hostcomputer, a SUN SparcStation 10 with 50 MHz clock speed, 128 MByte memory and several GByte disk space. Stereo viewing is enabled by the Crystal Eyes principle which is supported by the graphical accelerator GT (Graphics Tower). Besides the stereo measurement various other software components have been integrated into this system - like the generation of orthoimages from MOMS-02 data which will be explained in more detail in section 4.2.
The post-processing and the generation of follow-up-products is based on the idea that a Geographical Information System (GIS) that includes all functions for graphical operations as well as for the input and output of image data can fulfill these tasks very efficiently. Therefore, several tools have been developed under the GIS Arc/Info that perform topology building, overlays, statistical analysis, map creation and so on. Two examples, the moduls for the semi-automatic production of orthoimage maps and the derivation of vector data by mono-plotting will be presented in the next sections.

4.2 Generation of orthoimages and orthoimage maps

A digital orthoimage is a digitally rectified image, which was derived from one or more distorted images and a Digital Elevation Model (DEM). Distortions in the original images are due to projections different from the desired orthogonal map projection and due to relief displacements coming from differences in terrain heights.
Digital orthoimages offer various advantages for the creation and revision of cartographical databases, for example:

- X high information content and abstraction-free representation,
- X large coverage,
- X exactly known capture date,
- X scale independency (theoretically),
- X easy manipulations for enhancing purposes,
- X fast processing and transmission,
- X suitability as layer within a GIS.

On the other hand, there are still the high purchase costs for the input and output devices for digital images. Nevertheless, digital orthoimages from aerial or satellite images have already proofed to be a cheap and fast solution for the mapping problem.
The general process for the generation of digital orthoimages is described in more detail by Schiewe (1995). In the case that MOMS-02 image data are used some particularities have to be considered and to be integrated into the software. The main difference to aerial images is the fact that MOMS-02 is a line scanner and that theoretically for every line scan a distinct set of exterior orientation parameters have to be computed. Using the indirect method for creating the orthoimage one has to find the corresponding orientation line to the current X-Y-coordinate pair in a iterative process (Siebe and Schiewe, 1993).
Digital orthoimage maps are based upon aerial or satellite images which have been digitally ortho-rectified and have been completed with cartographical features like a coordinate grid and a legend. Orthoimage maps derived from space data represent a even more developed but still cheap alternative to traditional line maps (Konecny, 1995).
Today a couple of digital systems for the generation of digital orthoimage maps do exist. To use all highly developed functions of a GIS for a variable generation of orthoimage maps the tool AROMA (Arc/Info-based Orthoimage Map Generation) under the GIS Arc/Info has been developed. This tool allows a menu-driven, semi-automatic creation of orthoimage maps with various layouts and the superimposition with vector-oriented Arc/Info-coverages. The digital maps can be stored in different

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data formats and transformed into analogue outputs. An example showing the test site Dubai-City is given in Figure 4.

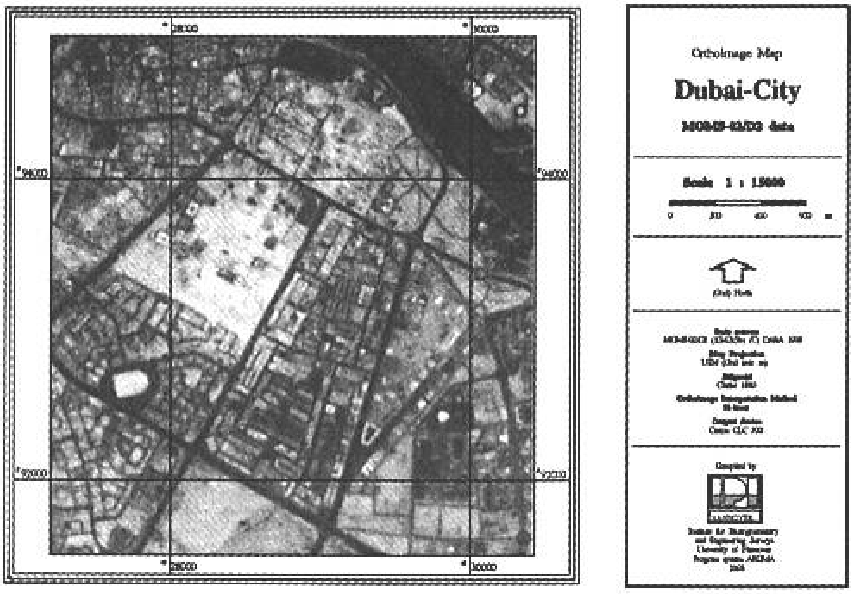

Figure 4: Orthoimage map "Dubai-City" (image data courtesy DARA, 1993).

4.3 Mono- and Stereo-Plotting

Mono-plotting is the capture and revision of positional data on the basis of an image. Using stereo image pairs one can additionally get height data (stereo-plotting). In a digital environment a manual and interactive plotting can be realized by "on-screen-digitizing".
Especially for the revision of existing cartographical databases in digital form the interactive mono-plotting has already been proofed to be an effective method. If the vector data which shall be revised are a part of the GIS, they will be superimposed onto the up-to-date, by ortho-rectification geo-coded images, the changes can be detected visually and the new or changed objects can be edited on the screen. For these purposes at the Institute for Photogrammetry and Engineering Surveys at the University of Hannover the Arc/Info tool AMPLO (Arc/Info-based Mono-Plotting) has been developed.
With respect to faster and more flexible post-processing and analysis procedures the application of automatic or at least semi-automatic methods are necessary. In general, panchromatic data are considered to serve for the extraction of line objects (e.g., roads or outlines of buildings) and multi-spectral data for the description of areal featurs (e.g., fields). The method for the revision of linear objects starts with the detection of edges within the image and the building of lines by filling and skeletonizing the edges. The example in figure 5 shows that the line building reduces the density of information and produces a representation similar to a line map, but an automatic object extraction with a following comparison with the old vector data seems to be very difficult.

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a b c

Figure 5: (a) MOMS-02 image of Dubai-City, (b) extracted edges, (c) derived lines.

For the future work it is planned to apply a "knowledge-based" method for the check of the data which already exist in the old vector data set. Therefore, a single vector is taken and a search for a line of the same or similar direction takes place in a defined area of the image. All detected lines can be processed geometrically and topologically using existing GIS-tools and can be used for a comparison with the existing data. Nevertheless, the processing of detected lines is still complicated because of inhomogenious image data and problems to define appropriate thresholds (Schiewe, 1995).

5. CONCLUSIONS

The theoretical as well as the practical examinations of the cartographical potential of MOMS-02/D2 data have shown that this data source can be used - with some restrictions - for topographical mapping at medium scales of 1 : 50 000 or 1 : 25 000. Due to the relatively small pixel size of 4.5 m and the along-track stereo capability MOMS-02 made some progress compared to existing civilian space-borne systems like SPOT-HRV or Landsat TM. Furthermore, a better coverage compared to the experimental MOMS-02/D2 mission is planned for the mission onboard the Russian MIR-station from 1996 on and for the use as "MOMS-freeflyer" from 1998 on.

The horizontal accuracy in the range of 3 to 5 m is good for mapping at the desired scales. In contrast, the vertical accuracy is not always sufficient - depending on the quality of the reference material and the terrain variations. The actual identification of topographical objects corresponds to the theoretical exspectations: Whereas roads and building blocks of 15 m × 15 m or larger can be detected without problems, single houses and paths cannot be distinguished from the surrounding due to the still limited ground resolution. On the other hand, comparisons with existing maps of the desired scales elucidate that the high demands regarding the geometrical accuracy and even more the information content which are coming from developed countries are not necessary for many applications in other regions of the world.

Finally, some tools for the post-processing and the analysis of MOMS-02 image data using the functionality of an existing GIS have been presented. Nevertheless, there is a lack of operational tools for the automatic extraction of topographical objects from digital data sets which is essential for a fast and economic evaluation of satellite image data in the future. But from experiences with the solution of old problems it can be derived that the current technical and algorithmic drawbacks will be solved within a couple of years in order to diminish the existing mapping deficit.

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