APPLICATIONS OF THE DIGITAL PHOTOGRAMMETRY SYSTEM DPS, A RIGOROUS THREE DIMENSIONAL COMPILATION PROCESS FOR PUSH BROOM IMAGERY

O.Hofmann
Messerschmitt Bölkow Blohm GmbH, München
West-Germany
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Abstract:

The German Aero-Space Company Messerschmitt Bölkow Blohm GmbH (MBB), Munich, developed a new concept for a digital stereo-scanner with three line sensor arrays working on the push broom principle and a suitable analytical compilation method.
The digital stereo camera in combination withthe DPS compilation method is to be expected to compete with the frame camera in the future.
The possibilities of the application of the DPS to photogrammetry and cartography, topographic and thematic mapping, generation of digital terrain models, ortho- and stereo-orthophotos, computer supported interactive evaluations are described and advantages and problems are discussed.
The DPS will be applied with special advantages in those cases where large areas have to be mapped in medium and small scales in a short time. Therefore this new technology is suitable for developing countries and countries with large areas.

1. Introduction

Messerschmitt Bölkow Blohm GmbH (MBB) is developping a "Digital Photogrammetry System (DPS)" for the rectification and three dimensional restitution of push-broom scanner imagery produced with a three line opto-electronic digital camera using CCD linear array sensors. Different papers have already been published (/1/,/2/,/3/) and relating to technical details it will be refered to those publications. The working principle of this system is based on:

a) the synchronized and simultaneous scanning of the terrain with a three line camera,
b) the determination of identical image points of respectively the same terrain points by area correlation and
c) computation of the orientation parameters of the camera along the flight path and the DEM-coordinates of the terrain points by least squares bundle adjustment.

The DPS was originally developed in order to rectify push-broom imagery. But now this digital camera together with hard- and software systems for image processing makes possible an accurate and practical stringent geometric three dimensional compilation of the whole model in a consequence its application in the wide field of photogrammetry. With this development a serious competitor arises to the photographic frame camera. In the following we deal with the different applications, features and advantages of the DPS.

The system is not yet completely developed but its working principle has been tested successfully by computer simulation and the hard- and software system will be implemented in different programs. It is applicable for aircraft and space craft.

2. The Hardware of the DPS

Fig. 1 shows the system and the most important components of the hardware. The DPS-stereo-scanner and the high density digital tape recorder (HDDT) are mounted in the aircraft.

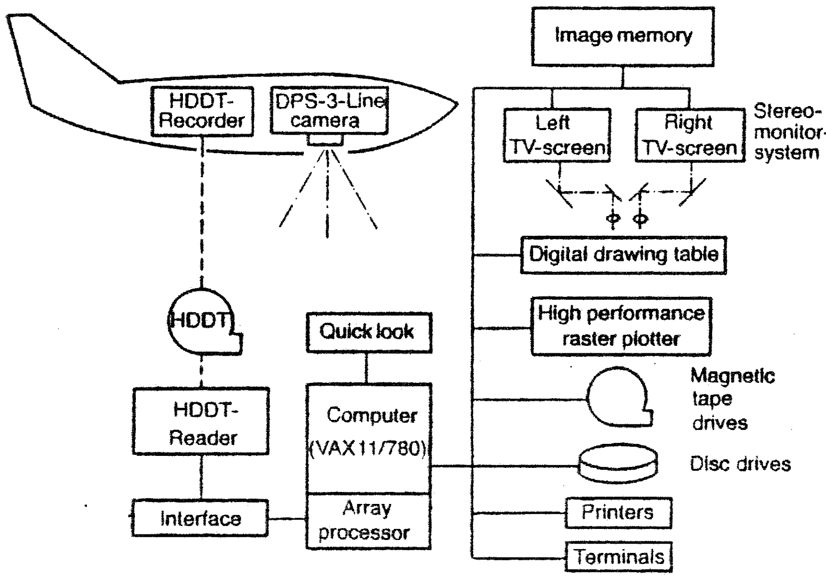

Fig.1 Hardware of the DPS

The heart of the compilation and evaluation process is a powerful 32-bit minicomputer, for example the VAX 11/780 of DEC. The image data stored on the HDDT are transmitted via a special interface to the computer and thence to magnetic discs or computer-compatible tapes (CCT's). A quicklook device, a fast plotter or a videoterminal permit the operator to make a preliminary inspection of the image strips.

In order to accelerate the computation process an array-processor supports the main computer. In addition to the usual peripheral devices such as magnetic discs, magnetic tape recorders, terminals and printers

- a raster plotter of high performance
- a digital drawing table
- and a stereo video monitor system

are connected to the main computer.

The stereo monitor system consists of

- a special image memory
- two refresh video screens
- a stereo viewing device
- operational controls for manual shift and positioning of the images or the measuring marks on the screens.

The stereo monitor system has the same function as the viewer of an analytical plotter. Electronically generated luminous marks on both screens permit the setting and measurement of image points.

In spite of the nearly automatic data flow from the scanning process to the results, visual control and interactive corrections and additions are desirable and necessary. The operator need not work "blind". This fact is very important and the stereo monitor system allows the following tasks and functions:

a) Visual selection and manual setting of the first point(s) of correlation;
b) identification and setting of control points;
c) on the stereo screens the process of correlation is visible and controllable by the operator. He can correct false correlations and take action if the correlation fails and stops.
d) The stereo monitor is a useful and indispensable tool for the visual and manual evaluation and interpretation of the image strips.

In general the stereo monitor system in combination with the computer is the analytical plotter of the next generation.

3. Combination of Stereo- and Spectral Modules

The three line stereo module of the digital camera can be complemented by spectral modules. This means that optically parallel to the middle line sensor B further linear sensor arrays S_1 ... S_n can be added, in each case with a separate lens and a spectral filter (Fig. 2). In the future CCD-IR sensors will be also available and used. At MBB we are developing CCD-sensors which are sensitive in the IR spectral region between 1 and 5 micrometers.

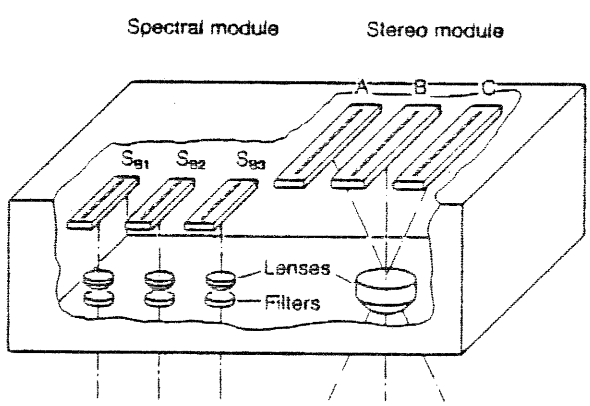

Fig.2 DPS-3-line camera with additional spectral modules

The effective length and the total number of pixels of one whole sensor line can be selected by the combination of single sensor chips by beam-splitters or the so-called double lens system used for example in the MOMS-camera. Presently sensor chips with about 4000 pixels in one line and pixel sizes of 7 µm are available. This corresponds to a comparable resolution of about 70 Lp/mm.

But it is not necessary to require the same geometric resolution for the stereo module and the spectral modules. Normally, for spectral classification the requirements for geometric resolution are not so high. Therefore the focal length, the number of pixels per line, and as a consequence, the data stream of the spectral modules can be reduced.

This modular concept makes it possible to complement the stereo module by spectral modules even in the reflective and thermal infrared region.

As a consequence of the combination of the stereo with spectral modules the rectification of all image strips of the spectral modules is automatically performed.

4. The Input and Primary Output Data of the DPS and further Image Processing

The most important feature of the DPS is its independence of other measurements and external aids, for example stabilised platforms,measurements of positions and inclinations, control points etc. It is applicable to aircraft and space craft, neither the uncontrolled and unknown perturbations of the carrier nor the earth's rotation need be measured and they do not influence the compilation process. The orientation parameters of the camera along its flight path in any dense sequence of orientation points, the digital elevation model (DEM), ortho- and stereo-orthophotos are determined solely by the image data. The compilation process is homogenous and automatic.

As a consequence the input data to the compilation process are the digital image data of three image strips A_S, B_S, C_S, produced by the three line camera and stored on High Density Digital Tape (HDDT). For absolute orientation a few control points must be added via a stereo monitor in the course of computation. For absolute orientation not only ground control points can be used; in space missions, orbital data could be inserted, for example in those areas where ground control points are not available.

The primary output data are

- the orientation parameters of the so-called "orientation points" P_j and the
- terrain coordinates X, Y, Z of the DEM-points P_i (Fig. 3).

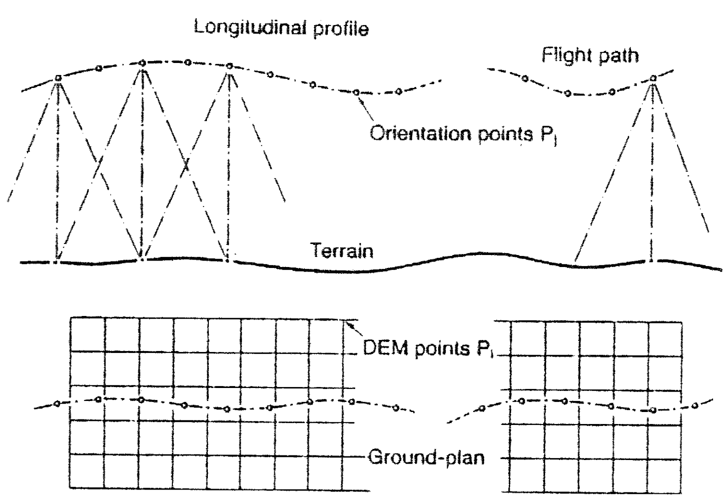

Fig. 3 DPS-model

Besides these data, all image data of the three image strips A_S, B_S, C_S are available on mass storage devices.

On the basis of these data all other computations and manipulations can be applied within the wide field of image processing and interactive evaluation.

4.1 The Production of Ortho- and Stereo-Orthophotos and Images with Central Perspective

The recorded image data, the correlated and meshwise arranged DEM-image points in the three image strips A_S, B_S, C_S (Fig. 4), their line and pixel numbers and the coordinates X, Y, Z of their corresponding DEM points permit important geometrical rectifications and manipulations.

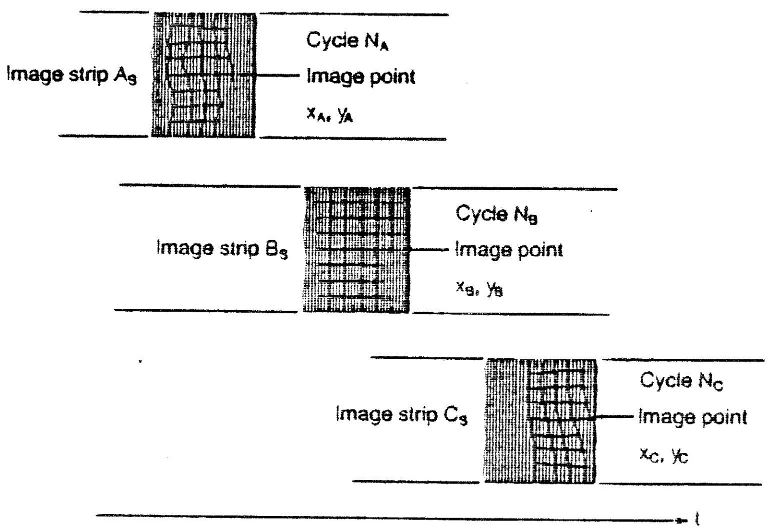

Fig. 4 DPS image strips A_S, B_S, C_S

The production of orthophotos is performed by meshwise and perspective transformation of all image points within one DEM-mesh from the middle strip B_S to their true and orthogonal ground position. The parameters of transformation are derived from the four corner points of one mesh. Likewise stereo-orthophotos can be produced. In this case the image-strips A_S and C_S are used. On the other hand, the three-dimensional DEM points are projected in the ground plane by an inclined, parallel projection, whose angle of projection corresponds to the half angle $\gamma/2$ of convergence (Fig. 5). Now the image points within one mesh of A_S or C_S are transformed to the corresponding meshes on the ground plane.

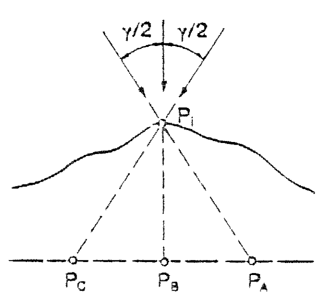

Fig. 5 Ortho- and stereo-orthoprojection geometry

In a similiar way images with central perspective can be produced. The DEM points are projected on to the ground plane through a point of central perspectivity and the image points are meshwise transformed to the corresponding meshes on the ground plane.
In this way these images can be evaluated in detail by simple stereoscopic instruments for observation and parallax measurement and in normal stereo plotters whose working principles are based on central perspectivity.

4.2 Further Possibilities of Image Processing

The images are now ready for further digital and graphical processing. Some examples may be mentioned:

- Automatic computation and drawing of contour lines;
- Raster plotting of ortho- and stereo-orthophotos;
- Visual evaluation and interpretation of topographic details on the stereomonitor as it is usual with stereo plotters. It can be expected that this work will be supported more and more by the computer.

The digital images can be complemented by other digital or digitized information, they can be overlayed and combined with other digital images. The wide field of image data processing, e.g. Fourier transformation, filtering, image improvement, enhancement, extraction of informations, spectral classification and thematic mapping is opened.

5. Possibilities of Application

The DPS is applicable in a wide range of scales for photogrammetry, topographic and thematic mapping and remote sensing. The configuration of the scan-camera depends on the application. For purely geometric evaluation, usual in photogrammetry, the three-line scanner meets all requirements.

Nearly all photogrammetric cartographic products can be delivered automatically or semi-automatically by the DPS, whereby the pixel-resolution on the ground is determined by the map scale and the required accuracy. The DPS is used to advantage in those cases where the topographic objects and certain physical features (spectral reflectivity) of large areas are to be acquired and evaluated in a short time.

The application of the DPS may be preferred for thematic mapping and change detection. It may be applied for the generation of digital elevation models (DEM) preferably in small and medium scales. The automatic correlation is favoured by the digital image acquisition, by the reduced angle of convergence and by small image scales. For example in one conventional stereo pair about 50 000 DEM points are to be measured for the production of a map scale of 1:50 000. It would be a considerable progress if this process could be automated. The DPS offers a good chance.

As mentioned, the DPS is applicable for aircraft and space craft. Map scales of 1:250 000 and smaller may be suitable for satellite imagery, for larger scales up to 1:50 000 and 1:25 000 high altitude aircraft may be preferred.

In general, we believe that the DPS will be advantegous in those cases where large areas have to be surveyed and evaluated in a short time and we are convinced that the reduction of time and costs will be considerable.

To what extend the DPS will be really used in practice in the future will be only decided by its general technical performance, its efficiency and by economic aspects. These depends essentially on the investment costs, the operating expenditures and the speed and quality of production.

We don't believe that the conventional photographic frame camera will be displaced by the digital camera, but the digital camera will complement and extend the tools of photogrammetrists and remote sensing experts considerably.

6. Advantages of the DPS

What are the advantages and problems of the DPS compared will "classical" photogrammetry?
The general advantages of digital image processing, the combination of geometric rectification with spectral measurements and classification have already been mentioned. Beyond these important facts we see further advantages of the DPS:

a) The height determination of DEM points by the DPS is more accurate than with frame photography, specially from space. The basic formulas for both cameras are the following:

Photographic frame camera: $$m_h = \frac{h \cdot m_p}{s(1-u)}$$

DPS-camera: $$m_h = \frac{h \cdot m_p}{2.f.\tan \gamma/2}$$

The parameters have the following meaning:

m_h = Elevation error
m_p = Parallaxe measurement error in the image plan
h = Flight altitude
f = Focal length
s = Format of the camera
u = Factor of overlapping (ca. 0.6)
γ = Angle of convergence

It is remarkable that in conventional photogrammetry the elevation error is only proportional to the flying height h and not influenced by the focal length f. In contrast the elevation error can be reduced by a longer focal length f of the DPS camera.

b) The digital images can never loose their quality by any manipulation or storage.

c) The middle strip B_S of the DPS camera delivers a near orthophoto with least possible distortions.

d) The scanning of three completely overlapping strips by the DPS camera permits the computation of the whole strip in one homogeneous, closed and automatic process without the determination of tie points and manual manipulations.

The main problem up to now is the large amount of digital data and in consequence the relatively long times of computation. But this disadvantage is more and more alleviated by the general development in the field of computer and storage technology. In so far the whole development meets the DPS.

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