

ANALYTICS IN NON-TOPOGRAPHIC PHOTOGRAMMETRY

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Abstract

The paper describes possibilities and procedures for the analytical restitution of photogrammetric images, including strategies for simultaneous determination of the image space parameters. The orientation of small format matrix-sensors is especially taken into account.

Introduction

The analytical formulation and numerical realization of image restitution has increased the possibilities of photogrammetry very much:

The photogrammetric parameters can be chosen according to the situation on site, without restrictions caused by the limited possibilities of the camera and the restitution procedure.

Recently developed recording techniques, analogue photography as well as electronic digital imaging, can be applied to photogrammetry, enlarging the possibilities especially in non-topographic applications.

By means of a general analytic formulation, the given non-photogrammetric information can be used simultaneously in the photogrammetric restitution process. The combined adjustment of photogrammetric and non-photogrammetric information offers best possible preconditions for precision and reliability.

1. Bundle orientation

1.1. Photogrammetric bundles

The simultaneous orientation of all the bundles given in a photogrammetric network (fig. 1) is the basic procedure in non-topographic photogrammetry (bundle adjustment). According to fig. 2 equations 1 describe the photogrammetric information, that are the measured image coordinates, as a function of the unknown object coordinates and the orientation parameters. This leads to a redundant system which allows to determine the unknown parameters by means of least square adjustment: The object coordinates and the orientation parameters in object

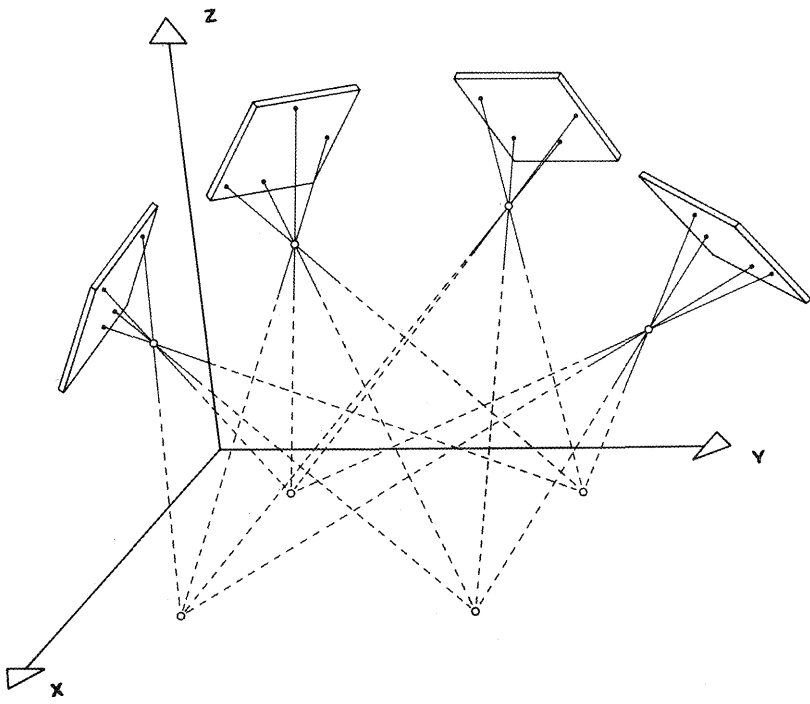


Fig. 1 Multi-Image-Triangulation

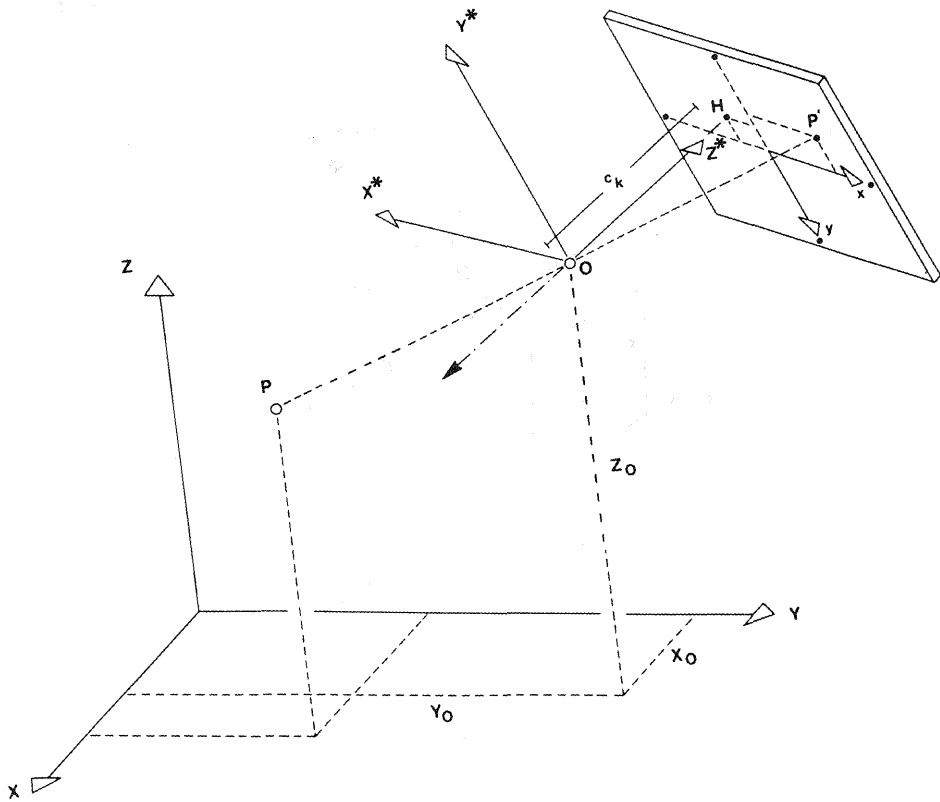


Fig. 2 Definition of a photogrammetric direction

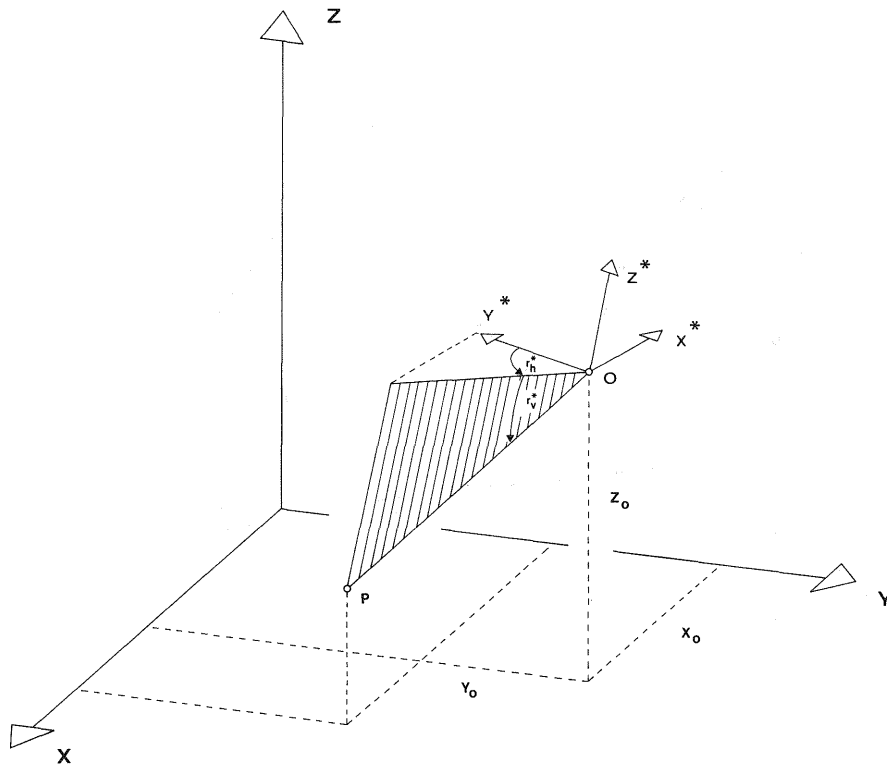


Fig. 3 Definition of a direction measured with a theodolite

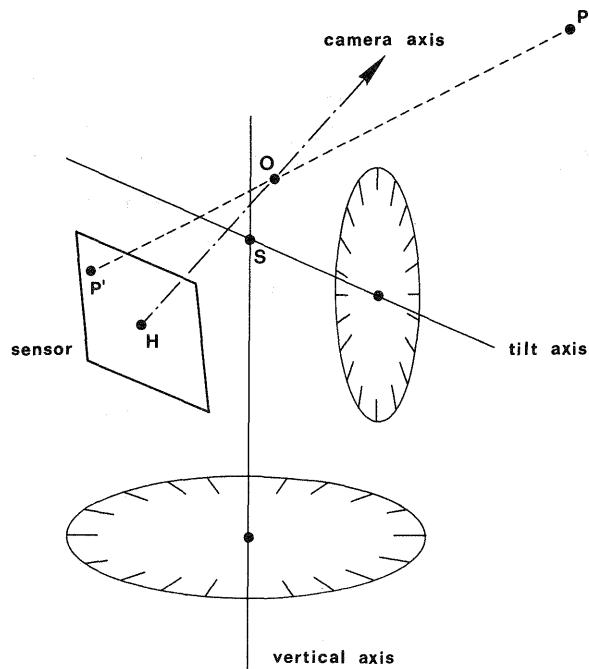


Fig. 4 CCD-matrix-sensor integrated into the telescope of a electronic theodolite

and image space are determined in order to fit the bundles of rays, which are defined by the object points and the perspective centres, to the measured image points in the best possible way, following the restriction that the square sum of the deviations between the projected and the measured image points has to be minimal (Wolf 1975, Wong 1975, Hell 1979, El-Hakim 1982, Wester-Ebbinghaus 1985).

The photogrammetric network may be adjusted free, using only the measured image coordinates, or restricted, orientating the model absolutely in object space by means of additional control information (Zinndorf 1985, Papo 1986, Fritsch 1986, Koch 1988).

1.2. Bundles measured with a theodolite

According to fig. 3, equations 2 formulate the horizontal and vertical directions r_h^* and r_v^* , measured with a theodolite, as a function of the object coordinates and the orientation parameters of the theodolite axes. By these means, bundles measured with a theodolite can be introduced into bundle adjustment (Wester-Ebbinghaus 1985).

Similar to chapter 1.1 the parameters are determined, minimizing the deviations between the measured directions r_h^* and r_v^* and those, projected by means of the equations 2.

If the instrument was levelled or if the direction of the vertical axis was measured on-site (Elmiger and Meyer 1981), ω and φ may be introduced as additional observations (Wester-Ebbinghaus 1985).

1.3. Bundles measured with a video-theodolite

With a CCD-matrix sensor, integrated into the telescope of a motorized electronic theodolite (fig. 4), it is possible to measure the rays automatically (Gottwald and Berner 1987, Wester-Ebbinghaus 1988, b). The theodolite needs to be directed towards the object point only approximately, just to make the target appear inside the frame of the matrix sensor (fig. 5). In order to introduce the measurements into bundle adjustment, equations 3 describe the image coordinates x, y as a function of the orientation parameters of the theodolite axes in the object coordinate system, the measured directions r_h^* , r_v^* and the parameters describing the orientation of the matrix sensor system in the system of the theodolite axes. X_0, Y_0 and Z_0 are the object coordinates of S , the centre of the theodolite axes. In order to describe the situation generally, the vertical axis Z_T^* of the theodolite is not considered to be vertical orientated rigorously. Y_T^* defines the horizontal and vertical zero direction. In order to move the instrument into the recording position, the theodolite is first turned horizontally by r_h^* around Z_T^* , transferring X_T^* to \tilde{X} , and then tilted by r_v^* around \tilde{X} , transferring Y_T^* finally to \tilde{Y} . Vector \vec{r}_0 is defined between S and the perspective centre O .

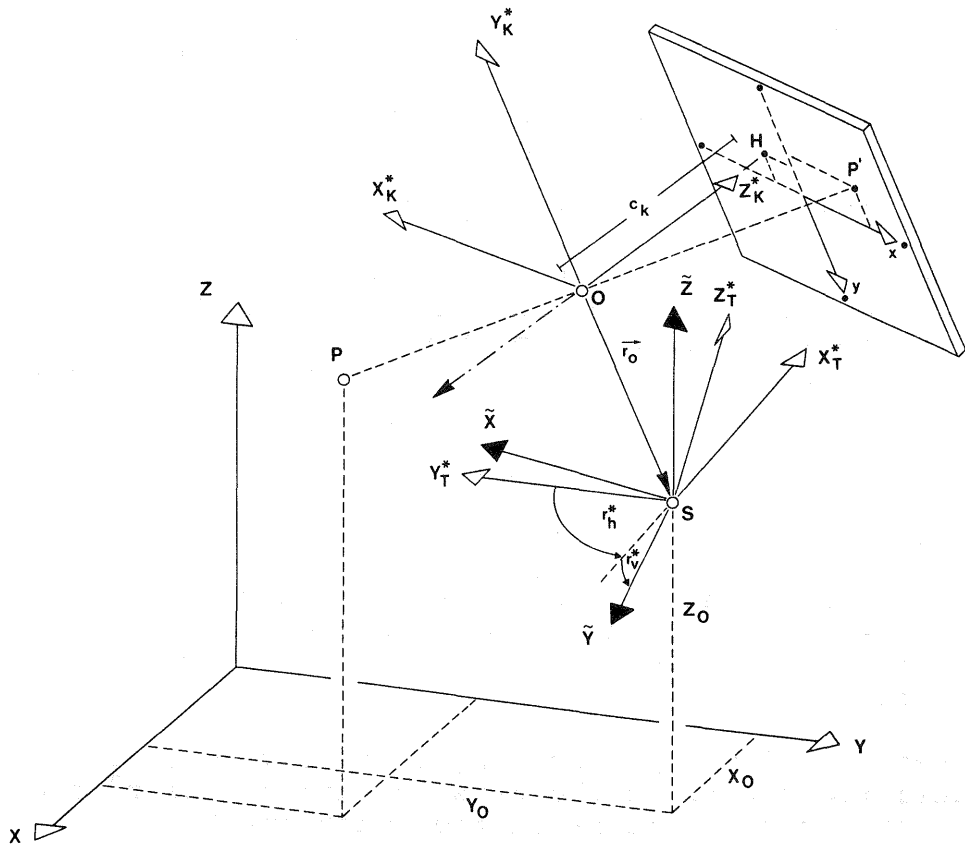


Fig. 5 Definition of a direction measured with a video-theodolite

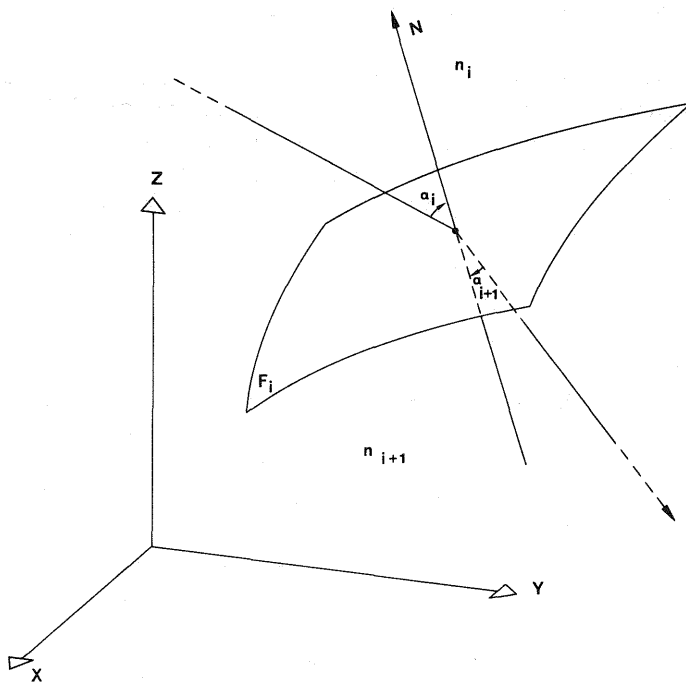


Fig. 6 Refracting surface in a bundle of rays, Multi-Media-Photogrammetry by rigorous ray tracing (Kotowski 1987 and 1988)

1.4. Alternative parameters for the orientation of bundles of rays

Hinsken (1987, 1988) presented an algorithm, which allows the spatial orientation of bundles of rays without predefining initial values, the algebraic rotation parameters are derived from a formulation, Pope presented 1970. The algorithm is very well suited to realize a step wise orientation strategy in order to determine initial values for the parameters of the bundle adjustment. The bundle adjustment itself, also formulated by these alternative parameters, proved to converge in a robust and rapid way.

2. The photogrammetric camera

2.1. Correction of film deformations by means of réseau technique

Réseau cameras have become very important in non-topographic photogrammetry. In addition to high precision large format cameras ($13 \times 18 \text{ cm}^2$ - $23 \times 23 \text{ cm}^2$) like Zeiss Jena UMK and GSI CRC1 (Fraser and Brown 1986) with mechanical film flatening, small format cameras ($6 \times 6 \text{ cm}^2$ - $2,4 \times 3,6 \text{ cm}^2$) like Hasselblad MK70/MKW, Rolleimetric 6006/3003 and Leitz Elcovision, equipped with a glas réseau plate for numerical correction of film-deformation, allow to use professional photo technique for photogrammetry. Conventional terrestrial photogrammetric medium format cameras ($6 \times 9 \text{ cm}^2$ - $9 \times 12 \text{ cm}^2$) like Wild P31/P32 and Zeiss Oberkochen TMK/SMK, mainly designed for the use of photo plates, dissappeared from the market.

Kotowski (1984) presented a flexible analytical procedure for the correction of film deformations by means of réseau information. A synthetic regular interpolation grid is derived from the deformation, determined at the réseau points, which may be measured in non-regular distribution. The procedure is similar to strategies for object hight interpolation in topographic photogrammetry, using finite elements (Ebner 1983). In order to carry out a least square adjustment, the deformation measured at the réseau points is described as a function of the deformation to be determined at the grid points, using bi-linear interpolation. Continuity between adjoining meshes is realized by additional observations, defining the degree of restriction by a suitable observation weight.

2.2. Analytical camera calibration

In non-topographic applications with convergent photographs and spatial object range, often it is not possible to define the image space parameters instrumentally and to calibrate the camera in advance.

The image space parameters can be treated as unknowns within the bundle adjustment, if the photogrammetric net work is

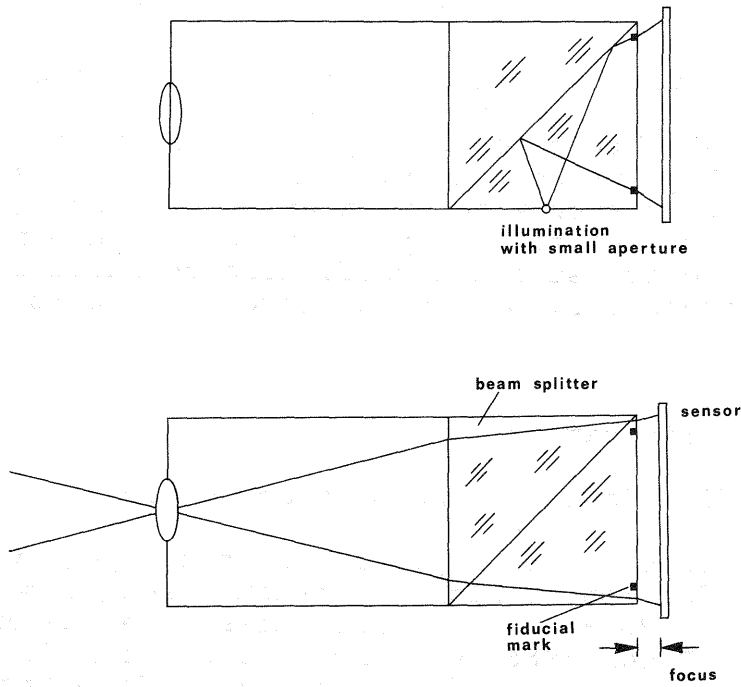


Fig. 7 Focusable CCD-video-camera with fiducial marks

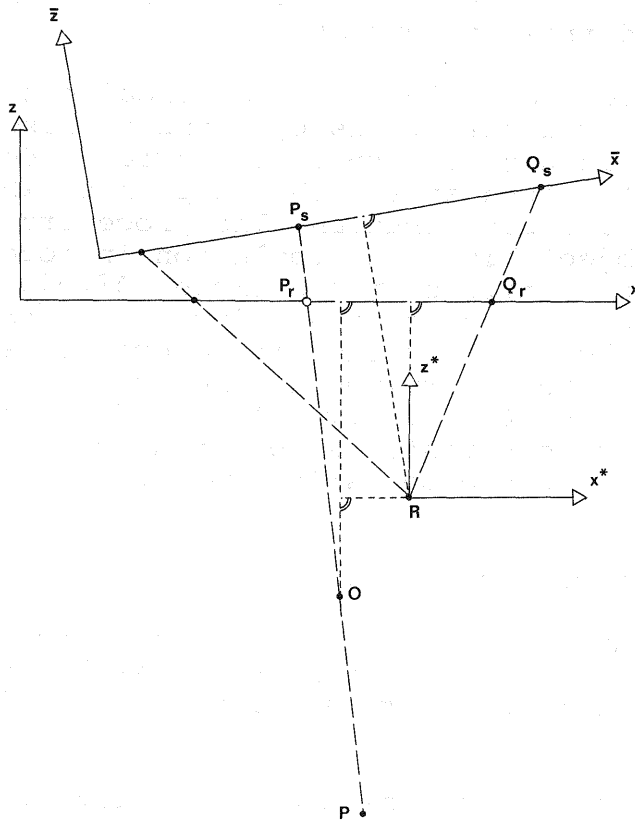


Fig. 8 Orientation of a matrix-sensor in image space by means of fiducial marks projected with a separate illumination source

designed in a suitable way, supported by additional geometric information in object space if necessary. A comprehensive description of typical schemes for camera calibration, simultaneously carried out within bundle adjustment, was presented by Wester-Ebbinghaus (1988 a).

By means of simultaneous camera calibration the photogrammetric net can be restituted in the best possible way, making use of the measured image information independent from instrumentally defined, pre-determined parameters.

3. CCD-matrix-sensors in the photogrammetric recording system

3.1. Metric CCD-video-camera

CCD-matrix-sensors in principle are suitable for photogrammetric applications. The solid state surface offers the geometric preconditions for the recording of digital images on-site, which allow photogrammetric restitution on-line.

The image transfer of conventional television technique however provides digital images with considerable geometric deformations, mainly the so called line-jitter (Beyer 1988), affine deviation between the x- and y-coordinates and shift of the image reference system. While line-jitter can be corrected electronically by means of external synchronisation, (Wester-Ebbinghaus 1988 b), affine deformation and shifting of the image reference system can be adjusted photogrammetrically, by projecting fiducial marks onto the sensor (fig. 7).

Using a special illumination with small aperture, the fiducial marks are projected with great depth of sharpness. Therefore the camera can be focused for every single object point, shifting the sensor perpendicularly to the fiducial plane; by reprojecting the individually focused images into the fiducial plane by means of the fiducial marks, all the recorded object points are finally defined in the same image plane with constant image space parameters.

The perspective relation between the fiducial illumination source and the fiducial marks can not be considered to correspond exactly to the perspective relations between the centre of the object recording and the fiducial marks. Therefore the orientation and the reprojection of the images has to be carried out in separated steps, distinguishing between the centre of fiducial projection and the centre of object recording.

In fig. 8 O is the projection centre of the object recording and R the illumination source for the fiducial projection. Equations 4 describe the coordinates of the fiducial mark Q_r in the fiducial plane x, y as a function of the coordinates of the projected fiducial mark Q_s in the sensor system

$\bar{x}, \bar{y}, \bar{z}$, the orientation parameters of x^*, y^*, z^* in the sensor system $\bar{x}, \bar{y}, \bar{z}$ and the coordinates of R in the fiducial system x, y, z . By means of equations 4 the orientation of x^*, y^*, z^* in $\bar{x}, \bar{y}, \bar{z}$ can be determined using at least four fiducial marks.

By means of the equations 5 the image point P_S in the sensor system $\bar{x}, \bar{y}, \bar{z}$ is transferred to P_R in the fiducial plane x, y : after P_S is transformed from $\bar{x}, \bar{y}, \bar{z}$ into x^*, y^*, z^* by means of the orientation parameters of x^*, y^*, z^* in $\bar{x}, \bar{y}, \bar{z}$, determined by the equations 4, x^*, y^*, z^* is translated from R to O in order to carry out the central projection of P_S into P_R with respect to O, using the coordinates of O in the fiducial system x, y, z .

3.2 Réseau-scanning-camera

A réseau-scanning-camera allows high resolution digital object recording by means of sequentially recorded large scale partial images, shifting an matrix-sensor in the image plane of a photogrammetric camera. The orientation of the partial images in the image space of the camera is realized optic-numerically by means of a réseau plate in the image plane (Luhmann and Wester-Ebbinghaus 1987, Riechmann 1988).

The focusing, the orientation and the projection of CCD-images, described in chapter 3.1, can be applied to réseau-scanning as well, using the four points of the réseau meshes as fiducial marks for the partial images concerned.

Conclusions

The paper tried to point out some aspects of the state-of-the-art in analytical non-topographic photogrammetry, basic formulations which are already used in operational systems as well as recent developments for systems to be realized in the near future.

Electronic matrix-sensors, providing digital images on-site, offer exciting new applications for non-topographic photogrammetry, but they need special analytical solutions in order to use these new potentials consequently.

$$\begin{bmatrix} X^* \\ Y^* \\ Z^* \end{bmatrix} = D(\omega, \varphi, x) \cdot \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \frac{-c_k}{Z^*} \cdot \begin{bmatrix} X^* \\ Y^* \end{bmatrix} + \begin{bmatrix} x_H + dx \\ y_H + dy \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} X^* \\ Y^* \\ Z^* \end{bmatrix} = D(\omega, \varphi, x) \cdot \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix}$$

(2)

$$r_h^* = \arctan \frac{X^*}{Y^*} \quad r_v^* = \arctan \frac{Z^*}{\sqrt{X^{*2} + Y^{*2}}}$$

$$\begin{bmatrix} x_{Q_S}^* \\ y_{Q_S}^* \\ z_{Q_S}^* \end{bmatrix} = D(\omega, \varphi, x) \cdot \begin{bmatrix} \bar{x}_{Q_S} - \bar{x}_R \\ \bar{y}_{Q_S} - \bar{y}_R \\ -\bar{z}_R \end{bmatrix}$$

(4)

$$\begin{bmatrix} x_{Q_R} \\ y_{Q_R} \end{bmatrix} = \frac{z_R}{z_{Q_S}^*} \cdot \begin{bmatrix} x_{Q_S}^* \\ y_{Q_S}^* \end{bmatrix} + \begin{bmatrix} x_R \\ y_R \end{bmatrix}$$

$$\begin{bmatrix} x_{P_s}^* \\ y_{P_s}^* \\ z_{P_s}^* \end{bmatrix} = D(\omega, \varphi, x) \cdot \begin{bmatrix} \bar{x}_{P_s} - \bar{x}_R \\ \bar{y}_{P_s} - \bar{y}_R \\ -\bar{z}_R \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} x_{P_r} \\ y_{P_r} \end{bmatrix} = \frac{z_O}{z_{P_s}^* - z_O^*} \cdot \begin{bmatrix} x_{P_s}^* - x_O^* \\ y_{P_s}^* - y_O^* \end{bmatrix} + \begin{bmatrix} x_O \\ y_O \end{bmatrix}$$

$$\begin{bmatrix} x_T^* \\ y_T^* \\ z_T^* \end{bmatrix} = D(\omega, \varphi, x) \cdot \begin{bmatrix} X - X_O \\ Y - Y_O \\ Z - Z_O \end{bmatrix}$$

$$\begin{bmatrix} \tilde{X} \\ \tilde{Y} \\ \tilde{Z} \end{bmatrix} = D(r_h^* + dr_h^*, r_v^* + dr_v^*) \cdot \begin{bmatrix} x_T^* \\ y_T^* \\ z_T^* \end{bmatrix}$$

(3)

$$\begin{bmatrix} x_K^* \\ y_K^* \\ z_K^* \end{bmatrix} = D(\omega_O, \varphi_O, x_O) \cdot \begin{bmatrix} \tilde{X} & r_{x_O}^* \\ \tilde{Y} & r_{y_O}^* \\ \tilde{Z} & r_{z_O}^* \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \frac{-c_k}{z_K^*} \cdot \begin{bmatrix} x_K^* \\ y_K^* \end{bmatrix} + \begin{bmatrix} x_H + dx \\ y_H + dy \end{bmatrix}$$

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In non-topographic photogrammetry FOD embraces such aspects as camera and target point locations, imaging geometry, camera selection, and the influence of self-calibration in the final bundle adjustment. The most common approach to FOD is. Given an ideal Q , both A and P are updated to improve the network. Simulation, notably through the use of interactive computer graphics (Mephram and Krakiwsky, 1981), has proven a successful method for TOD in geodetic network design. As in SOD, the densification problem seems to be somewhat simplified for non-topographic photogrammetric networks. As will be shown in a later section of this paper, the impact on object point precision of adding additional points in an already "strong" network, as measured by the change in Q , is minimal.

Non-topographic photogrammetry /. Saved in: Other Authors: Adams, L. P., Karara, H. M. Published: Falls Church, Va. : American Society for Photogrammetry and Remote Sensing, 1989. Edition: 2nd ed. Photogrammetry is the science of obtaining reliable information about the properties of surfaces and objects without physical contact with the objects, and of measuring and interpreting this information. The name "photogrammetry" is derived from the three Greek words phos or phot which means light, gramma which means letter or something drawn, and metrein, the noun of measure.

maps topographic maps special maps. Figure 1.3: Photogrammetry portrayed as systems approach. Non-atness would not only decrease the image quality (blurring) but also displace points, particularly in the corners. Magazine Obviously, the magazine holds the Im, both, exposed and unexposed. A Im roll is 120 m long and provides 475 exposures.