HIGH RESOLUTION DIGITAL OBJECT RECORDING BY VIDEO-THEODOLITE

Wilfried Wester-Ebbinghaus

Institut für Photogrammetrie und Bildverarbeitung
der Technischen Universität Braunschweig
Gaußstraße 22, 3300 Braunschweig
Federal Republic of Germany

Commission V

Abstract

A video theodolite was realized mounting the photogrammetric CCD-Video-Camera Rollei VC metric to the telescope of the electronic theodolite Zeiss ETh 3.

Introduction

CCD-matrix-sensors allow simultaneous photogrammetric real-time object recording and processing. The resolution of these sensors, however, is more than ten times lower than that of conventional photogrammetric analogue imaging systems. Therefore the accuracy of photogrammetric object restitution achieved with available CCD-matrix-sensors is limited on principle: although the digital determination of image points is possible within one tenth of a pixel or even better (Fraser and Brown 1986), Luhmann 1986, Beyer 1987), the corresponding accuracy in object space will not be much better than 10^{-4} (Haggren 1987).

If the object is stable and need not be totally recorded at the same time, the resolution and accuracy achieved by CCD-video-systems can be increased by sequential large scale recording. The high resolution partial images obtained by this approach can be recorded simultaneously at several stations and processed in real-time.

Sequential digital large scale recording may be realized by reducing the distance between object and recording station. Because of the increasing number of images and stations, however, image orientation will be difficult.

A more effective procedure for high resolution digital object recording can be realized by means of long focus cameras, allowing concentration on a limited number of suitable triangulation stations. The relative orientation of the narrow angle partial images, recorded sequentially at one station, can be determined instrumentally by means of a local measuring system. In order to restitute all the partial images achieved at all the chosen stations, only the orientation of the local systems, defined instrumentally at every station, has to be determined. This can be carried out numerically by means of bundle adjustment (Wester-Ebbinghaus 1988).

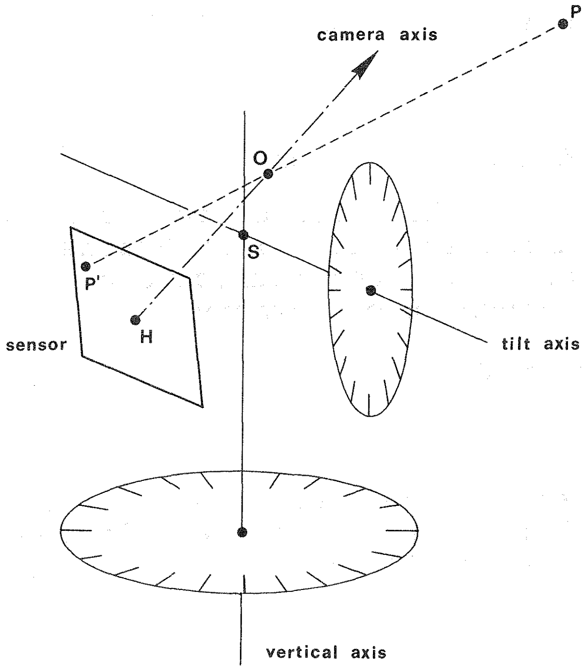

Fig. 1 local sensor orientation by means of the theodolite

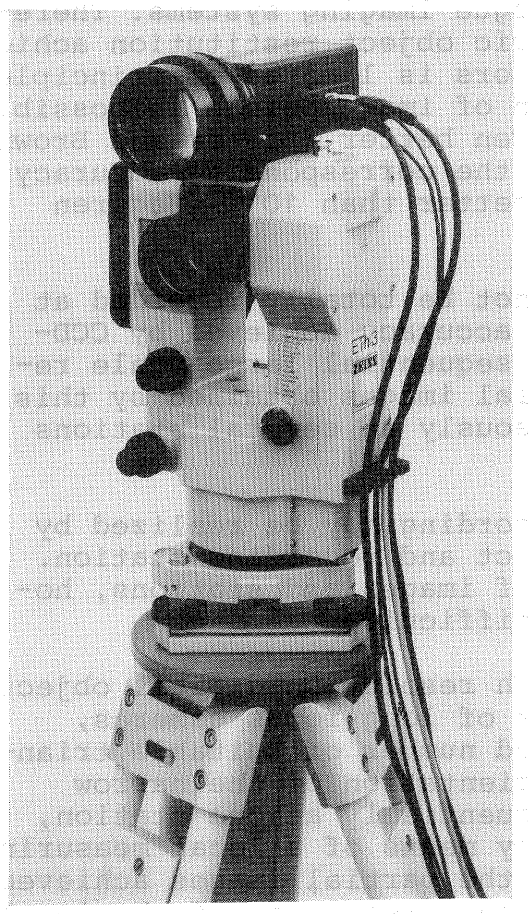

Fig. 2

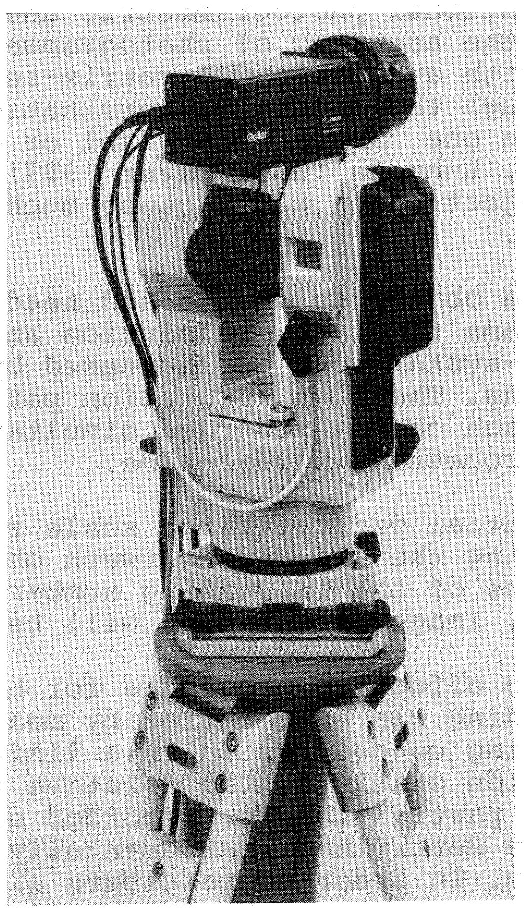

Fig. 3

Electronic theodolite Zeiss ETh 3, equipped with stepping motors and combined with the photogrammetric CCD-camera Rollei VC metric

A video-theodolite system

The geometric relation between long focus partial images of an object, recorded sequentially at one station, can be defined by means of the measuring system of a theodolite. The principle is shown in fig. 1. The sensor can be integrated into the theodolite telescope (Gottwald and Berner 1987). Less instrumental effort is required, when the sensor is part of a separate video camera, mounted to the theodolite telescope. In that case image space and theodolite axes are strictly separated.

Fig. 2 and 3 show the video theodolite which is developed at the Institut für Photogrammetrie und Bildverarbeitung der Technischen Universität Braunschweig in cooperation with Carl Zeiss/Oberkochen and Rollei Fototechnic/Braunschweig.

The electronic theodolite Zeiss ETh 3 is equipped with stepping motors for the vertical and the horizontal axis.

The video camera Rollei VC metric, which is also available seperately (Fig. 4), is specially designed for photogrammetric purposes: the external synchronisation avoids line jitter in the CCD-images and the fiducial marks, projected onto the sensor surface by central projection, define the image space coordinate system optically, independent from the affine deformation and the electronic shift of the CCD-image coordinate system.

According to fig. 5 and 6 the fiducial marks and the object are recorded separately. By means of a beam splitter, an internal illumination projects light onto the fiducial marks, while the camera shutter is closed (fig. 6). The image recorded by the sensor only consists of the projected fiducial marks. In such a pseudo binary image, automatic digital detection of the fiducial marks can be carried out with high accuracy and reliability.

Because of a very small aperture of the illumination source, the fiducial marks are projected with great depth of sharpness. Therefore fiducials and sensor need not be in the same plane in order to get a sharp image of both, the fiducial marks and the object (fig. 5): it is possible to focus the camera individually for every single object point by moving the sensor perpendicularly to the fiducial plane. Because of the perspective reprojection into the fiducal plane, all the partial images are defined finally in one entire and constant image space coordinate system. This leads to a focusable video system with constant interior orientation.

The relation between the measuring system of the theodolite and the image space of the video camera can be taken into account numerically. In order to determine the unknown parameters of the system and in order to integrate a priori known paramters, bundle adjustment is to be carried out, using a direct mathematical formulation, which describes the image coordinates of the CCD-camera as a function of the object coordinates, the orientation parameters and the horizontal and vertical angles, provided by the theodolite system (Wester-Ebbinghaus, 1988).

Fig. 4 Photogrammetric CCD-camera Rollei VC metric: motorized focusing, fiducial marks (see fig. 5 and 6) and external line synchronisation

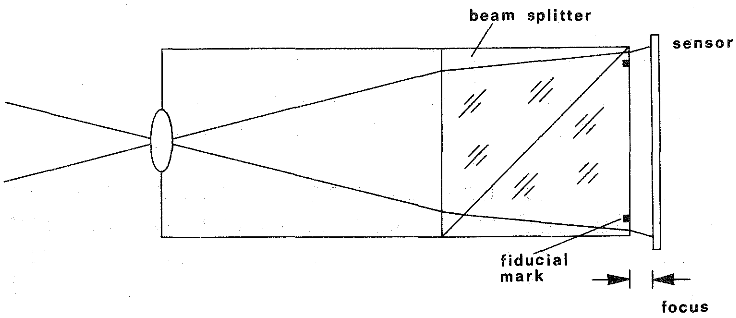

Fig. 5 CCD-camera with fiducial marks, object recording (compare fig. 6)

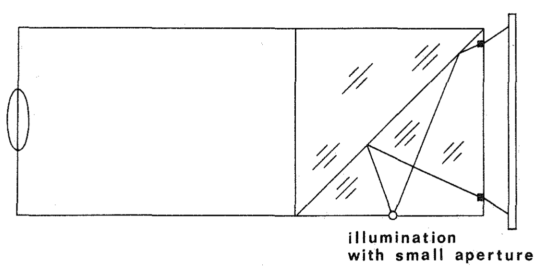

Fig. 6 CCD-camera with fiducial marks, recording of the fiducial marks (compare fig. 5)

Conclusions

High resolution digital object recording with small format matrix sensors can be carried out with long focus lenses, scanning the object sequentially with narrow angle partial images.

The relative orientation of the partial images can be determined instrumentally in a local system, defined at every station by means of a theodolite.

Fiducial marks, projected onto the sensor, allow to focus individually for every single object point without changing the image space parameters. At the same time, the main geometric deformations of digital images achieved from CCD-matrix-sensors, such a affine deformation and shifting of the coordinate system (Beyer 1987), are corrected when transforming the digital images onto the instrumentally defined marks.

References

Beyer, H. A., 1987: Some Aspects of the Geometric Calibration of CCD-Cameras. ISPRS Conference "Fast Processing of Photogrammetric Data", Interlaken.

Fraser, C., Brown, D.C., 1986: Industrial Photogrammetry-New Developments and Recent Applications. The Photogrammetric Record 12 (68).

Gottwald, R., Berner, W., 1987: Electronic Theodolites - Sensor-Systems for Real-Time-Photogrammetry ? . ISPRS Conferences "Fast Processing of Photogrammetric Data", Interlaken.

Haggrén, H., 1987: Mapvision - The Photogrammetric Machine Vision System. ISPRS Conference "Fast Processing of Photogrammetric Data", Interlaken.

Luhmann, T., 1986: Ein Verfahren zur rotationsinvarianten Punktbestimmung. Bildmessung und Luftbildwesen 54 (4).

Wester-Ebbinghaus, W., 1988: Analytics in Non-Topographic Photogrammetry. ISPRS Congress Kyoto, Invited Paper for Commission V.