PERFORMANCE EVALUATION OF A 5 MEGAPIXEL DIGITAL METRIC CAMERA FOR USE IN ARCHITECTURAL PHOTOGRAMMETRY

J. Peipe [a], M. Stephani [b]

[a] Bundeswehr University Munich, D-85577 Neubiberg, Germany - j-k.peipe@unibw-muenchen.de
[b] Technical University Munich, D-80290 Munich, Germany - manfred.stephani@bv.tu-muenchen.de

Commission V, WG V/4 & IC WG III/V

KEY WORDS: Digital Camera, Metric Camera, Camera Calibration, Architectural Photogrammetry, Rectification of Cylindrical Surfaces

ABSTRACT:

The stability and geometric quality of a Rollei d7 metric[5] digital camera equipped with a 5 megapixel CCD sensor and several metric features were investigated. From a series of calibration measurements it could be stated that the camera provides quite stable values of the interior orientation parameters. In addition, a narrow nearly circular cylindrical apse of a small church of the Romanesque period covered with frescoes was photographed with the d7 metric[5]. For the evaluation of the photos a new procedure for rectification of cylindrical surfaces was used.

1. METRIC CAMERAS

Analogue metric cameras have been used in aerial photogrammetry for a long time. They are characterized by technical features such as

- robust mechanical structure of the lens-camera system
- high stability of the camera geometry: the interior orientation parameters remain unchanged and can be treated as known over a long period of time (fixed focal length, fixfocus)
- lenses are almost free of distortion
- principal point offset is equal to zero
- plane image surface by mechanical flattening
- definition of an image coordinate system by fiducial marks

In the same way, the metric camera principle has been applied to the construction of instrumentally stable terrestrial cameras for close range photogrammetry applications (Luhmann, 2000). Metric cameras such as WILD P31 and Zeiss UMK provide large image formats up to 130 x 180 mm^2. If their calibration parameters are once determined, they allow for immediate and uncomplicated image measurement and processing. On the other hand, these cameras are not easy to handle, heavy, unflexible and expensive. They have been successfully applied, e.g. in architectural and archaeological photogrammetry, but were not successful in solving industrial measurement tasks.

Off-the-shelf digital cameras have to be regarded as non-metric cameras. They have been developed so far for the mass market but not in accordance with photogrammetric stability demands. The interior orientation values of such a camera have to be determined by simultaneous calibration within the 3-D object reconstruction process - as far as somewhat precise results are required.

In this paper, a new 5 megapixel SLR camera is described which presents several important metric features, e.g. fixfocus and a solid connection between lens and CCD sensor. Some calibration work using a targetted point field and automated measurement software was carried out to prove the stability of the camera. In addition, the photogrammetric performance of the d7 metric[5] was tested in an architectural photogrammetry application.

2. D7 METRIC[5] DIGITAL CAMERA

The Rollei d7 metric[5] is a digital single-lens reflex (SLR) camera equipped with a colour CCD sensor of approx. 5 million pixels (Fig. 1; Tab. 1; Bock & Pomaska, 2002; Rollei Fototechnic, 2003). The images can be displayed immediately after acquisition on a 2.5" colour screen to check the image quality.

Figure 1. Rollei d7 metric[5]

Sensor	2/3" CCD	Sensitivity	equivalent to ISO 100
Number of pixels	2552 x 1920	Dimensions	151 x 102 x 106 mm^3
Sensor format	approx. 9 mm x 7 mm	Weight	approx. 650 g
Lens	7 mm focal length (= 28 mm for 35 mm camera)		
Image data	6.4 MB uncompressed raw data per image		
Storage medium	SmartMedia, CompactFlash, PCMCIA Card Typ I, II, III		

Table 1. Technical specifications of the Rollei d7 metric[5]

The digital data are saved to memory cards inserted into the camera (SmartMedia, CompactFlash, PCMCIA Cards .....). Subsequently, they can be downloaded to a computer and converted from the special Rollei RAW format into usual data formats such as BMP, TIFF, JPEG by the Rollei d-Image software.

The 7 mm wide angle lens - equivalent to 28 mm for 35 mm cameras - is fixed at a certain focus setting. In addition to the compact and rugged construction of the camera, there is a rigid connection between the lens and the CCD sensor. These features are undoubtedly attributes of a metric camera.

3. RESULTS OF CAMERA CALIBRATION

In the course of a project to determine deformations of an object in aircraft industry by photogrammetric means, a d7 metric[5] was calibrated several times over a period of six weeks (Peipe & Stephani, 2003). The interior orientation and lens distortion parameters of the camera, i.e. principal distance c, principal point offset x_0/y_0, radial-symmetric and tangential distortion coefficients were calculated simultaneously with the numerical 3-D reconstruction process by bundle adjustment.

The results (Tab. 2) show differences of only a few µm between the six data sets of c, x_0 and y_0. Standard deviations amounted to 0.8 µm for c, 0.5 µm for x_0 and 0.6 µm for y_0. As far as the distortion parameters are concerned, corresponding values (in relation to their accuracy) were derived from the six bundle adjustments. Therefore it can be stated, that the d7 metric[5] can be regarded and used as digital metric camera, i.e. the interior geometry of the camera remains stable over a longer period of time.

c (mm)	x_0 (mm)	y_0 (mm)
7.428	0.293	- 0.042
7.429	0.294	- 0.048
7.429	0.293	- 0.044
7.428	0.293	- 0.049
7.428	0.293	- 0.043
7.431	0.298	- 0.048

Table 2. Results of camera calibration

4. EXAMPLE FROM CULTURAL HERITAGE

The photogrammetric performance of the digital metric camera was tested in an application related to architectural photogrammetry. Using the new equipment a narrow nearly circular cylindrical apse of a small church of the Romanesque period covered with frescoes was photographed. Images of the lower vertical cylinder and the semi-spherical ceiling were taken (Fig. 2 and 3). For capturing the images inside the apse presenting a diameter of 5.50 m and a height of 4.40 m only, the internal flash unit of the camera was used. Unfortunately, the intensity of the flash light was not perfectly adjusted at that time. This caused suboptimally exposed areas in the images.

Figure 2. Image of the lower central part of the apse

Figure 3. Image of the ceiling

Drawings of the frescoes exist; they were performed earlier by the Politecnico di Milano. Some results of this work are published in Bezoari et al. (2001; see Fig. 4 and 5).

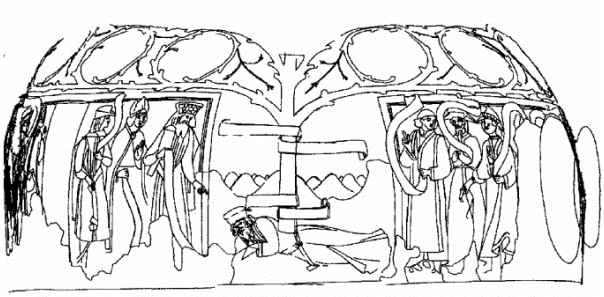

Figure 4. Drawing of the lower part of the frescoes

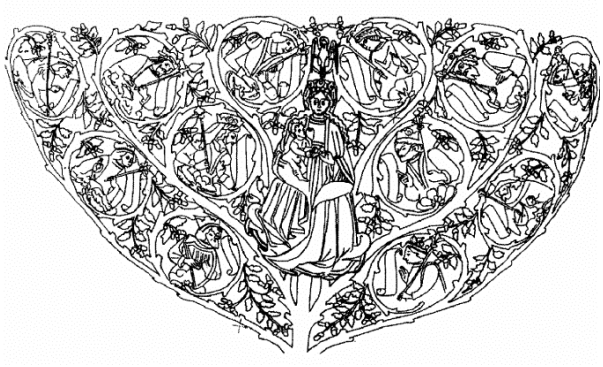

Figure 5. Drawing of the central ceiling

Figure 6. Scaled image mosaic of an orthographic view of the lower central part of the apse

For the evaluation of the digital photos, a new procedure for rectification of curved surfaces was applied (Stephani, 2001). Due to irregularities of the cylindrical shape of the apse one has to accept small discrepancies if an orthographic projection of the lower central part using more than one image is performed. A mosaic of two orthographically restituted images is presented in Fig. 6.

5. CONCLUDING REMARKS

The Rollei d7 metric[5] color camera is well suited for both, industrial and architectural photogrammetry. The stability of the interior orientation elements allows for applications where on the job camera calibration is not desired or even not possible. The high resolution of the sensor in combination with a small and stable focal length provides wide angle images which are necessary if high accuracy of the object reconstruction is demanded. The new camera is easy to handle. As image data storage CompactFlash cards should preferably be used instead of a microdrive due to lower thermal strain of the interior of the camera.

6. REFERENCES

Bezoari, G., Vitelli, G., Selvini, A., Guerra, F., Miniutti, D., 2001. Santuario della Madonna della Ghianda con cappelletta del XIV secolo in Mezzana di Somma Lombardo. In*: Misura e rappresentazione*, Casa Editrice Ambrosiana, Milano, pp. 279 - 282.

Bock, I. ,Pomaska, G., 2002. Software Development for Remote Control of Digital Metric Cameras via LAN and Internet. In: *Int. Archives of the Photogrammetry, Rem. Sensing & Spatial Information Sciences*, Vol. 34/5, Korfu, pp. 3-6.

Luhmann, T. (2000). *Nahbereichsphotogrammetrie*. Wichmann, Heidelberg, 571 p.

Peipe, J., Stephani, M., 2003. Untersuchungen zur Stabilität und metrischen Qualität einer digitalen 5 Megapixel Messkamera. In: *Photogrammetrie - Laserscanning - Optische 3D-Messtechnik* (ed. T. Luhmann), Wichmann,Heidelberg (in press)

Rollei Fototechnic (2003). Product Information d7 metric[5]

Stephani, M. (2001). Rappresentazione digitale per mezzo della trasformazione proiettiva di un'immagine fittizia. In*: Rivista dell'agenzia del Territorio*, Nr.2, Roma, pp. 21-30.