HIGH RESOLUTION DIGITAL IMAGE DATA ACQUISITION – NEW DEVELOPMENTS

Jürgen PEIPE
Institute for Photogrammetry and Cartography
University of Federal Armed Forces Munich
D-85577 Neubiberg, Germany
E-mail: j-k.peipe@unibw-muenchen.de

Commission V, Working Group 1

KEY WORDS: Digital Camera, Large Format CCD Imager, High Resolution, Micro-Scanning

ABSTRACT

High Resolution CCD cameras enable high precision photogrammetric object reconstruction required for a number of industrial applications. Sensors of up to 2k x 2k or 3k x 2k pixels are typical of a first (or second!) generation of high resolution image acquisition systems. Recently, pixel numbers of 4k x 4k and more are provided by newly developed digital cameras. Special importance is to be attached to the metric quality (stability) of a camera. In the paper, a brief review of high resolution imaging systems is given. In addition, the Jenoptik *eyelike* digital camera is described which provides 4k x 4k and 6k x 6k pixels by micro-scanning. Test measurements were carried out to determine the metric performance of the camera.

KURZFASSUNG

Hochauflösende CCD Kameras ermöglichen hochpräzise photogrammetrische Objektrekonstruktion, wie sie für eine Reihe von Anwendungen in der Industrie erforderlich ist. Sensoren mit bis zu 2k x 2x oder 3k x 2k Pixeln sind charakteristisch für eine erste (oder zweite!) Generation von hochauflösenden Kameras. Neu entwickelte digitale Kameras stellen nun 4k x 4k Pixel und mehr zur Verfügung. Dabei ist besonderer Wert auf die metrische Qualität (Stabilität) der Kameras zu legen. In diesem Bericht wird ein kurzer Überblick zu hochauflösenden Abbildungssystemen gegeben. Außerdem wird die Jenoptik *eyelike* Kamera beschrieben, die 4k x 4k und 6k x 6k Pixel durch Mikro-Scanning liefert. Mit dieser Kamera wurden Testmessungen durchgeführt, um ihre metrische Leistungsfähigkeit zu bestimmen.

1. INTRODUCTION

Digital image data for close range photogrammetry can be obtained by a variety of direct image acquisition systems such as camcorders, standard or high-resolution CCD cameras, HDTV or scanning cameras, and digital camera backs connected with medium and large format analogue cameras (Atkinson, 1996). A major limitation of digital against photographic cameras is often the resolution of the imagery being used. Higher resolution, especially required in industrial applications, can be achieved with large CCD sensors or scanning techniques.

Recently, sensors providing 16 million pixels and more have been introduced. Cameras based on the Dicomed BigShot digital camera back are available and can be used for photogrammetric purposes. The aim of this paper is to report on new developments concerning high resolution digital area array cameras. In addition, the Jenoptik *eyelike* digital camera system based on a modular concept is presented. The eyelike can be operated in three modes to generate 2048 x 2048 pixels and - in scan mode - 4096 x 4096 pixels or even 6144 x 6144 pixels.

2. HIGH RESOLUTION SENSORS AND CAMERAS

High resolution area array cameras are required for a number of close range photogrammetry applications, especially in industry, e.g. for the high precision measurement of large structures. Cameras of up to 2k x 2k or 3k x 2k pixels such as the Kodak DCS 460 still video camera and the Kodak Megaplus 4.2i or 6.3i, respectively, have been widely and successfully used.

Recently, 4k x 4k cameras and digital camera backs have been developed, i.e. the Kodak Megaplus 16.8i providing 4096 x 4096 pixels of 9 x 9 µm in size and 36.86 x 36.86 mm image area (Kodak, 1997). The

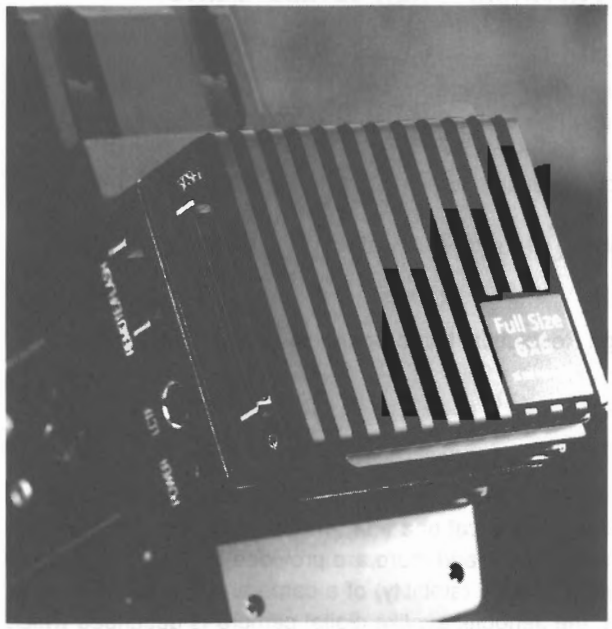

Figure 1 Dicomed BigShot digital camera back incorporated into the Rollei Q16

Dicomed BigShot digital camera back can be attached to several analogue cameras via adapter (Fig. 1). The 4096 x 4096 pixel Loral Fairchild CCD sensor with 15 x 15 µm pixel space covers an image area of 60 x 60 mm. The metric performance of the BigShot camera back connected to a Hasselblad body and also incorporated into the Rollei Q16 MetricCamera was investigated (see Peipe, 1997; Schafmeister, 1997; Godding, 1998).

Apart from the resolution, two aspects seem to be important to the development of CCD cameras used for high precision photogrammetric measurement. First, the stability of the camera, i.e. in particular the stability of interior orientation (calibration stability) should be improved in comparison to cameras designed for photo-journalism and photo-studio applications. In this way, the Rollei Q16 (Godding, 1998) and the new Imetric cameras of 1k x 1.5k, 2k x 3k and 4k x 7k (Beyer, 1998) are making satisfactory progress.

Secondly, the entire photogrammetric measurement process has to be automated more and more. Automated target detection is a well-known example. Another breakthrough is characterized by the introduction of intelligent cameras like the Leica/GSI INCA (Dold, 1997) which provides an integrated computer to support and perform the measurement.

3. THE EYELIKE CAMERA SYSTEM

The name *eyelike* refers to a new digital imaging system manufactured by Jenoptik, Digital Camera Division, Eching/Germany (formerly Kontron Elektronik Digital Camera Division). The camera has been developed to meet the requirements of professional photographers and photographic studios engaged in prepress and reproduction applications, high quality still life and catalogue photography etc.. Technical specifications of the camera are given in Table 1.

The eyelike (eyelike, 1998; Fig. 2) can be used as digital camera back attachable to several 4 x 5" view cameras such as Cambo, Sinar, Linhof, but also as stand-alone camera. In the latter case, 35 mm and medium format lenses are mounted directly to the eyelike housing via lens mount adapters. Hasselblad, Mamiya, Nikon and Rodenstock lenses are applicable. The computer controlled shutter of the camera is incorporated in the housing.

Sensor size	28.67 mm x 28.67 mm
Basic resolution	2048 x 2048 pixel
Scan resolution	4096 x 4096 pixel
	6144 x 6144 pixel
Exposure time	1/60 sec up to 1 sec (internal shutter)
	≥ 1/1000 sec (external shutter)
Digitizing time	2k x 2k: 2 sec, 4k x 4k: 16 sec, 6k x 6k: 40 sec
	(maximum values, depending on the exposure time)
Size	161 x 220 x 180 mm
Weight	3 kg

Table 1 Technical specifications of the eyelike camera

Figure 2 The eyelike digital camera attached to a Cambo view camera

Resolution	2048 x 2048	4096 x 4096	6144 x 6144
s_0 a posteriori	0.24 µm	0.18 µm	0.16 µm
s_X	0.010 mm	0.008 mm	0.007 mm
s_Y	0.011 mm	0.008 mm	0.007 mm
s_Z	0.027 mm	0.021 mm	0.018 mm

Table 2 Results of bundle triangulation of the eyelike imagery

The camera features the Thomson 2048 x 2048 pixel full field CCD image sensor. RGB colour filters are in front of each individual light-detecting element on the chip. In live mode, colour pictures are continually transferred to the computer via a 20 m fibre optic cable. Thus, setup and image quality (focus, exposure) can be controlled on-line on the computer monitor. Overexposure or underexposure are indicated; the focus setting can also be done computer-supported. The one-shot mode of the camera generates 12 MByte colour image data (2048 x 2048 pixels, 12 bit per colour channel).

In addition, the eyelike is equipped with Piezo controlled Aperture Displacement (PAD), i.e. micro-positioning of the chip in two directions by x, y piezo-translators. PAD is applied, on the one hand, to enhance the quality of the digital colour images, and on the other hand, to increase resolution. In the so-called four-shot mode the sensor is shifted four times by a distance of one pixel in x or y direction, thus delivering not interpolated, but real RGB data (2048 x 2048 pixel, 12 MByte). The second option is well-known as micro-scanning (Lenz & Lenz, 1993). The sensor is moved two-dimensionally by 0.5 pixel, i.e. the resolution is increased to 4096 x 4096 pixel. Due to the four-shot mode, in this case 16 steps of the sensor are necessary. The colour image file size amounts to 48 MByte. Finally, the sensor can be shifted by 1/3 pixel in four-shot mode, i.e. 36 steps and a resolution of 6144 x 6144 pixel (108 MByte). It has to be considered, that micro-scanning increases the resolution (number of pixels), but cannot enlarge the image area.

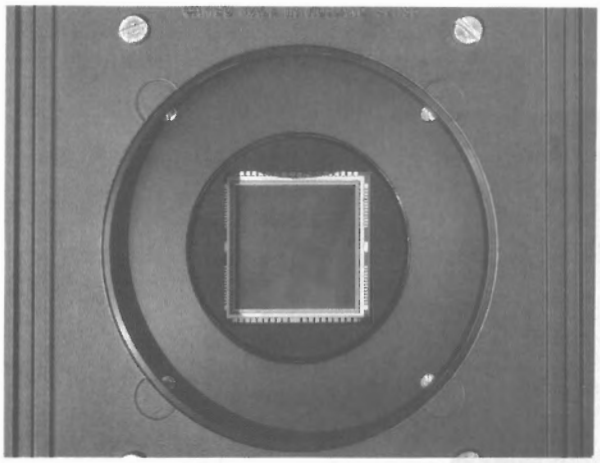

Figure 3 CCD sensor of the eyelike camera

Although developed for professional photo-studio application, the eyelike can be applied for photogrammetric purposes too. Therefore, a 3-d point field of 2.1 x 2.1 x 1.8 m^3 in size marked with 52 targets was recorded under laboratory conditions with the camera using a 55 mm Mamiya lens. Nine digital images were combined to a multi-station convergent block including images required for simultaneous camera calibration. All the three resolution modes of the eyelike were used. The image data were measured on the Digital Photogrammetric Station DPA-WIN (Schneider, 1996) and processed with the CAP bundle adjustment program. The additional parameter model used for simultaneous camera calibration included terms for the principal distance, principal point offset, radial-symmetric and tangential distortion, affinity and non-orthogonality.

The outcome of the bundle triangulation is given in Table 2. The calculated accuracy of both image coordinate measurement and 3-d object reconstruction is quite satisfactory. It has to be considered, of course, that the results of the bundle triangulation express the internal precision only, but can be used as a coarse indicator for the metric quality of the camera in comparison with other imaging systems. The advance in resolution by micro-scanning yields an increased accuracy in image and object space coordinates. But, there is no linear increase: with the 4096 x 4096 resolution nearly the same results are achieved as with 6144 x 6144 pixels.

Generally speaking, the eyelike camera proved to be an accurate digital image acquisition tool, possibly suitable for some close range photogrammetry tasks.

REFERENCES

Atkinson, K.B. (ed.), 1996. Close range photogrammetry and machine vision. Whittles Publishing, Caithness, Scotland, UK, 371 pages: pp. 129-151.

Beyer, H.A., 1998. Next generation metrology cameras and machine control. In this volume.

Dold, J., 1997. The role of a digital intelligent camera for the automation in industrial photogrammetry. Presented paper, Optical 3-D Measurement Techniques IV, Zurich, 9 pages.

eyelike, 1998. Product information. WWW home page, http://www.eyelike.com

Godding, R., 1998. Q16 – A new digital measuring camera with high resolution. In this volume.

Kodak, 1997. Kodak Megaplus Camera, Model 16.8i. Information sheet, Eastman Kodak Company, San Diego, USA, 2 pages.

Lenz, R., Lenz, U., 1993. New developments in high resolution image acquisition with CCD area sensors. Optical 3-D Measurement Techniques II (Eds. A. Gruen and H. Kahmen), Wichmann, Karlsruhe, pp. 53-62.

Peipe, J., 1997. High-resolution CCD area array sensors in digital close range photogrammetry. In: Videometrics V (ed. S.F. El-Hakim), San Diego, USA, SPIE Vol. 3174, pp. 153-156.

Schafmeister, R., 1997. Erste Erfahrungen mit der neuen Rollei Q16 MetricCamera. Presented paper, 17. Wiss.-Techn. Jahrestagung der DGPF, Frankfurt / Main, in press.

Schneider, C.-T., 1996. DPA-WIN – A PC based Digital Photogrammetric Station for fast and flexible on-site measurement. Int. Archives of Photogrammetry & Rem. Sensing, Vol. 31/B5, Vienna, pp. 530-533.

ACKNOWLEDGEMENT

The author wishes to thank the Jenoptik Laser, Optik, Systeme GmbH, Digital Camera Division, for providing the eyelike camera and supporting the test measurement.