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HIGH RESOLUTION DIGITAL CAMERAS IN ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

Digital techniques have been increasingly applied in architectural photogrammetry over the last years. Digital image data can be obtained by analogue/digital conversion of photographs taken with analogue cameras or by direct digital data acquisition. High resolution digital cameras allow for high precision photogrammetric object recognition and reconstruction. In the paper, digital cameras providing 1.5k x 1k pixel, 2k x 2k, 3k x 2k and - by micro-scanning - 4k x 4k and 6k x 6k pixel are compared with each other and also with the results achieved by analogue 35 mm and medium format cameras. The differences between the various sets of 3-d object point data calculated by bundle triangulation show relatively similar values of some millimetres which is also typical of the definition of natural points on an architectural surface. However, the results demonstrate the performance of analogue and digital methods of image acquisition and data processing in architectural photogrammetry.

KURZFASSUNG

In der Architekturphotogrammetrie wurden in den letzten Jahren zunehmend digitale Techniken angewendet. Dabei werden digitale Bilddaten durch Analog/Digitalwandlung photographischer Bilder oder durch direkte digitale Aufnahme erhalten. Hochauflösende digitale Kameras ermöglichen hochpräzise photogrammetrische Objekterkennung und Objektrekonstruktion. Im vorliegenden Bericht werden die mit verschiedenen Kameras erzielten Ergebnisse der Vermessung einer Hausfassade miteinander verglichen - digitale Kameras mit 1.5k x 1k Bildelementen, mit 2k x 2k, 3k x 2k und - durch Micro-Scanning - 4k x 4k und 6k x 6k Bildelementen wurden eingesetzt, zusammen mit analogen Kleinbild- und Mittelformat-Kameras. Die Differenzen der verschiedenen Datensätze dreidimensionaler Objektkoordinaten - berechnet durch Bündeltriangulation - zeigen Abweichungen im Millimeterbereich. Diese Größenordnung ist ebenfalls typisch für die Genauigkeit der Definition natürlicher Punkte an einem Bauwerk. Bedenkt man dies, so sind die eingesetzten analogen und digitalen Techniken der Bildaufnahme und photogrammetrischen Auswertung grundsätzlich zur Vermessung von Gebäuden und Monumenten geeignet.

1. INTRODUCTION

Digital image data can be obtained by analogue/digital conversion of photographs taken with analogue cameras or by direct digital data acquisition using camcorders, standard or high resolution CCD cameras, HDTV or scanning cameras, and digital camera backs connectable with medium and large format analogue cameras (Atkinson, 1996). A major limitation of digital against photographic cameras is resolution. Low and medium resolution consumer cameras - medium resolution means the so-called megapixel cameras - are available for less than US $ 1,500 (e.g. Li & Faig, 1998; Ogleby et al., 1999). These cameras are more or less suited for photogrammetric purposes. Apart from resolution, they may show also some other drawbacks such as small on-board storage capabilities, automatic image data compression, insufficient stability of the interior orientation (automatic focusing, zoom lenses etc.). However, such rather inexpensive off-the-shelf digital cameras will be used in the documentation of cultural heritage due to the increasing interest in generating 3-d models and visualising artefacts, buildings and monuments, also by non-photo-grammetrists.

Higher resolution can be achieved with larger CCD sensors or scanning techniques. Sensors providing 16 million pixels and more have been introduced, but the market for such expensive imaging devices is growing rather slowly.

The aim of this paper is to point to some high resolution digital cameras and, in addition, to a newly developed camera system with variable image resolution based on micro-scanning. Moreover, the photogrammetric survey of a building performed with two analogue and three digital cameras will be described.

2. HIGH RESOLUTION DIGITAL CAMERAS

High against low resolution means, e.g.

- higher demands on the storage capability of the camera and the computer used for image processing
- better object recognition and interpretability
- higher accuracy of object reconstruction
- high resolution cameras are considerably expensive.

Under these circumstances, the application of high resolution digital cameras in architectural photogrammetry will be limited to some special tasks. On a cost/benefit basis, photographic cameras plus A/D conversion may be the better option for high resolution object recording.

However, portable digital cameras providing more than 2k x 2k pixels such as the Kodak DCS 460 (3k x 2k pixel) and the Kodak Megaplus 6.3i have been successfully used in a number of close range photogrammetry applications, especially in industry but also in architectural photogrammetry (Streilein & Niederöst, 1998). In addition, 4k x 4k cameras and digital camera backs have been developed, e.g. 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 Rollei Q16 Metric Camera (Godding, 1998; Fig. 1) is equipped with a Dicomed BigShot digital camera back providing a 4096 x 4096 pixel CCD sensor with 15 x 15 µm pixel space and an image area of 60 x 60 mm. Unfortunately, the Rollei camera is not available on the market at present. The Imetric cameras Icam6 (3072 x 2048 pixel, 36.8 x 24.6 mm sensor size) and Icam 28 (7168 x 4096 pixel, 86.0 x 49.2 mm sensor size) are especially designed for metrology applications in industry (Beyer, 1999; Fig. 2).

In the following, the new high resolution imaging system Jenoptik eyelike is described briefly (eyelike, 1999; Peipe, 1998). 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., but can be applied for photogrammetric purposes too. Technical specifications are given in Table 1.

The eyelike (Fig. 3) 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.

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).

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

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

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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.

3. AS-BUILT DOCUMENTATION

The as-built documentation of a building (Fig. 4 and 5) situated in Schwabing, Munich will be described to demonstrate the performance of different analogue and digital techniques of image acquisition and processing in architectural photogrammetry.

3.1 DATA ACQUISITION AND PROCESSING

The facade of the building was photographed with the analogue réseau cameras Rolleiflex SLX metric and Leica R5 as well as with the digital cameras Kodak DCS 200, DCS 460 (see also Peipe and Zavec, 1998) and Jenoptik eyelike (Table 2). The photographs of each camera can be combined to a block of convergent images in such a way that all object points are included in at least three photographs. The Rollei photographs covered completely the facade whilst the other cameras recorded only the part of the facade which was used to compare the different image processing methods. All the cameras are easy to handle on-site with the exception of the eyelike, of course: transport of camera and computer is rather troublesome, and external power supply is required.

Rollei (A)	55 x 55 mm	
Rollei (D)	55 x 55 mm	4096 x 4096 pixel
Leica R5 (A)	24 x 36 mm	
Leica R5 (D)	24 x 36 mm	4096 x 6144 pixel
DCS 200 (D)	13.8 x 9.2 mm	1524 x 1012 pixel
DCS 460 (D)	27.6 x 18.5 mm	3060 x 2036 pixel
eyelike (D)	28.7 x 28.7 mm	2048 x 2048 pixel
eyelike (D)	28.7 x 28.7 mm	4096 x 4096 pixel
eyelike (D)	28.7 x 28.7 mm	6144 x 6144 pixel

Table 2 Cameras, image size, number of pixels (A = analogue, D = digital)

The photographs of the Rollei and Leica cameras were digitized and stored on Kodak Pro Photo CD. The Pro Photo CD allows the A/D conversion of relatively large image formats up to 4 x 5 inches with high resolution, not exceeding 6144 x 4096 pixels. The main problems of scanning photographs, against direct digital image acquisition, are geometric instabilities and deformations in the image data possibly introduced through the line scanning and compression / decompression process. However, several investigations demonstrate the practicability of the Photo CD for photogrammetric purposes (e.g. Hanke & Weinold, 1995; Thomas et al., 1995), in particular if a réseau camera is used. In this case, image deformations can be eliminated to a great extent by transforming the image onto the réseau crosses.

The analogue images were measured on an analytical plotter, the digital and digitized images on the PC based Digital Photogrammetric Station DPA-WIN (Schneider, 1996). 48 natural points clearly detectable on the facade such as corners of stones or windows were selected to represent the facade. The 3-d co-ordinates of eight control points were determined by a theodolite system.

All the image co-ordinates were then adjusted with the CAP bundle triangulation program. The interior orientations of the cameras were derived by a priori calibration as well as simultaneous calibration within the bundle adjustment. The comparison of the resulting 3-d data sets of the same object points allows to determine the accuracy of the different photogrammetric survey methods, i.e. between the analogue and the digital world.

3.2. RESULTS

The outcome of the Rollei camera (analogue version) is regarded as reference data. The accuracy of the image co-ordinate measurement of the natural points on the facade of about 5 - 6 µm is quite well. This applies also to the standard deviations s_X = 1.6 mm, s_Y = 1.3 mm and s_Z = 2.5 mm of the calculated 3-d object co-ordinates (internal precision after the bundle adjustment). The transformation of the object points achieved by photogrammetry onto the control points yields discrepancies of about 2 - 3 mm. Similar values of about 2 - 4 mm result from the comparison of the Rollei (analogue) object co-ordinates with the Rollei (digital), Leica (analogue) and Leica (digital) data sets, i.e. all the object points are determined with an accuracy of some millimetres which is also typical of the definition of clearly detectable natural points on an architectural surface. This holds true for the DCS 460 and eyelike 2k x 2k data sets too. The eyelike 4k x 4k and 6k x 6k show approx. 10 - 15 % better results due to the increased resolution and object interpretability, whilst the DCS 200 provides a degraded accuracy caused by the lower resolution and the smaller image scale chosen.

As far as the accuracy of the 3-d reconstruction of such an architectural object is concerned, it can be stated that all the data sets show satisfactory results. However, differences appear if the economic efficiency

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is taken into account. That means the cost of a measurement system, handling of hardware and software, time required to perform the photogrammetric work etc.. Here, the purely digital procedure has the advantage from the direct digital data transfer. Film development, A/D conversion and the measurement of réseau crosses are not necessary. But, an advantage of the analogue cameras, in particular the Rolleiflex medium format camera, is obvious: the large image format (Tab. 2) allows to cover larger parts of the facade at the same image scale. The comparison of the results achieved with the three resolution options of the eyelike camera points to an accuracy improvement when using high resolution cameras.

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., 1999. Design and performance of a metrology camera with 6 and 28 million pixel CCD-sensors. In: Videometrics VI (eds. S.F. El-Hakim and A. Gruen), San Jose/USA, SPIE Vol. 3641, pp. 194-198.

eyelike, 1999. Product information. Web site http://www.eyelike.com

Godding, R., 1998. Q16 – A new digital measuring camera with high resolution. Int. Archives of Photogrammetry & Rem. Sensing, Vol. 32/5, Hakodate, pp. 67-69.

Hanke, K., Weinold, T., 1995. Using the Photo CD as a source and digital memory for photogrammetric images. In: Digital Photogrammetry and Remote Sensing '95 (ed. E.A. Fedosov), St. Petersburg/Russia, SPIE Vol. 2646, pp. 42-48.

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.

Li, X., Faig, W., 1998. A survey on low-resolution digital cameras. Geomatics Info Magazine (GIM), Vol. 12 (1), pp. 67-70.

Ogleby, C., Papadaki, H., Robson, S., Shortis, M., 1999. Comparative camera calibrations of some “off-the-shelf” digital cameras suited to archaeological purposes. Int. Archives of Photogrammetry & Rem. Sensing, Vol. 32/5W11, Thessaloniki/Greece, pp. 69-75.

Peipe, J., 1998. High resolution digital image data acquisition - new developments. Int. Archives of Photogrammetry & Rem. Sensing, Vol. 32/5, Hakodate, pp. 139-142.

Peipe, J., Zavec, O., 1998. 3-d object reconstruction in architectural photogrammetry with analogue and digital cameras - a comparison. Int. Archives of Photogrammetry & Rem. Sensing, Vol. 32/5, Hakodate, pp. 633-636.

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.

Streilein, A., 1998. Reconstruction of the Disentis monastery from high resolution still video imagery with object oriented measurement routines. Int. Archives of Photogrammetry & Rem. Sensing, Vol. 32/5, Hakodate, pp. 271-277.

Thomas, P.R., Mills, J.P., Newton, I., 1995. An Investition into the use of Kodak Photo CD for digital photogrammetry. Photogrammetric Record, Vol. 15 (86), pp. 301-314.

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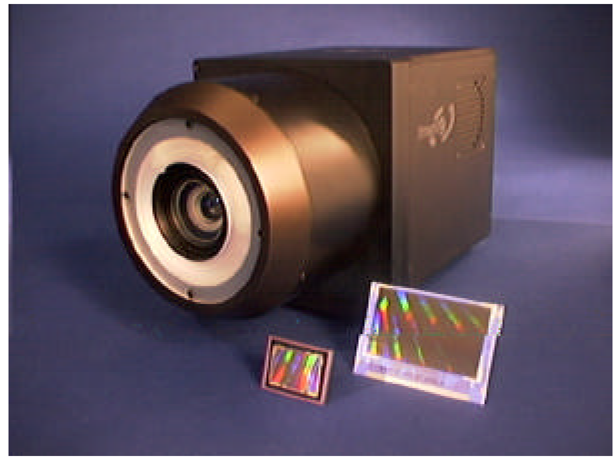

Fig. 2 Imetric ICam with different sensors

Fig. 1 Rollei Q16

Fig. 3 The eyelike digital camera attached to a Cambo view camera

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Fig. 4 Metric photograph of the facade

Fig. 5 Facade of the building derived from CAD model