ISPRS Intercongress Symposium,
Melbourne, Australia, March 1-4, 1994
IAPRS Vol. 30, Part V, pp. 250-255

Experiences with a high resolution still video camera in digital photogrammetric applications on a shipyard

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ISPRS Commission V, Working Group 2

KEY WORDS: Close-range photogrammetry, digital high resolution camera, self-calibration, industrial metrology

ABSTRACT

The Kodak DCS200 high resolution still video CCD camera seems to be a very interesting image acquisition device for a large variety of applications in digital close range photogrammetry. It offers the full functionality of the modern mirror reflex camera Nikon 8008s, combined with a 1524 x 1012 pixel CCD sensor, a framegrabber and an internal harddisk with a storage capacity of 50 uncompressed images.

In this presentation practical experiences of the use of the camera in several projects will be reported. The goal of these projects was the determination of the coordinates of object points, which were signalized with retro-reflective targets, for dimension checking and control in the ship building industry. Results of a simultaneous calibration of the camera will be given showing its accuracy potential.

1. INTRODUCTION

Automated or semi-automated digital close range photogrammetric systems may be very powerful tools for a number of measurement tasks on a shipyard. To be able to judge their functionality and performance in some typical applications several pilot studies were conducted by the Institute of Geodesy and Photogrammetry, ETH Zurich, on the shipyard of Bath Iron Works Corporation, Maine (USA). Some of the projects required high resolution cameras in order to warrant high accuracy and detectability of small details. A high resolution still video camera is ideally suited for these tasks due to its independence on external power supply, frame grabbing and storage devices. While the CCD cameras usually used in digital close range photogrammetry or machine vision applications require a local host computer for image acquisition and storage, a still video camera provides a completely autonomous digital image acquisition system. For the pilot studies conducted in the shipyard a Kodak DCS200 was leased from a local photo shop. The DCS200 is a camera which is mainly being used for publishing and related purposes and is of course not calibrated for metric applications. As laboratory facilities or an exact calibration field were not available locally, the camera had to be calibrated simultaneously by self-calibration methods.

2. THE KODAK DCS200 STILL VIDEO CAMERA

The Kodak DCS200 consists of a modified Nikon 8008s camera body with a 1524 x 1012 pixel CCD sensor in the imaging plane. The camera is offered alternatively with a black-and-white or a color CCD sensor; images can be stored on a 2 MB DRAM or optionally on a 80 MB internal harddisk, which offers storage capacity for 50 uncompressed images. The model used for these studies was the DCS200mi with black-and-white sensor and internal 80 MB harddisk (Fig. 1). Table 1 summarizes the relevant technical specifications of the camera system. For the image acquisition the Nikkor lenses 18 mm and 28 mm were used. Due to the reduced chip size the angle of the Nikkor 18 mm lens corresponds to a 45 mm lens and the Nikkor 28 mm lens to a 70 mm lens of a normal SLR camera.

Figure 1: Kodak DCS200mi still video camera

camera body:	Nikon 8008s
sensor:	1524 x 1012 full frame CCD, 14 mm x 9.3 mm, black-and-white
frame grabber:	in camera body
storage:	50 images, uncompressed, on harddisk in camera body
interface:	SCSI port
software:	Adobe Photoshop (Mac) / Aldus Photostyler (PC)
weight:	1.7 kg
power supply:	AC adaptor/charger
lens mount:	Nikon bajonet
lenses:	Nikkor 28mm, Nikkor 18mm

Table 1 : Technical data of the DCS200

The digital images were transferred from the internal camera harddisk into the computer via a SCSI interface. The software package Adobe Photoshop on a Macintosh computer allows the image acquisition from the camera, standard pre-processing, and storage into different standard image formats.

3. PRACTICAL EXPERIENCES

The functionality of the DCS200 is equivalent to the handling of a modern automatic SLR camera. The user can select between a manual mode and several automatic or semi-automatic exposure programs. For the photogrammetric applications the autofocus was switched off; as in most applications retroreflective targets were used, which gave sufficient light and allowed to use a small iris, the camera could be permanently focussed on infinity. A standard Nikon flash performed well in illuminating the retroreflective targets. The proper exposure settings for the imaging of retroreflective targets, which should neither be overexposed nor appear too dark in the digital images, cannot be solved by the automatic exposure programs and require some experience (this applies as well for the use of photographic systems).

Most of the pilot projects dealt with the positioning of signalized targets, some with edge detection. The object dimensions were between 2 x 2 x 2 m^3 and 30 x 30 x 30 m^3. In the following results from two applications including the camera calibration and examinations of linejitter will be shown.

3.1 LINE JITTER

It is known from standard video norm CCD cameras, that line jitter (Beyer, 1987, Maas, 1992) may influence the accuracy of coordinate measurements in the digital image severely. Line jitter is caused by inaccuracies of the detection of the h-sync pulse in the analog video signal by the frame grabber and can be avoided by using a pixelclock. As details about the frame grabbing in the DCS200 are not known, line jitter was examined in some practical images. To determine the magnitude of line jitter researchers have examined vertical plum lines in object space (Beyer, 1987) or electronically generated vertical lines in image space (Maas, 1992). As both can only be achieved perfectly under laboratory (illumination) conditions, this examination has to be restricted to the analysis of straight edges in the images. The position of some approximately vertical edges was determined by one-dimensional least squares matching (Fig. 2). It has to be noted that there is no guarantee that the edges were really straight in the object; furthermore, the figures do still contain systematic effects of lens distortion, which was not corrected for at this step of data processing, and the edges do not depict ideal step edges due to illumination conditions and object contrast. For these reasons the figures shown in Fig. 2 can only be considered rough approximations and an examination under laboratory conditions would most probably yield better results. The fact that neighboured edges in Fig. 2 show a rather uncorrelated behaviour indicates that the reasons for jitter along edges is more due to straightness of the edges in the object and illumination conditions

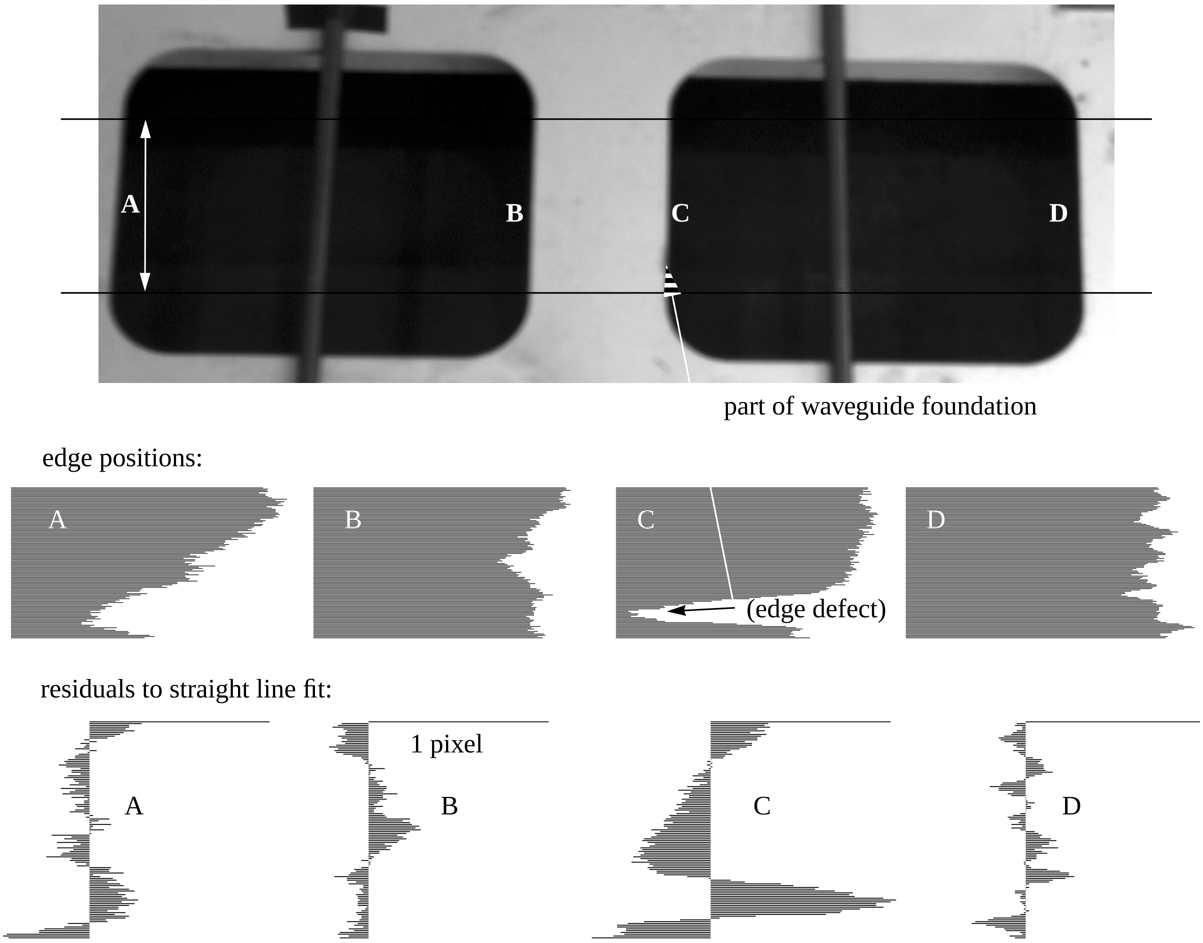

Figure 2: Jiiter of four neighboured edges

than due to line jitter. From these examinations one can only state that there is no obvious linejitter.

3.2 RESULTS OF SIMULTANEOUS CALIBRATIONS

The camera was calibrated simultaneously on some of the applications, while for other applications the calibration data were assumed to be unchanged. The image coordinates of signalized points were determined by least squares matching or by a centroid operator; camera orientation, object coordinates and additional parameters were determined simultaneously by bundle adjustment.

Only two of the pilot projects will be referred to here. In these applications σ_0 of the bundle adjustment with minimum datum was 0.44 µm and 0.47 µm, which corresponds to approximately 1/20th of a camera pixel. It has to be stated that these results were obtained under factory floor conditions, where the environmental conditions could not be controlled and ideal target distributions could not be achieved. For images, which were well suited for the centroid operator (i.e. images with uniform dark background, which is often the case in applications with retroreflective targets), no significant differences could be found between the results of least squares matching and centroid operator. For the DCS200 with 28 mm lens only the camera constant, the parameters k_1, p_1, p_2 for the lens distortion (Brown, 1971) and a scale factor in x' image coordinate direction were significant. In combination with a 18 mm lens also the principle point and a shear parameter were significant. The curves of radial lens distortion of the DCS200 are illustrated in Fig. 3. The sensor is affected by a maximum distortion of -107 µm for the 18 mm lens and -82 µm for the 28 mm lens at the sensor corner.

To compensate for occlusions and to warrant a strong network geometry for the simultaneous calibration a total number of 8 images (including some images with panned or rotated camera axis) was taken from 5 camera stations for project 1 (Fig. 4), while 19 images were acquired for project 2 (Fig. 5). The object dimension in project 1 was

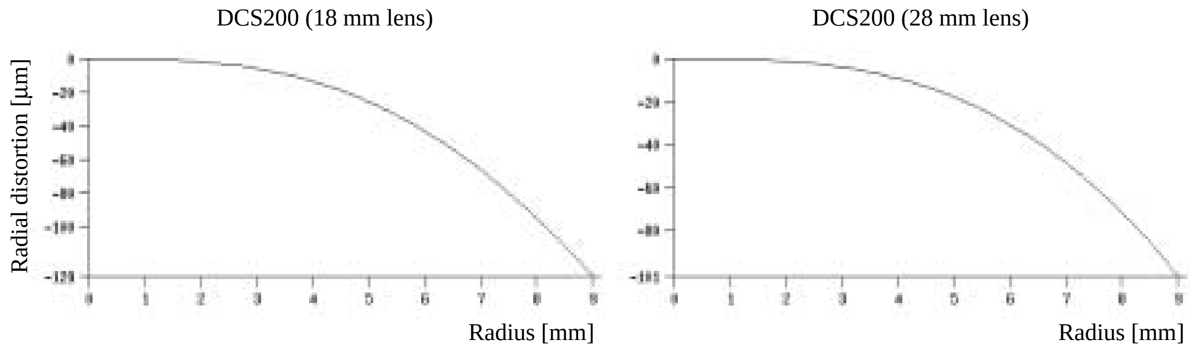

Figure 3: Radial lens distortion of the Kodak DCS200 (18mm and 28 mm lens)

approx. 3 m x 2 m x 10 m, in project 2 approx. 25 m x 12 m with only a small depth extension. The average scale of the images were 1 : 350 for project 1 and 1 : 1500 for project 2. In the first project 136 points were measured (6.8 rays per point in average), while in the second project a higher degree of freedom was reached with 415 measured points (12.6 rays per point in average). Table 2 shows the results of the bundle adjustment of two typical applications on the shipyard.

In these investigations under factory floor condition a relative lateral accuracy of 1: 40,000 was attained in object space. This compares well to the results of Peipe et al. (1993), who achieved a relative accuracy of 1: 50,000 for the calibration of the DCS200 (35 mm lens) with a color sensor, using 7 images from a spatial testfield with 86 signalized points. A similar accuracy was also reached by van den Heuvel (1993) in a testfield calibration of a monochrome Kodak DCS200 (35 mm lens), processing 6 images from a spatial testfield with 80 signalized points.

To test the stability of the camera calibration parameters, one of the pilot projects was processed with simultaneous calibration and the results were compared with a processing where calibration parameters determined in a former measurement were used. No significant differences could

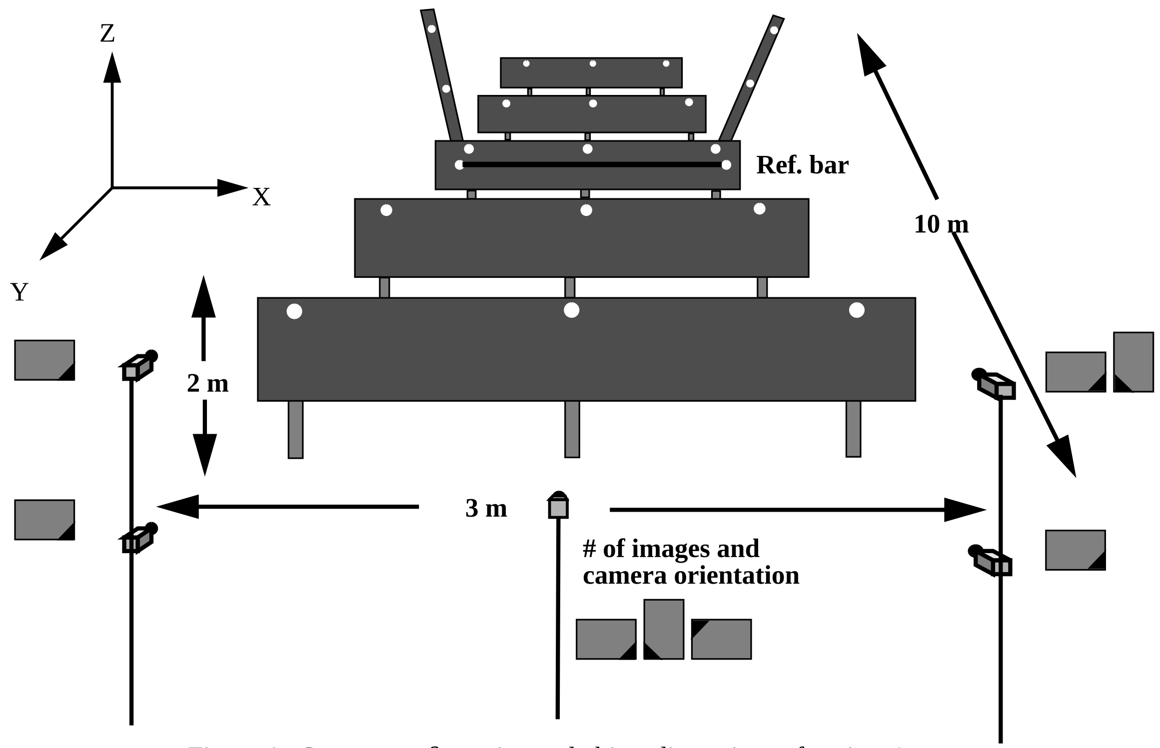

Figure 4: Camera configuration and object dimensions of project 1

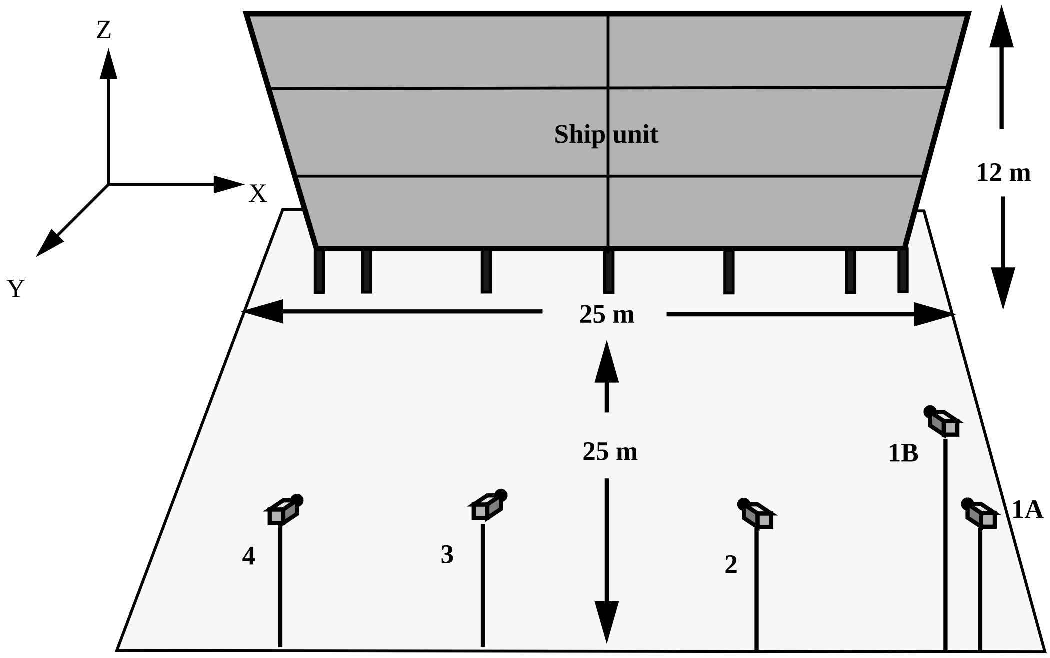

Figure 5: Camera configuration and object dimensions of project 2 (rotated and panned images on stations 2, 3, panned images on stations 1A, 4)

Project	Lens [mm]	Images	Points	Obs	U	r	$\hat{\sigma}_0$ [µm]	Precision from adjustment				
								Object space [mm]			Image space [µm]	
								σ_X	σ_Y	σ_Z	σ_x	σ_y
1	**28**	**8**	**20**	**272**	**107**	**165**	**0.47**	**1.03**	**3.64**	**0.27**	**0.36**	**0.37**
2	**18**	**19**	**33**	**830**	**212**	**618**	**0.44**	**0.47**	**1.39**	**0.43**	**0.41**	**0.35**

Obs..........Number of observations
U ....Number of unknowns
r...............redundancy
$\hat{\sigma}_0$ ....Standard deviation of measured image coord. a posteriori
σ_{XYZ}...........Theoretical precision in object space
σ_{xy}..............Theoretical precision in image space

Table 2: Results of the point positioning with simultaneous calibration for the DCS200

be found between the results of these two versions; this means that it is not absolutely necessary to do a simultaneous calibration in each application, so that the effort can be reduced considerably.

4. CONCLUSIONS

The DCS200 high resolution still video CCD camera has proved to be very well suited for applications in digital close range photogrammetry. As an autonomous image acquisition system including camera, A/D conversion, data storage and power supply it offers a high flexibility and easy handling, especially for outdoor or factory floor applications. A σ_0 in a bundle adjustment of 1/20th pixel in image space under factory floor conditions can be regarded a good accuracy. Further examinations under laboratory conditions should be performed to show the real accuracy potential of the camera.

5. ACKNOWLEDGEMENT

The photogrammetric image acquisition was performed on the shipyard of Bath Iron Works Corporation, Maine (USA). The support of Bath Iron Work is gratefully acknowledged. Especially, we wish to express our acknowledgement to the team of George W. Johnson for the good teamwork and the fruitful discussions during the data acquisition period.

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