3-D OBJECT RECONSTRUCTION IN ARCHITECTURAL PHOTOGRAMMETRY WITH ANALOGUE AND DIGITAL CAMERAS - A COMPARISON

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Commission V, Working Group 5

KEY WORDS: Architectural Photogrammetry, Digital Cameras, 3-D Object Reconstruction, Accuracy

ABSTRACT

In the paper, a comparison between analogue/analytical and digital image acquisition and processing techniques in architectural photogrammetry is reported on. Photographs of a facade of a building were taken with analogue and digital cameras. Digitized images stored on Photo CD were also included into the investigation. Bundle triangulation resulted in 3-d coordinates of object points used for the comparison. The differences between the 3-d data sets show relatively similar values of some millimeters which is also typical of the definition of natural points on an architectural surface. However, concerning the accuracy of 3-d object reconstruction, all the analogue/analytical and digital methods described in the paper are suitable for the recording of the facades of buildings and monuments.

KURZFASSUNG

Es wird über einen Vergleich analog/analytischer und digitaler Techniken der Bildaufnahme und Bildverarbeitung in der Architekturphotogrammetrie berichtet. Dabei wurde eine Hausfassade mit photographischen und digitalen Kameras aufgenommen. Zusätzlich wurden digitale Daten durch Scannen der analogen Bildvorlagen erzeugt und auf Photo-CD gespeichert. 3D-Koordinaten der Fassadenpunkte wurden durch Bündeltriangulation bestimmt. Die Differenzen der dreidimensionalen Datensätze ähneln einander; ihre Größenordnung beträgt wenige Millimeter. Solche Werte sind ebenfalls typisch für die Definition natürlicher Punkte an einem Bauwerk. Betrachtet man also die Genauigkeit der 3D-Objektrekonstruktion, so bedeutet dies, daß alle analog/analytischen und digitalen Methoden, die in diesem Bericht beschrieben werden, gleichermaßen geeignet sind zur Aufnahme der Fassaden von Gebäuden und Monumenten.

1. INTRODUCTION

Recently, digital techniques have been increasingly applied in architectural photogrammetry. Digital image data can be obtained by means of A/D conversion of photographs taken with analogue cameras or by direct data acquisition using digital cameras. In this paper, a practical project is used to demonstrate the performance of analogue and digital methods of image acquisition and processing. The facade of a building was photographed with the réseau cameras Rolleiflex SLX metric and Leica R5 as well as with the digital cameras Kodak DCS 200 and DCS 460. In addition, the analogue photographs were converted into digital form and stored on Kodak Photo CD. The analogue images were measured on an analytical plotter, the digital and digitized images on the PC based Digital Photogrammetric Station DPA-WIN. All the image coordinates were then adjusted with the CAP bundle triangulation program. The comparison of the resulting 3-d data sets of the same object points allows to derive the accuracy of the different photogrammetric survey methods, i.e. between the analogue and the digital world.

2. DATA ACQUISITION

The building that was to be renovated (Fig. 1) is situated in Schwabing, a well-known quarter of Munich, Bavaria. The facades were recorded from a lifting platform using four cameras, listed in Table 1.

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 number of images and their scale can be seen from Table 1 too. 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.

	Rolleiflex SLX metric (analog)	Leica R5 (analog)	DCS 200 (digital)	DCS 460 (digital)
lens	40 mm	35 mm	15 mm	28 mm
image area	55 mm x 55 mm	24 mm x 36 mm	13.8 mm x 9.2 mm	27.6 mm x 18.5 mm
number of pixels	---	---	1524 x 1012	3060 x 2036
pixel size	---	---	9 µm x 9 µm	9 µm x 9 µm
number of images	7	6	7	7
image scale	1 : 300	1 : 340	1 : 800	1 : 430

Table 1

	Rolleiflex SLX metric (digital)	Leica R5 (digital)
lens	40 mm	35 mm
image area	55 mm x 55 mm	24 mm x 36 mm
number of pixels	4096 x 4096	4096 x 6144
pixel size	13.4 µm	5.9 µm
number of images	7	6
image scale	1 : 300	1 : 340

Table 2

Figure 1 Rollei photograph of the facade

All the cameras are easy to handle on-site. However, the digital still video cameras need some seconds to transfer the image data to the internal storage medium. But that was of less importance since some minutes were required in any case to change the camera positions. The same exposure distance of about 12 m was used for the four cameras. The 3-d coordinates of several control points were measured by a theodolite system.

The photographs of the Rollei and Leica cameras were digitized and stored on Kodak *Pro Photo CD* (Tab. 2). 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 Kodak Photo CD is produced on a Professional Photo CD Imaging Workstation (PIW) consisting of a line scanner, data manager for compressing and storing the image data, CD writer and printer. 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. 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.

3. DATA PROCESSING

The analogue images of the Rollei and Leica cameras were measured monoscopically on a Zeiss Planicomp P2 analytical plotter. The digital data were processed with the 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. Eight points served as control points.

From the measured image data, 3-d coordinates of the object points were calculated by bundle triangulation with the CAP software. The interior orientations of the cameras were determined by a priori calibration as well as simultaneous calibration within the bundle adjustment. The 3-d data sets of object points were compared using a spatial similarity transformation.

4. RESULTS

The results of image measurement and bundle triangulation are given in Figure 2. Six data sets are characterized by camera name, image scale, RMS values of x,y residuals as a measure for the accuracy of image coordinates, standard deviations of object space coordinates, and RMS discrepancies between the 3-d object data sets after spatial similarity tranformation.

The outcome of *Rollei (analog)* is regarded as reference data (Fig. 2). The accuracy of the image coordinate measurement of the natural points on the facade of about 5 - 6 µm is quite well. This applies also to the calculated 3-d object coordinates. But, it has to be considered that the results of the bundle adjustment express only the internal precision and have to be enlarged two or three times to get realistic values of the 3-d object reconstruction. 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 (analog)* object coordinates with the *Rollei (digital)*, *Leica (analog)* and *Leica (digital)* data sets, i.e. all the object points are determined with an accuracy of some millimeters which is also typical of the definition of clearly detectable natural points on an architectural surface. This holds true for the *DCS 460 (digital)* data set too. The degraded accuracy of the object coordinates of *DCS 200 (digital)* is caused by the smaller image scale which was chosen in order to image the same area on the object as with the DCS 460.

As far as the accuracy of the 3-d reconstruction of such an architectural object is concerned, it can be stated that all the six data sets give satisfactory results. However, differences appear if the economic efficiency 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, the advantage of the analogue cameras, in particular the Rolleiflex medium format camera, is obvious: the large image format allows to cover larger parts of the facade at the same image scale. This is true especially in comparison with the DCS 200.

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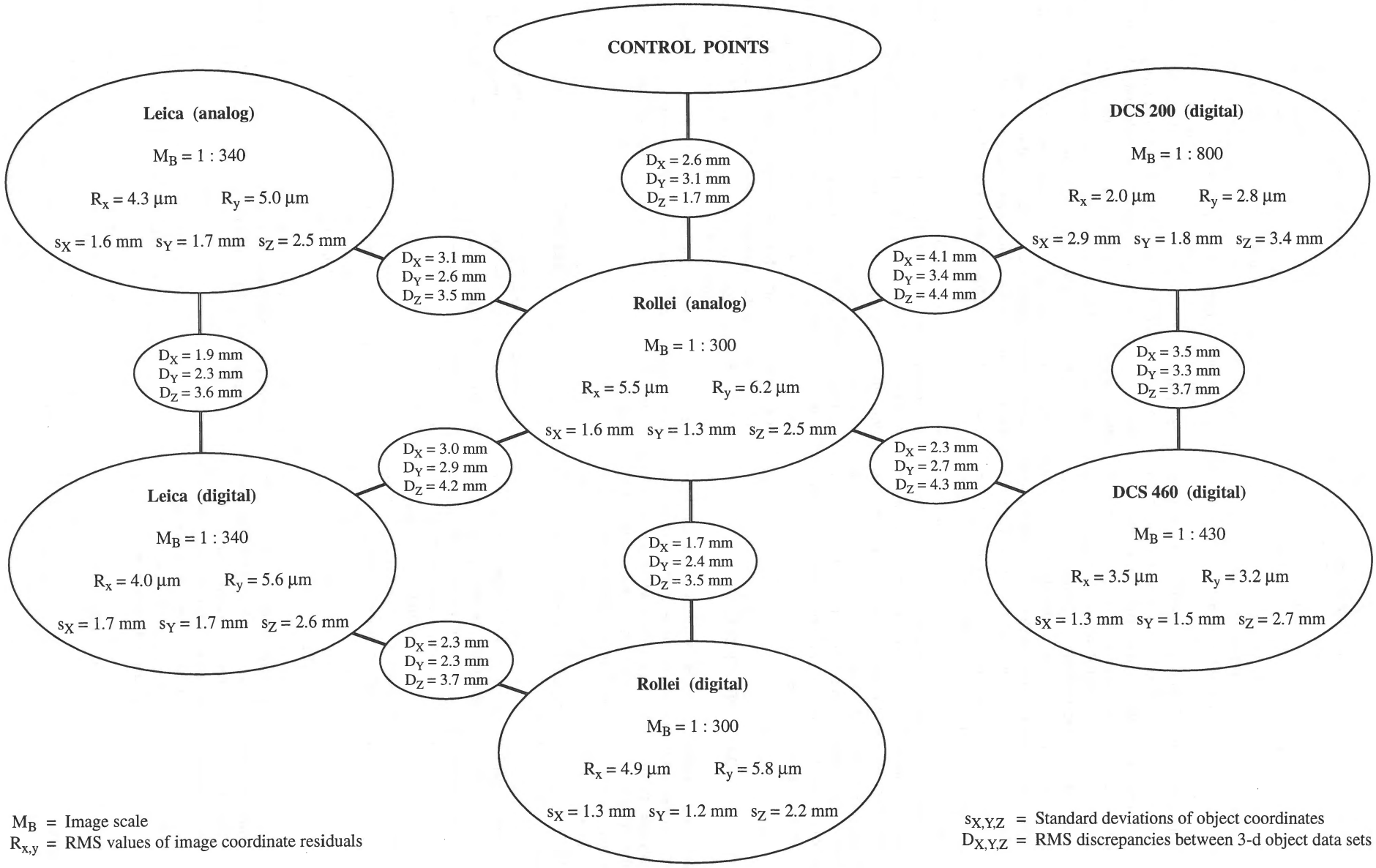
ACKNOWLEDGEMENTS

The authors wish to thank PMS AG, St. Margrethen / Switzerland, for providing the Leica réseau camera as well as *adiplan*, Munich, for the successful cooperation during the recording and measurement.



M_B = Image scale
$R_{x,y}$ = RMS values of image coordinate residuals

$s_{X,Y,Z}$ = Standard deviations of object coordinates
$D_{X,Y,Z}$ = RMS discrepancies between 3-d object data sets

Figure 2 Results of bundle triangulation