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Shorter Contributions

HIGH RESOLUTION STILL VIDEO CAMERA FOR INDUSTRIAL PHOTOGRAMMETRY

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Abstract

Still video cameras are easy to handle, portable, digital image acquisition devices for close range photogrammetry. They allow fast object recording without being connected to a computer. As an example of the new camera type, the high resolution Kodak DCS200 is presented in this paper, combined with the DPA digital photogrammetric station used for image measurement and object reconstruction. The performance of this three dimensional measurement system is illustrated by calibration results as well as applications to high precision dimensional inspection in industry.

INTRODUCTION

IN RECENT YEARS, opto-electronic sensors and digital measurement systems have gained importance in close range photogrammetric metrology applied to industry, architecture and medicine. Digital image acquisition can be done efficiently by means of CCD array sensors of different size (Lenz and Lenz, 1993; Uffenkamp, 1993). CCD cameras produce very fast sequences of digital images for automated or semi-automated measurement. These cameras are permanently linked to a host computer for image acquisition, data storage and power supply.

This paper focuses on a new type of digital camera that is not necessarily connected with a computer during image recording. A *still video camera* is an independent and easily portable imaging system and it can be operated like a modern film-based small format camera. Several still video cameras are available commercially (Bösemann *et al*., 1994). The high resolution Kodak DCS200 proved to be a very efficient and precise tool for photogrammetric application. Performance tests resulted in relative accuracies in object space, relative to the dimensions of the object, of up to 1:90 000.

A short description of the Kodak DCS200 will be given and its potential for close range photogrammetry tasks is illustrated by calibration results and application examples. The digital images produced with the DCS200 were measured in the DPA digital photogrammetric station (Peipe *et al*., 1993; 1994).

DPA DIGITAL PHOTOGRAMMETRIC STATION WITH KODAK DCS200

The DPA is a powerful but relatively inexpensive PC-based image processing system especially designed for close range photogrammetric metrology. The modular hardware and software concept allows the use of various imaging devices as data sources. For on site data processing, the use of a laptop is recommended to achieve a high degree of mobility and user friendly handling.

For the industrial applications described, the system (Fig. 1) consists of a portable

FIG. 1. Kodak DCS200 digital camera connected to a laptop computer for on site data processing.

FIG. 2. Kodak DCS200 still video camera.

laptop with 486 processor, a Kodak DCS200 still video camera and the DPA-Win software packages for image preprocessing, image measurement and data management, and CAP (Hinsken *et al*., 1992) for bundle triangulation. DPA-Win is a special version of the DPA software running under the Microsoft Windows user interface. The derived data can be interfaced to CAD or quality control systems.

The DCS200 camera (Fig. 2) with its high resolution CCD sensor (1524×1012 pixels of 9×9 μm size) provides 80 MByte memory on an internal hard disk for 50 digital images. The sensor/storage unit is mounted on a slightly modified Nikon camera body. All the standard Nikon lenses can be applied with the restriction of a reduced viewing angle due to the 2·6 times smaller photosensitive area of the CCD chip ($9{\cdot}2 \times 13{\cdot}8$ mm) compared to a 24×36 mm film. The digital images of 1·5 MByte size can be transferred into a PC via SCSI interface. Finally, special drivers supplied by Kodak for use with the Adobe Photoshop or Aldus PhotoStyler image processing software allow data acquisition and visualization.

PERFORMANCE TESTS

Several investigations were carried out to apply the Kodak DCS200 to close range photogrammetric tasks. Relative accuracies in object space of about 1:40 000 (van den Heuvel, 1993), 1:50 000 (Peipe *et al*., 1993), 1:40 000 (Maas and Kersten, 1994), 1:90 000 (Fraser and Shortis, 1994), 1:75 000 (Kersten and Maas, 1994) and 1:90 000 (Bösemann *et al*., 1994) have been published.

These relative accuracies were calculated using the estimated theoretical standard deviations of object co-ordinates resulting from multistation self calibrating bundle adjustments. The objects surveyed were test fields or components in the car or aircraft manufacturing and shipbuilding industry. Targets on the object were recorded and then measured in digital image processing systems. For the investigations cited, the image co-ordinate measurement accuracies varied between 0·2 μm and 0·5 μm (0·02 to 0·05 pixel).

The different values are mainly caused by different conditions during the image acquisition. For testfield calibration in a laboratory, the illumination, the target positions and the configuration of exposure stations can be optimized. That is not possible under factory floor conditions where other disturbing effects such as vibrations and variations in temperature may be encountered. Summing up, it can be stated that all the cited figures point out the high accuracy potential of the Kodak DCS200 for photogrammetric purposes.

A test arrangement published in Bösemann *et al*. (1994) will be described in more detail. A part of an automobile, $2{\cdot}6 \times 1{\cdot}2 \times 0{\cdot}5$ m in size and marked with 52 circular targets, was recorded under laboratory conditions. The black and white version of the Kodak DCS200 equipped with a 15 mm wide angle lens was used. Ten images were acquired from regularly distributed camera positions around the object (including images required for simultaneous camera calibration) and measured in the DPA digital photogrammetric station. As result of the bundle adjustment, three dimensional co-ordinates of the targets were determined with a standard deviation of $s_X = 0{\cdot}027$ mm, $s_Y = 0{\cdot}029$ mm and $s_Z = 0{\cdot}036$ mm, a relative accuracy of 1:90 000 in the direction of the largest object dimension. The accuracy of the image co-ordinate measurement amounted to $0{\cdot}3$ μm corresponding to $0{\cdot}03$ pixel in image space. When regarding the high object space triangulation accuracy values, it has to be considered that these are figures of the internal precision resulting from bundle adjustment and have to be verified by external measures of accuracy in practice (that is by control distances measured on site for example).

Further investigations using the same object were carried out to determine alterations of the interior orientation parameters of the Kodak camera when changing the lens or the focus setting. This is important if it is intended to use the DCS200 as a metric camera with fixed calibration data instead of on the job calibration. A series of interior orientation parameter sets was calculated for infinity focus setting from bundle adjustments of image blocks recorded after changing the focus setting and/or the lens. Relatively small maximal differences of less than 10 μm were obtained for the principal distance and less than 30 μm for the principal point offset, whereas the distortion and affinity parameters remained constant (Peipe and Schneider, 1994). These results encourage the use of the camera as a metric camera if the accuracy requirements are not too high.

In conclusion, the measurement of the same automobile side performed with an analogue film based medium format camera, the Rolleiflex 6006 metric equipped with 40 mm wide angle lens, is outlined. A block of seven images was acquired. The automated film mensuration was carried out in a Rolleimetric RS1 réseau scanner. The self calibrating bundle adjustment resulted in standard deviations of object co-ordinates of $s_X = 0{\cdot}025$ mm, $s_Y = 0{\cdot}026$ mm and $s_Z = 0{\cdot}046$ mm. These values are similar to the results from the DCS200, although the image format of the digital camera amounts only to about 9×14 mm compared to the 50×50 mm format of the analogue camera.

Calibration of the OLM OpticalTube Measurement System

The OLM optical tube measurement system (Bösemann and Sinnreich, 1994) is a photogrammetric measurement system for the quality control of mechanically bent tubes in the production line. The system consists of a measurement box equipped with several CCD cameras controlled by PC. The digital images are processed automatically using feature extraction and photogrammetric algorithms. The final result is three dimensional information of the tube. For calibration purposes, 36 control points are installed in the box filling the field of view of all cameras and covering the measurement volume of $2500 \times 1000 \times 500$ mm (Fig. 3).

During the installation of the system in the production environment, the co-ordinates of the control points have to be determined at a higher level of accuracy. Therefore the control point field was recorded with 18 digital images by a Kodak DCS200. The image measurement and the bundle triangulation resulted in an image accuracy of $0{\cdot}58$ μm and an object accuracy of $0{\cdot}04$ mm in the X and Y directions and $0{\cdot}05$ mm in the Z direction. The results show that the achievable laboratory accuracy is not completely transferable to this industrial application. The reasons for this are the hand held camera, some illumination problems and geometric restrictions of the image block due to surrounding obstructions. Nevertheless, the DPA-Win with the Kodak DCS200 proved to be a suitable tool for on site calibration of the optical tube measurement system.

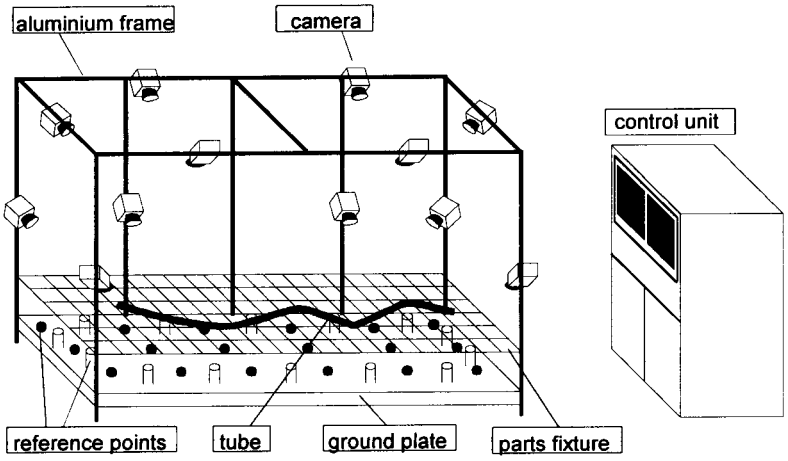

FIG. 3. The OLM optical tube measurement system.

IN-LINE CONTROL OF PRODUCTION TOOLS

The in-line control of production tools is an imminent task for total quality management. The aim is not to prove the manufactured parts but the machines and production tools with which they are produced. The following example of in-line control comes from the automotive industry. During the automatic welding process, the car body is fixed with movable brackets. These brackets define the shape of the car body and their positions have to be controlled periodically. To reduce the interruption of production to a minimum, this task is performed photogrametrically with the Kodak DCS200 and the DPA-Win.

In a measurement volume of $3500 \times 600 \times 1500$ mm, the position and rotation of 30 brackets, each signalized with four targets, have to be determined. Due to the extremely confined environment (for example, the distance between camera and object was less than 1000 mm), an image block of 40 bundles was recorded to cover the whole object sufficiently (Fig. 4). The image measurement and bundle triangulation resulted in an image accuracy of 0·41 μm and an object accuracy of 0·05 mm in the X and Y directions and 0·04 mm in the Z direction, that is a relative object accuracy of 1:70 000.

FIG. 4. Digital image of the targeted production tool.

Concluding Remarks

The practical applications presented in this paper have shown that the instant availability of digital images and on line data processing opens up a new field of tasks for photogrammetric metrology in an industrial environment. The Kodak DCS200 combined with a digital image processing system proved to be a high precision measurement tool. For the future, still video cameras can be expected to be standard image acquisition devices in digital close range photogrammetry.

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Résumé

Les caméras vidéo fixes constituent des systèmes d'acquisition d'images numériques faciles à manipuler et à transporter, adaptées à la photogrammétrie à courte distance. Elles permettent d'obtenir des enregistrements rapides d'objets sans devoir se relier à un ordinateur. On décrit dans cet article, à titre d'exemple de ce nouveau type de caméra, la caméra Kodak DCS200, à haute résolution, associée à la station de photogrammétrie numérique DPA, utilisée pour les mesures sur l'image et la reconstitution de l'objet. Les possibilités de ce système de mesure tridimensionnel sont matérialisées par les résultats d'étalonnage ainsi que par les applications industrielles, pour les contrôles nécessitant une grande précision dimensionnelle.

Zusammenfassung

Still Video Kameras sind einfach zu handhabende, portable Aufnahmegeräte für die digitale Bilderfassung in der Nahbereichsphotogrammetrie. Sie ermöglichen rasche Objektaufnahme, ohne mit einem Computer verbunden zu sein. Im vorliegenden Bericht wird die hochauflösende Kodak DCS200 als Beispiel für diesen neuen Kameratyp vorgestellt—in Verbindung mit der Digitalen Photogrammetrischen Arbeitsstation DPA, die zur Bildmessung und Objektrekonstruktion eingesetzt wird. Die Leistungsfähigkeit dieses 3D-Meßsystems wird durch Ergebnisse von Kalibrierungen und Anwendungsbeispiele aus dem Bereich der hochgenauen industriellen Meßtechnik verdeutlicht.