# DPA-WIN - A PC BASED DIGITAL PHOTOGRAMMETRIC STATION FOR FAST AND FLEXIBLE ON-SITE MEASUREMENT

Carl-Thomas Schneider
AICON-Industrial Photogrammetry and Image Processing
Bültenweg 23
D-38106 Braunschweig
Tel.: ++49 / 531 / 34 45 01
Fax: ++49 / 531 / 34 45 04

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## ABSTRACT

The request for a powerful but relatively inexpensive measurement system for a great variety of applications in close range photogrammetry has led to the development of the PC based Digital Photogrammetric Station DPA-WIN. Major charateristics are the modular concept of the image processing and object reconstruction software and the user friendly handling of the DPA-WIN. Different digital imaging devices such as CCD cameras, still video cameras, and scanners can be used as data sources.
For industrial applications the DPA-WIN is offered with still video cameras as the Kodak DCS 420 or 460 or the Rollei Chippack as a mobile, flexible, and precise photogrammetric system for industrial measurement tasks. This paper combines some recent developments and results achieved from application examples in industrial photogrammetry and test measurements for verification of accuracy at the PTB (German federal office for calibration and metrology) in order to illustrate performance and practicability of the DPA-WIN. Special emphasis is laid on additional tools for easy data interpretation and interfaces to CAD and quality management systems.

## 1. INTRODUCTION

A digital photogrammetric station can be regarded as a system for computerized production of object data from digital imagery. The three major fields of photogrammetric activity - aerial photogrammetry, remote sensing and close range photogrammetry - produce different demands and tasks to be solved. Design, functionality, and performance of a digital photogrammetric station have to refer to a number of object specific and user defined requirements in order to be applied in the daily practice of photogrammetry. In close range photogrammetry, digital imaging techniques are promising, e.g. in industry, medicine and architecture.

Digital image data can be acquired directly by means of various types of digital cameras with sensors of different sizes. On the other hand, analogue film-based photographs are converted into a pixel array using desktop scanners, special purpose photogrammetric scanners or repro scanners, respectively. The retrieved pixel data have to be processed by software implemented in a PC or workstation. Nowadays, different softcopy systems are available on the market or they are in an experimental stage in research institutions. Digital measurement systems especially designed for close range photogrammetry applications have been realized (Beyer, et al. 1995, Brown, Dold, 1995, Fraser, Shortis 1994).

To meet user expectations as mobility, easy handling and low cost, digital systems should consist of inexpensive hardware and user friendly software tools. In previous publications design and realization of the Digital Photogrammetric Station DPA-WIN as a PC based measurement system for close range photogrammetry has been described (Peipe, Schneider, Sinnreich 1993). Major characteristics are a modular software concept with a variety of image processing and measurement tools for 2-D and 3-D object reconstruction and a user friendly handling of the system. Digital data from a wide range of image sources can be imported.

Special features of the system are the use of coded targets for fully automated image measurements, automated orientation procedures, simultaneous camera calibration, threedimensional measurement of points, polylines and geometric elements in the oriented images and graphic representation and postprocessing of measurement results. Interfaces to CAD systems and tools for quality assurance allow an easy interpretation and further postprocessing of the results and the integration of the system into quality management systems.

By the mobile and flexible image acquisition with free choice of image stations the DPA-WIN is especially designed for cost reducing on-site measurements for production and production facility control, quality assurance, research and development.

## 2. SYSTEM CONFIGURATION

### 2.1 Hardware components

For the industrial applications described, the DPA-WIN consists of a portable laptop with Pentium processor, a Kodak DCS 460 still video camera and software packages for image processing, image measurement and data management.

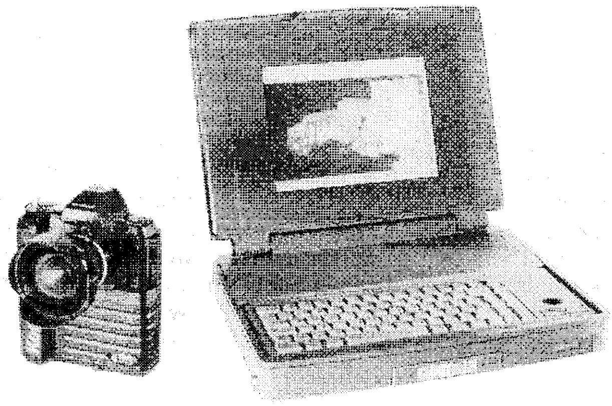

Fig. 1: DPA-WIN

The DCS 460 camera with its high resolution CCD sensor (3048 x 2024 pixels of 9 µm x 9 µm size) provides an internal slot for PCMCIA drives as image store with a capacity up to 54 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 slightly reduced viewing angle due to the 1.3 times smaller photosensitive area of the CCD chip (18.4 mm x 27.6 mm) compared to a 24 mm x 36 mm film. The digital image of 6 MByte size can be transfered into a PC via a PCMCIA drive or an internal 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.

### 2.2 Targetting

The demand for a high degree of automation in industrial applications has led to the development of coded retroreflecting targets. The coded targets allow an image measurement without any interactive point detection and identification. These targets, first presented in Schneider (1991), consist of a circular target in the centre and a code ring outside. The code represents a range of point numbers from 150 up to 3000 pointnumbers in black and white images and up to 9000 pointnumbers in colour images. The coded targets can be detected, identified and measured in the images fully automatical. In addition the code ring contains sophisticated error checks to ensure that even partly covered points will get the correct pointnumber. Figure 2 shows a coded target in a digital image.

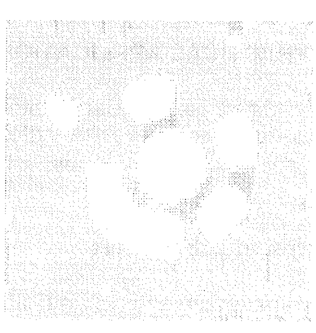

Fig. 2: Coded target in digital image

As well as coded targets also non coded targets can be measured completely automatically. After measurement of the coded targets the image bundles will be pre-oriented by bundle adjustment. Then the non-coded targets which have already been detected during the automated image measurement can then be identified using identification algorithms.

### 2.3 Processing tools

After the automated image measurement the orientation of the image bundles is performed with the software packages NAWE and PROMPT by Rollei Fototechnic, Germany (Fellbaum, Godding, 1995) using robust balanced L1-norm estimation. The derived threedimensional object coordinates can be displayed and printed for interpretation with several add-on software packages integrated in the DPA-WIN as there are roundness control, plain control, variance comparison packages.

## 3. VERIFICATION TESTS

Due to the wide range of achieved accuracies presented in various publications (from 1:50.000 up to 1:250.000) using the same camera hardware, the achievable accuracy of the DPA-WIN is verified in comparisons with higher accuracy absolute reference data.

### 3.1 Verification test at the PTB (German federal institut for calibration and metrology)

The PTB has set up a special test object for the verification of digital photogrammetric systems. This object consists of three plane plates with 36 reference points on an area of 800 mm x 800 mm and 5 scale bars with an extension from 2130 mm to 3350 mm. Figure 3 shows the arrangement and extension of the test object.

The coordinates of the reference points were measured by an optical coordinate measurement machine (CMM) with an accuracy better than 10 µmicrons.

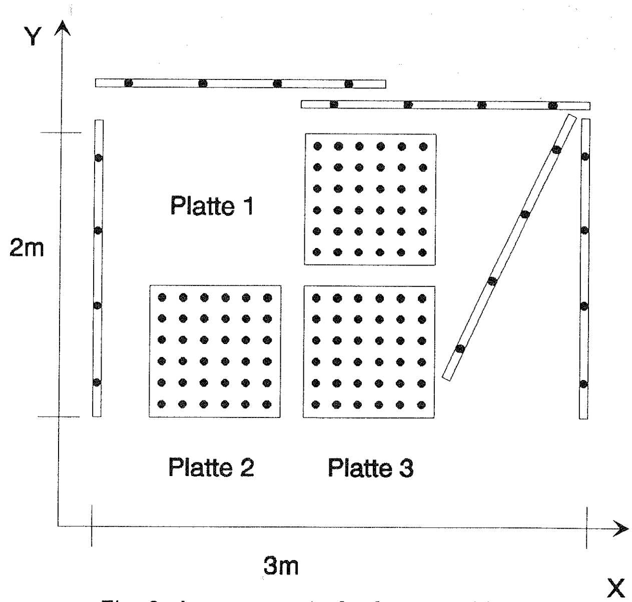


Fig. 3: Arrangement of reference objects

The object was recorded with 46 convergent images. 23 images covered the object format filling and 23 images covered 67 % of the object. For image recording a Kodak DCS 460 with 24 mm Nikon lens was used. The internal accuracy achieved was 6.1 µm in X-direction, 6.3 µm in Y-direction and 10.9 µm in Z-direction. Table 4 shows the RMS difference between DPA-WIN and CMM:

| Plate No. | RMS X [µm] | RMS Y [µm] |
|---|---|---|
| 1 | 6.7 | 6.5 |
| 2 | 13.1 | 14.4 |
| 3 | 7.7 | 7.8 |

Table 5 shows the scale bar variance comparison:

| | nominal | measured | difference |
|---|---|---|---|
| 12 - 13 | 699.909 | 699.923 | 0.014 |
| 13 - 14 | 699.859 | 699.845 | -0.014 |
| 21 - 22 | 700.023 | 700.029 | 0.006 |
| 22 - 23 | 699.660 | 699.654 | -0.006 |
| 23 - 24 | 699.959 | 699.943 | -0.016 |
| 32 - 33 | 699.923 | 699.941 | 0.018 |
| 33 - 34 | 699.893 | 699.867 | -0.026 |
| 42 - 43 | 699.841 | 699.866 | 0.025 |
| 52 - 53 | 700.108 | 700.104 | -0.004 |

Table 4 shows that the accuracy of plate 2 is two times worth than the accuracy of plate 1 and 3. The error ellipse in figure 6 show that the accuracies at the edge of the object are less good than in the centre. This is caused by the configuration of the image bundles which are captured in a way that all edge points of the object are also in the image edges and corners. Due to the fact that the correction of the lense distortion is not well defined in the edges and corners these object points are also not in the same accuracy as in the centre.

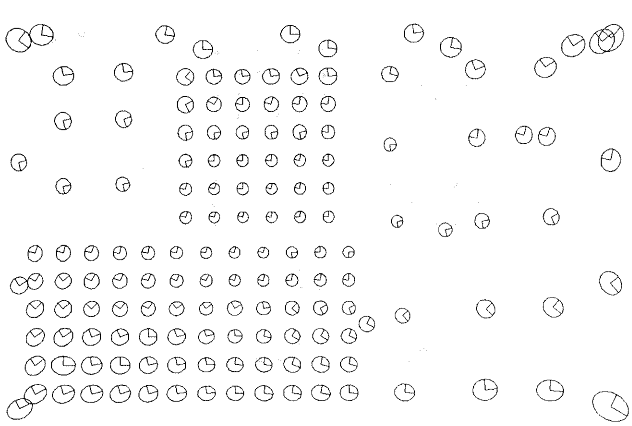

Fig. 6: Error ellipses of reference field

### 3.2 Aircraft industry

In the aircraft production at Daimler Benz Aerospace Airbus plant Hamburg, Germany large-scale production devices have to be controlled periodically. This measurement task is performed with the Rollei ILR system consisting of the large format camera LFC and the réseau scanner RS 1 (Dold, Riechmann, 1989). To enhance the productivity of the measurement team these tasks should be performed with digital systems in the future. Therefore a comparison between the actual measurement systems (ILR and Kern ECDS) has been performed. The object is captured with 68 images according to figure 7 from two different heights.

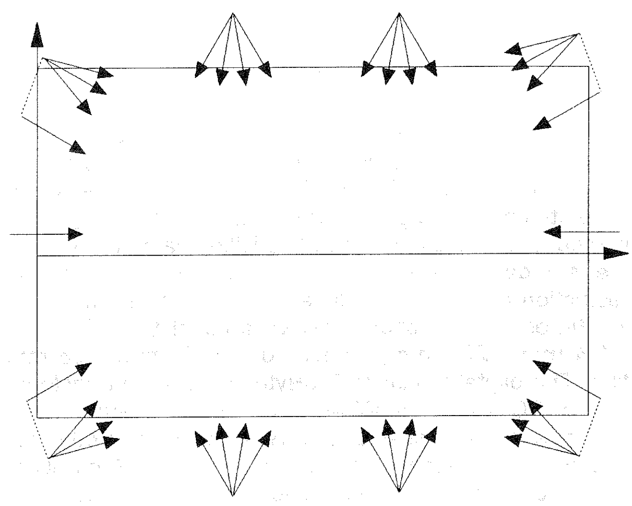

Fig. 7: Arrangement of images

The results were compared with a LFC and ECDS reference measurement. The reference accuracy is determined by Daimler Benz Aerospace Airbus to x=±0.042mm, y=±0.035mm and z=±0.028mm. The object size is 8800 mm x 6200 mm x 6300 mm. The coordinate differences between reference values and values by DPA-WIN in RMS are x=±0.16mm, y=±0.12mm and z=±0.08mm. These measurements were performed under realistic environmental conditions on the shopfloor regarding also a short time window in the production process for image recording. The results show a realistic achievable absolute and reproducable accuracy between 1:50.000 and 1:80.000. Higher absolute and reproducable accuracies can be achieved if the whole object can be imaged format filling or if the environmental conditions are laboratory-like.

## 4. PRACTICAL APPLICATIONS

Besides the verification tests under laboratory conditions and under industrial conditions DPA-WIN is in daily use by a cupple of users for production inspection and quality control.

### 4.1 Shape control of submarines

The roundness of submarines is an indicator of the diving behavior and quality. Therefore every submarine has to be controlled during the production process as well as at the final check in the delivery stage. The body of the submarine is signalized with retroreflecting coded targets in every frame plane. 25 images were taken around the submarine body from the shopfloor and from a crane.

The threedimensional coordinates of each frame plane were used for a roundness control by a least squares adjustment. The final result is a protocol sheet for every frame plane which has been approved by the manufacturer and the customer. This survey procedure is approved by the German Ministry of Military Procurement (BWB) as the final control of every submarine.

## 5. CONCLUSION

The camera hardware developments in the last years (e.g. Kodak DCS 460, Rollei Chipack), the performance enhancement of PCs and new developments in digital image processing and photogrammetric algorithms have brought forth a new generation of digital photogrammetric systems as the DPA-WIN. These systems are now at the step of becoming tools for the daily industrial measurement tasks. In the next development step the first experiences of users from the shopfloor have to be incorporated to enhance the system performance to achieve an even higher user satisfaction.

The verification tests performed in several companies and institutes combined with high accuracy reference measurements have contributed to make the accuracy evaluation of digital photogrammetric systems more transparent for the customers.

## 6. ACKNOLEDGEMENT

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