Easy field-applicable calibration of a miniaturized light sectioning sensor with application-specific illumination optics

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This proceeding demonstrates a calibration procedure for a light sectioning sensor consisting of a line laser and a miniaturized “NanEye2D” camera. The main focus of the proposed calibration method lies in its applicability for sensors with different, object-specific illumination optics. Therefore, after a thorough photogrammetric characterization, the camera is used as a calibration tool for the whole sensor system. A complete calibration is shown and quantitatively assessed.

1 Introduction

According to the “VDI-Roadmap 2020” [1], flexibility and miniaturization are the two major challenges for production measurement technology in the next 5 years. Therefore, miniaturized optical sensors that can easily be adapted to each application will become more and more important in the future. One approach to fulfil this requirement for 3D sensors is to use application specific illumination optics for each new inspection task. Figure 1 shows an example of such an application-specific sensor for the special task of borehole-inspection.

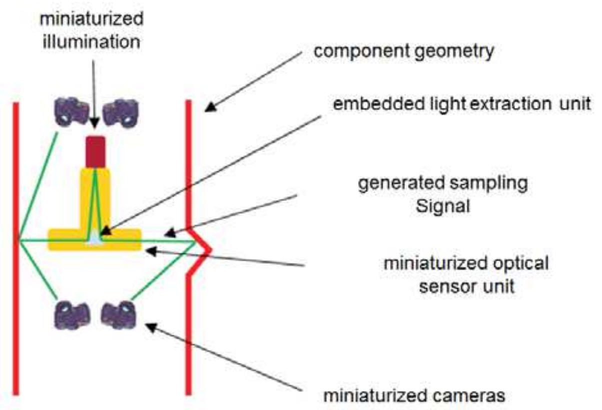

Fig. 1 *Sensor concept*

However, this idea is only feasible if there is an easy way to calibrate each new sensor setup – preferably also in the field. In this contribution, we demonstrate such a calibration procedure for a light sectioning sensor consisting of a line laser and a super-miniaturized “NanEye2D” camera manufactured by ams. As the camera is the only physical invariant in this setup – following an approach proposed by the OSMIN group of the University of Erlangen [2] – it is used as a calibration tool for the whole sensor. This requires a very good photogrammetric calibration of the camera itself, which is especially challenging considering the extremely distorting imaging optics involved.

2 Camera NanEye2D from ams

The NanEye2D camera is one of the smallest cameras currently available on the market (Fig. 2). The extremely miniaturized design with 1.0 mm x 1.0 mm x 1.7 mm is accompanied with a very short focal length resp. very wide-angle optics (field of view 120°). The camera has a CMOS chip with 250 x 250 pixels and a pixel size of 3 µm.

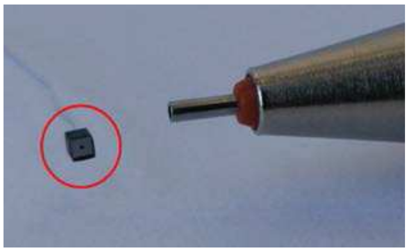

Fig. 2 *NanEye2D camera compared to a pen tip*

3 Photogrammetric camera calibration

Most methods for camera calibration use as a basis the pinhole or the extended pinhole camera model. The two commercially available calibration software packages used here (*Australis* by Photometrix and the *Matlab Camera Calibrator* by MathWorks / CalTech) are both based on the extended pinhole camera model and the principle of photogrammetric self-calibration [3].

In a first step, the two programs are compared “as is” using their “own” image processing algorithms for mark detection. For this purpose, special calibration targets – a regular grid with circular marks for Australis and a checkerboard target for the Matlab Camera Calibrator – have been prepared using a photographic plotter with 16,000 dpi resolution. The quality of the calibration results can be assessed by comparing the root mean square (RMS) of the back projection error (Fig. 3).

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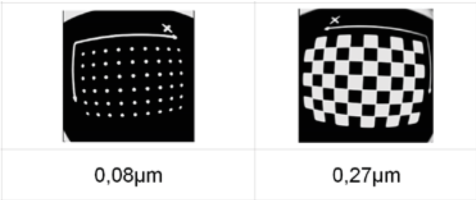

Fig. 3 *RMS results with circular marks for Australis (left) and a checkerboard pattern for Matlab (right)*

In this comparison, the Australis software shows a clearly better performance with a considerably smaller residual RMS value. However, it is not clear whether this is due to the calibration algorithm or to the quality of the localization of the marks.

Therefore, in a second step, both algorithms are compared using the exact same input data as image coordinates of the detected marks (Fig. 4).

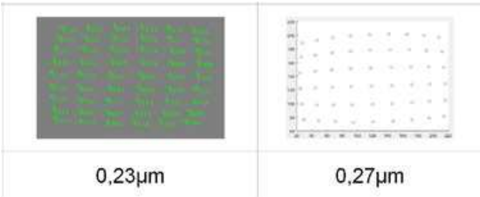

Fig. 4 *RMS results with the exact same input data at the image coordinate level for Australis (left) and Matlab (right)*

In this case, the Australis algorithm performs just slightly better than the Matlab Camera Calibrator (0.23 µm as opposed to 0.27 µm, see Fig. 4), most likely because of the superior bundle adjustment algorithm. This clearly shows that the image processing approach chosen for mark localization plays a crucial role for calibration quality.

Next, two different approaches to calibrate the whole sensor system are presented.

4 Conventional calibration

Conventionally, calibration is done using a very accurate planar calibration plate at well-known z-positions, typically provided by an equally accurate and precise linear stage (Fig. 5).

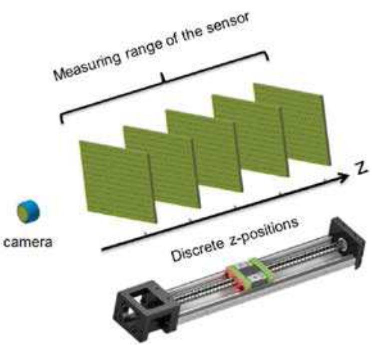

Fig. 5 *Conventional calibration using a linear stage (Hiwin Technologies Corp.) and a well-known planar calibration plate*

5 Camera-supported calibration

As an alternative, in the so-called “camera supported calibration”, the positions and orientations of the calibration plate are determined using photogrammetric resection based on the already calibrated camera, obviating the need for an expensive stage [2]. The images can be taken at arbitrary positions within the measuring range (Fig. 6).

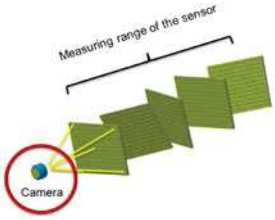

Fig. 6 *Camera-supported calibration based on resection*

6 Results

The quality of the calibration using the “camera-supported” approach has been assessed by measuring height steps of 1.3mm, 6.5mm, and 9.0mm utilizing exactly defined gauge blocks consisting of steel and ceramics (Fig. 7).

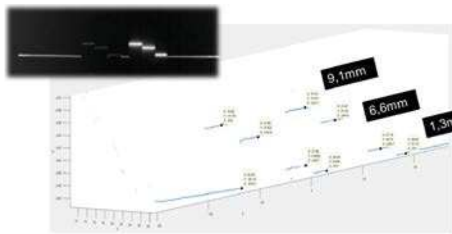

Fig. 7 *Measured gauge blocks consisting of steel (left) and ceramics (right) with 1.3 mm, 6.5 mm, and 9.0 mm*

The measurement results show a maximum deviation of about 0.1 mm, caused by the not yet optimized line width of the illumination optics.

7 Conclusion

The feasibility of the “camera supported calibration approach” for a miniaturized sensor setup with heavily distorting imaging optics has been successfully demonstrated. The next step is to implement this calibration method on bended calibration targets for the measurement of boreholes and freeform surfaces.

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References

[1] D. Imkamp,et al., tm – technisches Messen, pp 433-439, vol. 79 (2012)

[2] F. Schiffers et al.: “Calibration of multi-line light-sectioning”, Proc. DGaO 115, P12 (2014)

[3] Clive S. Fraser: “Digital camera self-calibration”, ISPRS Journal of Photogrammetry & Remote Sensing 52 (1997), p. 149-159

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