Voxel size and calibration for CT measurements with a small field of view

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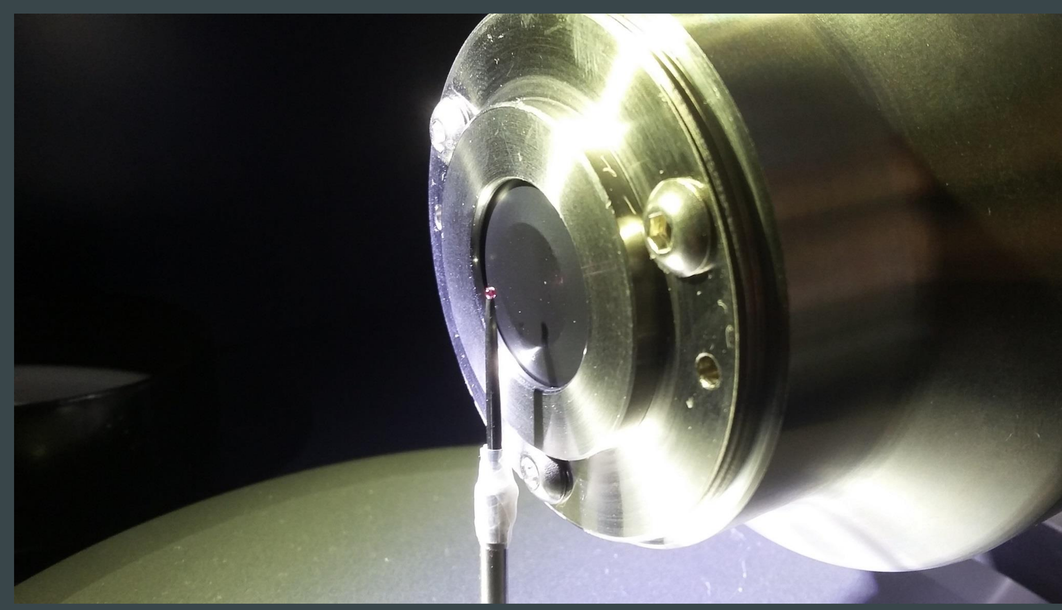
Abstract

Dimensional tomographic measurement is influenced by many factors. To achieve metrological traceability of results, knowledge of influence factors and their effect on measurement is important. This includes knowledge of the true value of voxel size and edge detection. Phantoms used for characterization and correction of error sources are calibrated usually on tactile or optical coordinate measuring machines. The challenge here is the manufacturing and calibration of small phantoms, which can be used in the field of view approximately 1 mm and less, which is the case of tomographic devices aiming at high resolution. In this work, abilities of a nano-coordinate measuring machine (nano-CMM) SIOS NMM-1 (Nanopositioning and Nanomeasuring Machine) to calibration of a phantom for X-ray computed tomography (CT) with the small field of view and high resolution are tested.



Introduction

To reduce errors in voxel size determination, calibration of CT by measurement of reference workpiece can be used. The object with the calibrated dimension is scanned and its dimension is measured. The voxel size of the subsequent scan in the same geometrical arrangement is recalculated to get the corrected value of voxel size [1]. Reference dimension for scale calibration must be independent on edge determination (e. g. two spheres center-to-center distance)

A challenging task is the manufacturing and reference measurement of calibration objects, suitable for the small field of view (FOV) under 1 mm.

New calibration object

Currently, the smallest successfully calibrated object were made of ruby balls with diameter 0.5 mm [2]. We manufactured a new object consisting of two ruby balls with nominal diameter 0.3 mm fixed on carbon rod.

CMM measurement

The measurements were carried out on a SIOS NMM-1 machine using a tactile probe., which is a high accuracy positioning system based on voice coil actuators and interferometric length sensors [3]. The measurements were ten times repeated to evaluate the reproducibility of the measuring method. The measured center-to-center distance of the two-ball phantom is 579.183 µm with repeatability below 0.010 µm. The uncertainty of the Gannen XP sensor, as estimated by the manufacturer, is 0.050 nm, which is the largest uncertainty component of the whole measurement.

CT measurement

CT measurements were performed using Rigaku Nano3DX. The linear voxel size was 0.54 µm with FOV 0.9×0.9×0.7 mm^3. Data was analyzed in VGStudio MAX 3.2.

To determine the influence of edge detection different methods were used for evaluation – three global thresholding methods (ISO 50%, Threshold 1 closer to background peak and Threshold 2 closer to material peak, shown in Fig. 4. and 5.) and gradient-based method available in VGStudio MAX.

The spheres were fitted on the surface using the least squares method, and the center-to-center distance was determined. To evaluate influence of operator when choosing initial fitting points, measurement of center-to-center distances was performed 5 times for every edge detection method, Measured distances with standard deviations are shown in Table 1 and Graph 1.

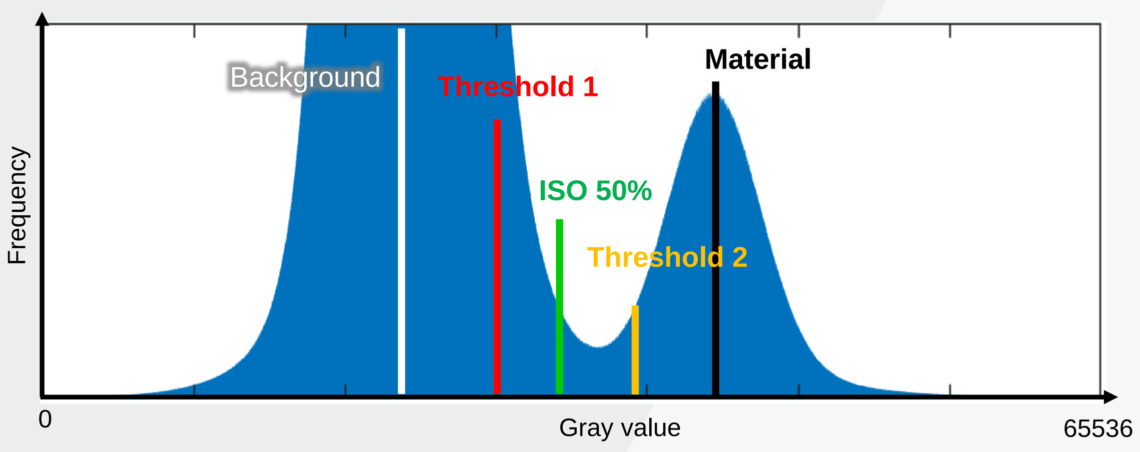


Fig 5. Histogram with segmentation threshold values

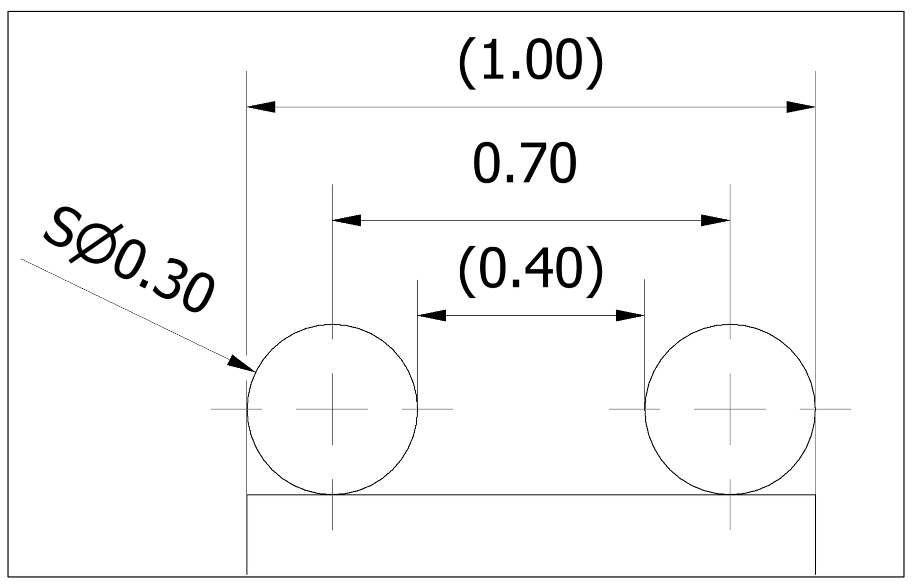


Fig. 1. Design of calibration object, dimensions in mm

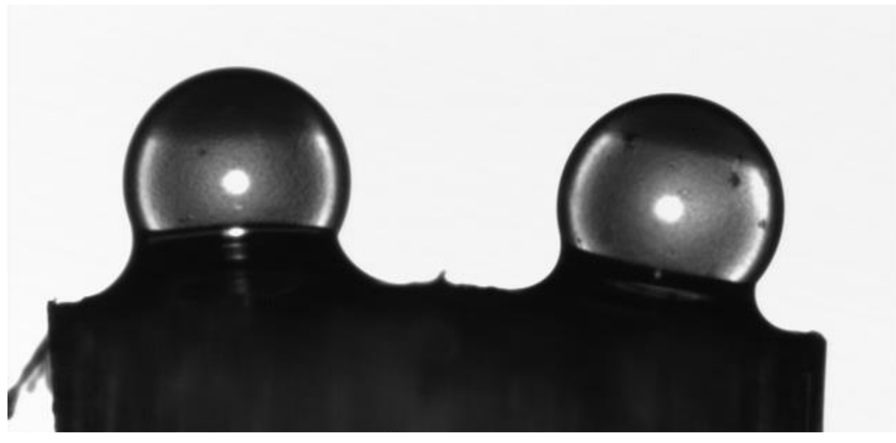


Fig 2. Manufactured calibration object

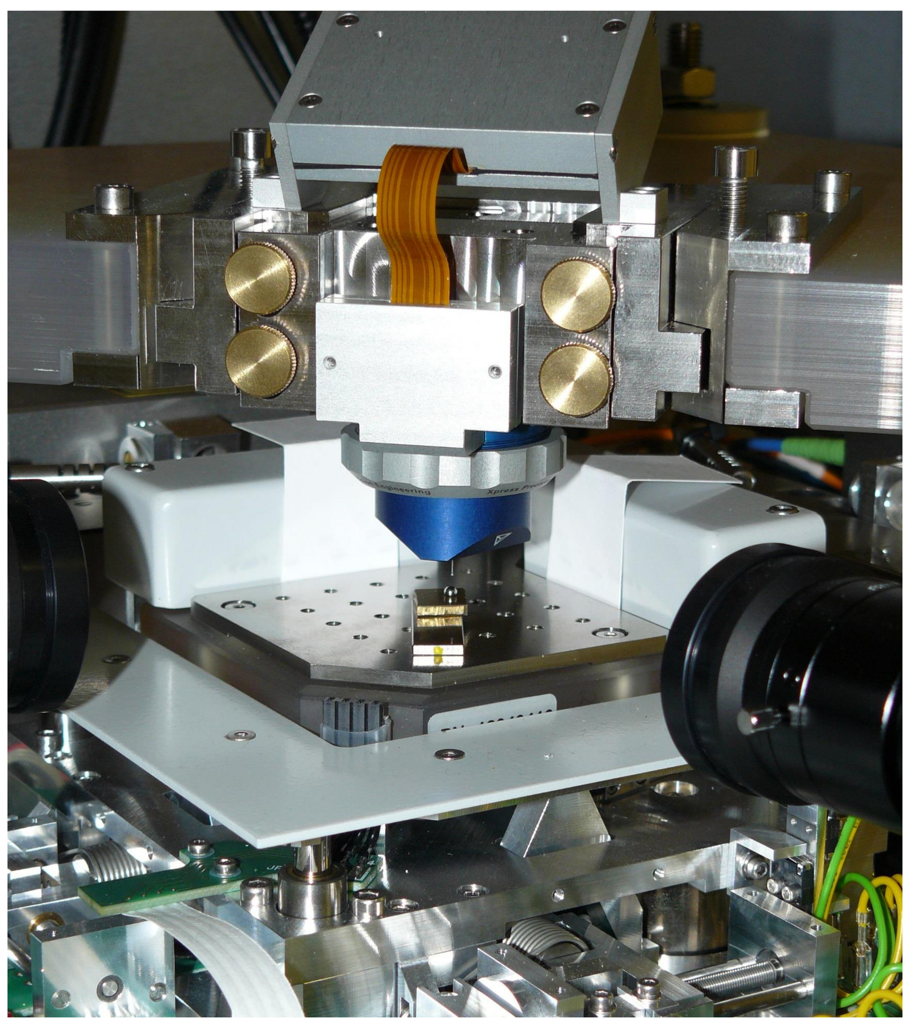


Fig 3. Measurement with tactile probe on SIOS NNM-1.

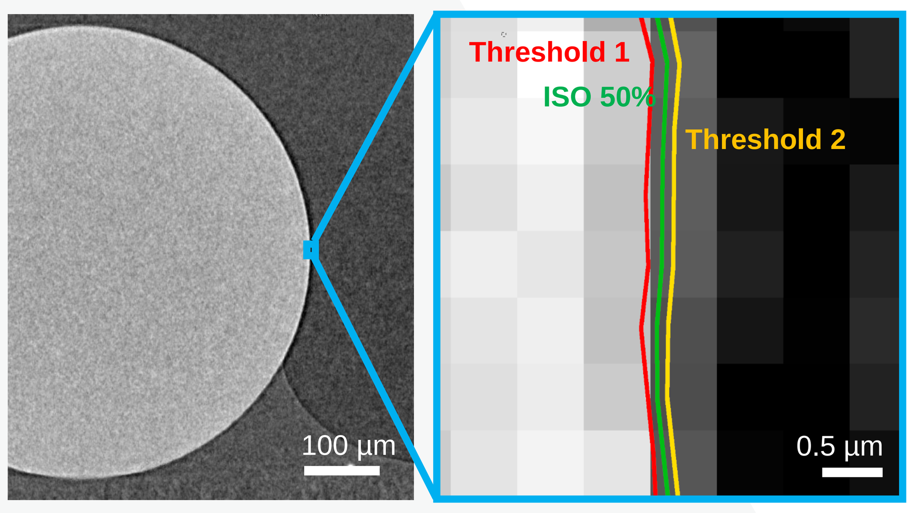


Fig 4. Visualization of edges segmented by local thresholding methods in a detail cross-section.

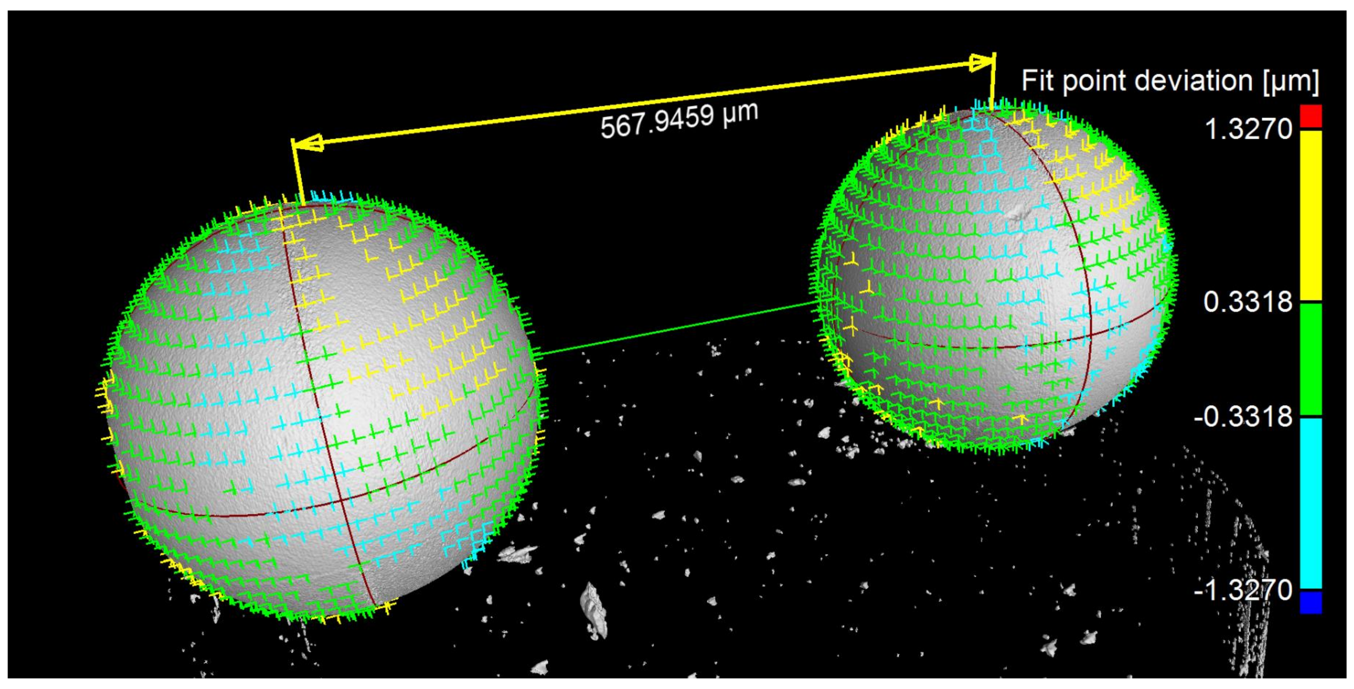
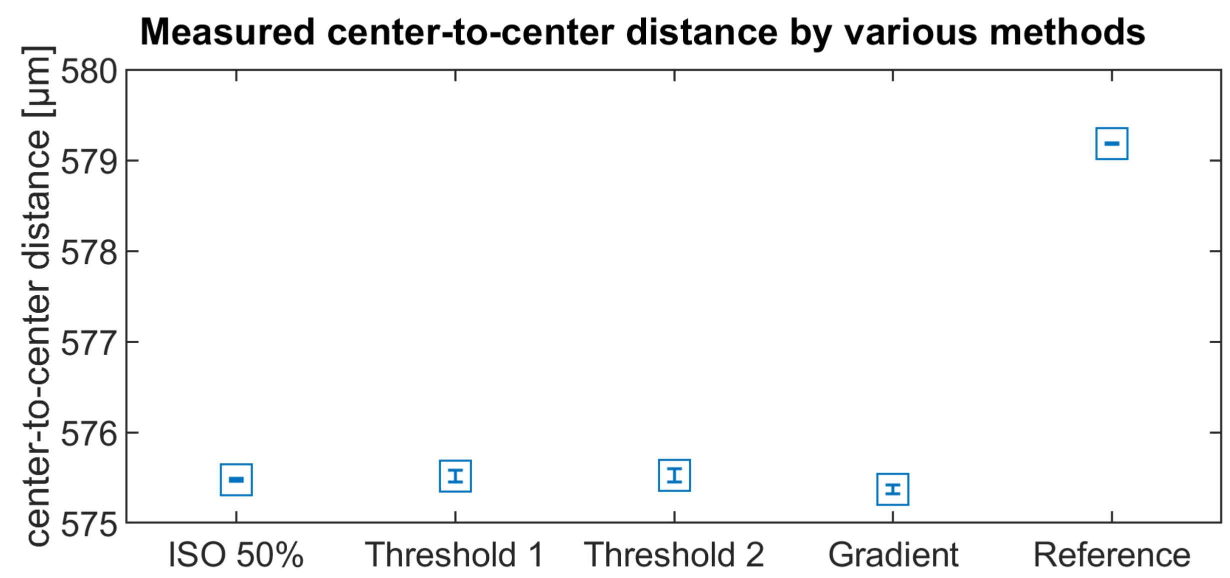


Fig 5. 3D render of ruby balls, visualization of fitpoints and measured distance

	Distance [µm]	Standard deviation [µm]
ISO 50%	575.47	0.02
Threshold 1	575.52	0.06
Threshold 2	575.52	0.07
Local thresholding	575.37	0.05
CMM measurement	579.18	0.01

Table 1. Measured center-to-center distances with standard deviations



Graph 1. Measured center-to-center distances with standard deviations from CT measurement compared to reference measurement

Conclusion

Measurement of newly developer calibration object consisting of two ruby balls with diameter 0.3 mm showed a significant difference between CT and reference measurement. NanoCMM SIOS NNM-1 was shown to be capable of performing reference measurements of small calibration object for FOV under 1 mm. Manufactured phantom is suitable for calibration of voxel size when using small FOV. Measured deviation of CT measurement from reference measurement is 3.7 µm. The influence of thresholding method and choosing of initial fit points by user was tested. In this case deviations caused by these effects are small compared deviation of CT measurement from reference measurement.

Acknowledgements

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References

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