Radiograph based SDD and SRD calculations

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Abstract
For high measurement accuracy with X-ray computed tomography (CT), that requires no scale calibration afterwards, due to incorrect assessment of voxel size during a CT scan, object magnification needs to be precisely calculated in order to minimize scale error of the reconstructed volume. Magnification, which is given by the z-axis of the machine's coordinate system, is defined by the ratio between the source-detector (SDD) and source-rotation axis distances (SRD). An inaccurate definition of either thereof distances leads to error in voxel size which by itself results in scale error of the reconstructed volume. A correct assessment of these distances is therefore of paramount importance.
In this work, a new methodology to correctly assess SDD and SRD is presented. The procedure bases itself in the use of radiographs acquired along the magnification axis rather than whole 3D scans. The newly developed method provides an accurate and fast way of calibrating both distances, improving dimensional metrology and quality control by X-ray CT. Boundary conditions, that enable the new methodology to work, were studied, tested and validated with both simulation and real data sets. Preliminary results indicate that the proposed calibration methodology reduces length error deviations in the measurements of a calibrated test object.

Keywords: X-ray computed tomography, magnification axis, calibration, scale error, dimensional metrology

1 Introduction

X-ray Computed Tomography (X-ray CT) is quickly finding acceptance in several sectors of industry where dimensional metrology and quality control are required for production quality control. The technology is well seen due to its non-invasive and non-destructive characteristics. There are, however, multiple sources of inaccuracy within an X-ray CT system that may degrade the measurement result [1-2]. This paper focuses on those that mainly cause scale error in the reconstructed volume due to miscalculation of the voxel size. Voxel size is defined by the ratio between detector pixel size and magnification, as described in Equation 1.

$$V_s = det_{ps}/M \qquad \text{Equation 1}$$

Whereas magnification is defined by the ratio between source-detector (SDD) and source-rotation axis distances (SRD), as illustrated in Figure 1 and described in Equation 2.

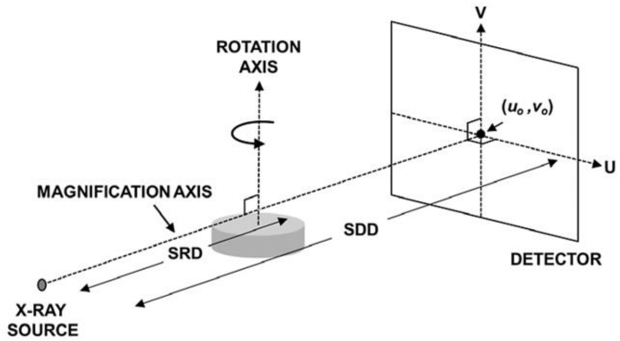


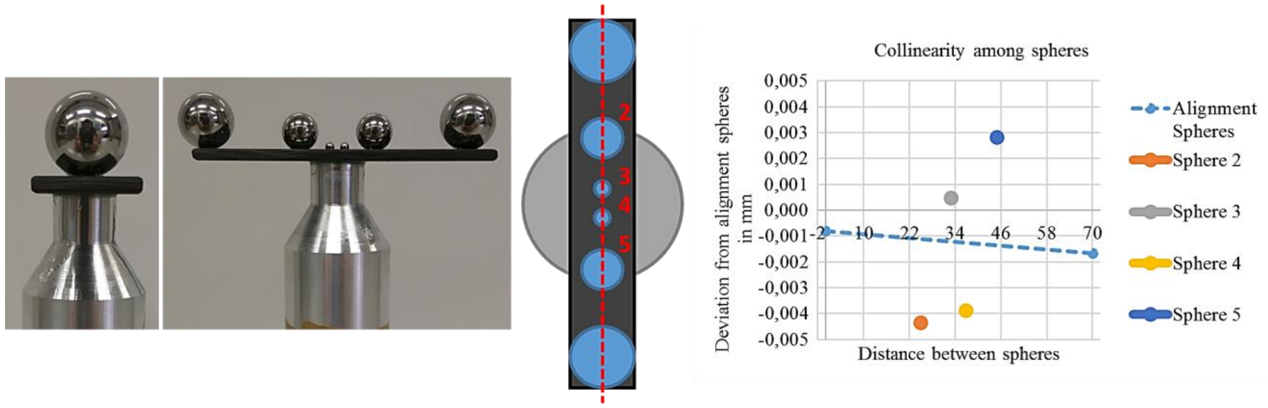
Figure 1: Schematic of an aligned X-ray CT system, adapted from [3].

$$M = SDD/SRD \qquad \text{Equation 2}$$

Any discrepancy between the assigned distances and the real distances will result in a global scaling error. Today, in order to overcome global scaling errors, a second object is measured together with the workpiece of interest, or right after the workpiece of interest has been measured. This object, usually made of spheres, provides calibrated distances that can be used to calculate a scaling factor that can be used to identify scaling error in XZ and Y planes [1-3]. A correct assessment of SDD and SRD minimizes the scaling error up to a point that a second scan, for scaling error compensation, becomes needless.

2 Methods

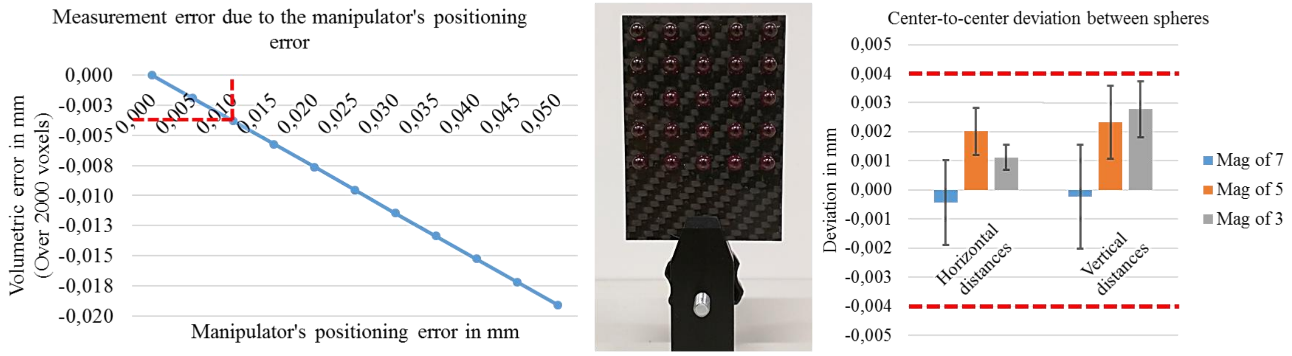
The proposed methodology, for SDD and SRD assessment, bases itself in acquiring multiple projections of a calibrated pair of spheres, Figure 2 (a), at different positions along the magnification axis of the system. A correlation between consecutives projections can be drawn, and SDD and SRD assessed, when looking at the changes of the calibrated distance of the paired spheres.



(a) (b)

Figure 2: The proposed object (a) consists of paired spheres, equally spaced in relation to the center axis of the main cylinder, that possess a collinearity of ± 5 µm (b).

For validation of the proposed methodoly, a calibrated ball plate containing 25 ruby spheres, Figure 3 (b), is used and their horizontal distances evaluated. The average of all horizontal and vertical distances is displayed in Figure 3 (c). The object has been measured at three distinct magnifications. Figure 3 (c) illustrates preliminary results of the newly developed methodology for self-calibration of X-ray CT systems in regards of SDD and SRD.



(a) (b) (c)

Figure 3: In (a) it is depicted how the manipulator`s positioning error influences length measurement. In (b) the test object used to validate the proposed methodology. In (c) the averaged results of all horizontal and vertical measurements of the test object at three distinct magnifications, where the standard deviation is atribuited to detector misalignment of the X-ray CT system.

The proposed SDD and SRD calibration technique is able to reduce mispositioning of the manipulator, which in its turn reduces length measurement errors. The biggest advantage of this process is that it can be fully automatized. Correct positioning of the object within the measurement volume, image acquisition and image processing can be fully integrated to the software managing the X-ray CT system.

Acknowledgements

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