Virtual atomic force microscope for three dimensional measurements

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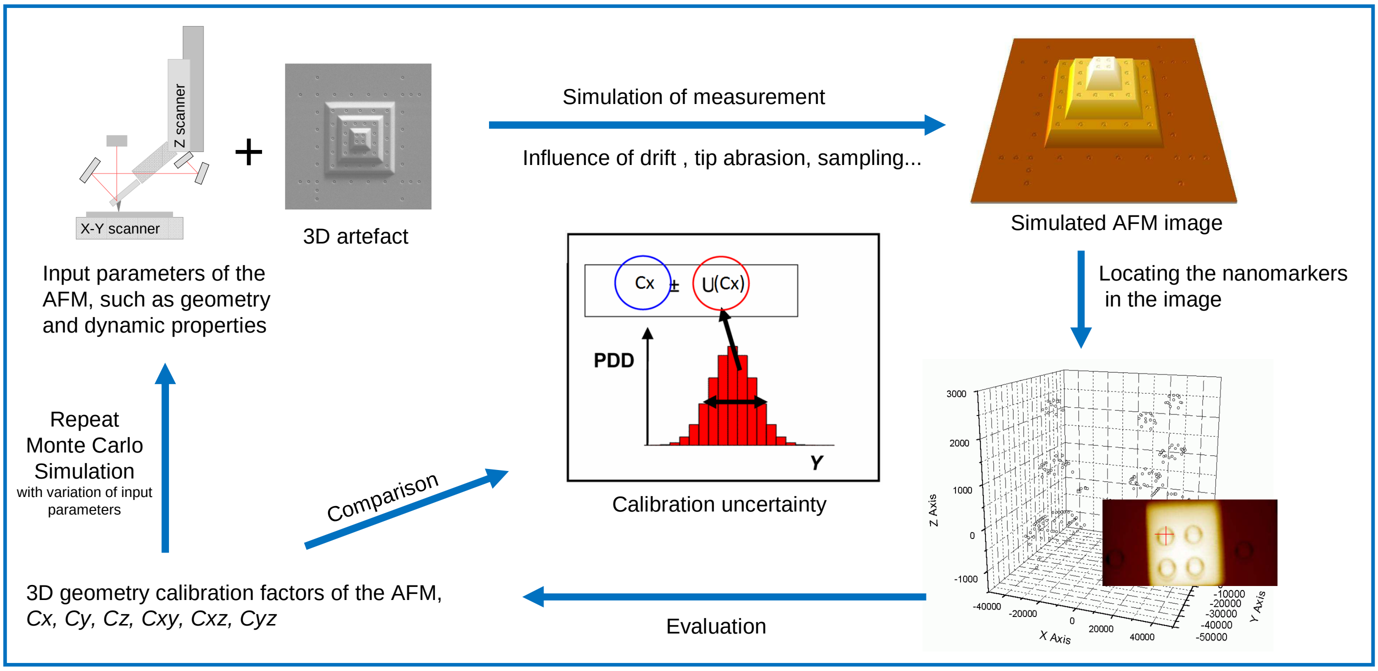
Introduction

A Virtual AFM was developed to determine the measurement uncertainty of an AFM. Through building numerical models for the individual errors from the AFM instrument, the artefact and the environment, and sequencing the error models to simulate the measurement process, the Virtual AFM calculates the measurement uncertainty from the statistical distribution of the simulation results. The Virtual AFM has been applied in evaluating measurement uncertainties of step height, 1D and 2D grating measurements. Now PTB cooperates together with m2c company to extend the Virtual AFM to 3D measurements.

In this poster the application of the Virtual AFM for 3D measurements of m2c pyramidal arrays is discussed. Here the scale factors and especially the orthogonality between the three axes can be calibrated through comparison of the measured 3D positions of nanomarkers and their reference positions.

Evaluation of the 3D calibration uncertainty



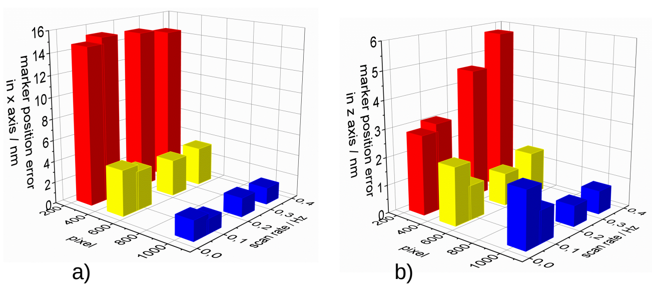
The 3D calibration results are influenced by the drift of the instrument, tip abrasion, evaluation algorithm and other factors from the instrument and environment. The Virtual AFM can evaluate the 3D calibration uncertainty through simulating the whole calibration procedure for many times with different influencing parameters generated randomly by Monte Carlo simulation methods. The calibration uncertainty is derived from the calculated *probability density distribution* (PDD).

Optimization of the measurement parameters during 3D calibrations

The selection of scan rate and image pixel number is critical for the 3D calibration results. Both parameters do have contrary effects, so a trade-off has to be found:

- High scan rate and few image pixels are required to reduce the scan time and thereby decrease the influence of drift.
- Enough pixels are necessary for the evaluation algorithm to get high detection precision.
- Low scan rate is favourable for the AFM motion stage to track the artefact surface properly.

The Virtual AFM simulates the 3D calibration procedure with different combinations of scan rates and image pixel numbers, and provides the optimal selection of the measurement parameters through comparing the resulting nanomarker position errors.



Dependence of the nanomarker position error on scan rate and pixel number for 40 µm × 40 µm images of a single pyramid (for SIS Nanostation II, now called N8 Neos by Bruker)
a) *X* position error, b) *Z* position error

Acknowledgement: Parts of this work are funded by the MNPQ-program of the Federal Ministry of Economics and Technology (BMWi) (MNPQ project 52026; Nr. 4/10)