Coordinate measurement with nano-metric resolution from multiple SEM images

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Keywords: 3D measurement, SEM, metrology

The 3D coordinate measurement of microscopic objects is an essential step for many industrial and academic investigations in fields such as fracture science [1], forensics or medical applications. So far, there are only very few methods available that operate with lateral and vertical resolutions in the small nano-meter range including atomic force microscopes (AFM) and a successful 3D measurement approach which uses two or three stereoscopic images from scanning electron microscopes (SEM) that have been obtained by tilting a specimen by several degrees [3]. Typical optical methods such as confocal systems or tactile devices do not fulfill these requirements since they either do not have the required lateral resolutions or use large tactile stylus tips.

Here we propose an extension to the existing mentioned stereoscopic approach, whose drawback so far is that it only delivers so called digital elevation maps or 2½D datasets that assign a height value for each point in the xy-plane, but cannot represent a 3D object around 360° or surfaces with undercuts. The new extension generates full 3D datasets which e.g. allows to measure a spherical object not only from above but all around. The input for this 3D measurement method are not two or three images with small differences in the tilt angles as traditionally but multiple images that are well distributed around the object to be measured. The method works in three steps. In the first step, multiple 2½D datasets are measured by the traditional approach using two or three images that have been obtained by small changes in the tilt angle (e.g. tilt angles of -5°, 0° and +5° around the y-axis). The system first finds corresponding points in the images and consecutively reconstructs the 3D points by trigonometric relationships that are provided by the tilt angle, the working distance and the metric size of a pixel in the SEM image. Once different datasets have been obtained in this manner for different viewing directions (as an example for 5 viewing directions at 0° and tilt angles in x- and y- direction of +/-45°) the different datasets are aligned in the second step to each other by a variant of the iterative closest point algorithm [2]. In the third step the aligned datasets are merged to a single dataset by a novel approach that automatically determines the overlapping regions and creates a seamless full 3D dataset of the imaged specimen.

The procedure is demonstrated on the measurement of a spherical object, for which one of the multiple SEM input images is shown in Fig. 1a. In Fig. 1b a 2½D dataset is provided that has been obtained by a traditional stereoscopic approach using 3 SEM images tilted at 0°, -5° and 5°. The dataset only shows the top part of the sphere since the stereoscopic approach can reconstruct the sphere only from one direction. Afterwards an additional 2½D datasets has been obtained from a different viewing direction. Afterwards the two datasets have been aligned to each other by the proposed alignment method. Fig. 2a shows the two datasets before the automatic alignment and Fig. 2b afterwards, where the two datasets are well aligned. The final 3D dataset that is obtained by the new merging procedure from 5 single 2½D datasets is provided in Fig. 3 where the colours represent the deviations to a fitted sphere with a radius of 50.14µm. The dataset shows that a much larger portion of the sphere is visible in contrast to Fig 1b and that no seams are visible where the datasets have been merged.

References

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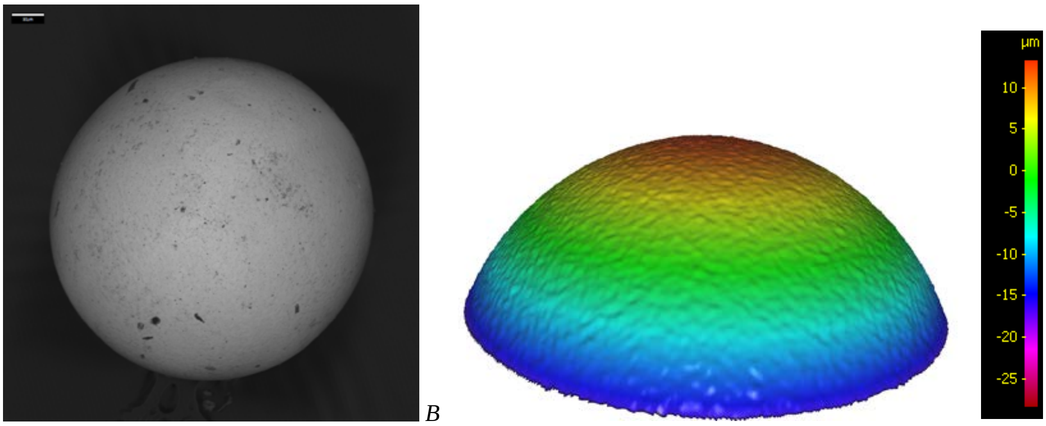
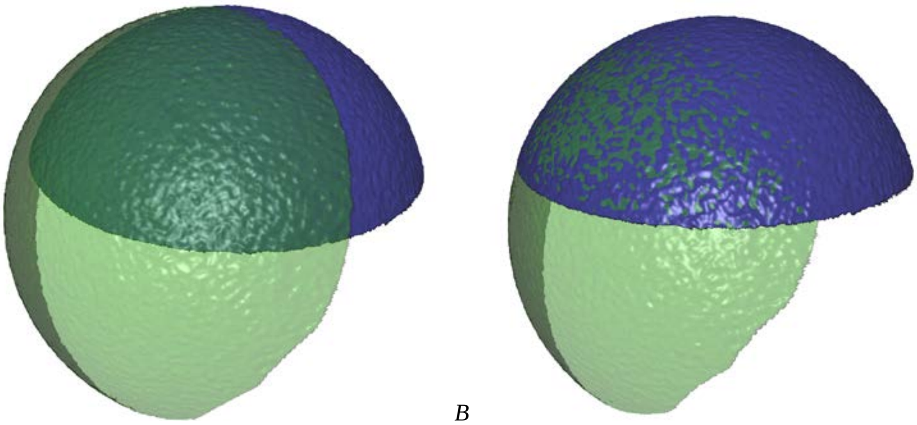
A 

Figure 1. *A: One of the two or three stereoscopic input images that are used for traditional stereoscopic measurement. B: Measured dataset where for each point in the xy plane a height value [µm] has been determined. So only the top region of the sphere can be measured.*



A *B*

Figure 2. *Registration of two of multiple 3D datasets obtained from different directions. A: Before registration. B: After registration.*

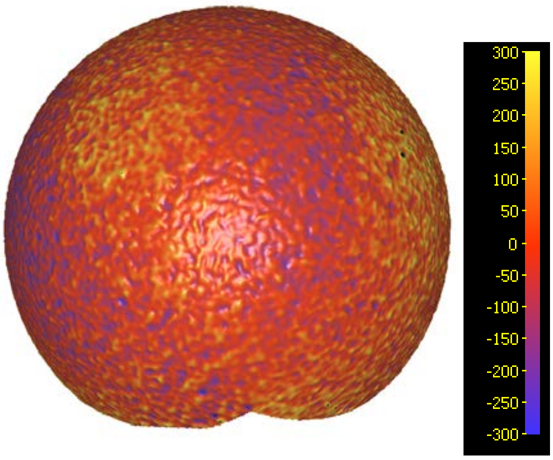


Figure 3. *Result of the new 3D measurement procedure. The whole sphere (radius = 50.14µm) has been measured and no overlapping regions are visible. The colors represent the deviations to the best fitted sphere in a least-square sense [nm].*