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The Spatial Resolution Dependency of a μCT Thresholding Method Based on the Correspondence with Microscopic Images

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Summary

The most critical step in the image analysis of X-ray microfocus computed tomography (μCT) images is finding the optimal threshold for binarization. Several review articles discuss and evaluate a range of threshold methods. However, they all conclude the same: that finding the optimal threshold is not a trivial issue and that there is no single threshold algorithm that is successful for all possible image variations in the spatial domain.

Thresholding method: In this study, a novel thresholding method is developed based on matching μCT images with their corresponding microscopic images. When overlaying both, the optimum is represented by a maximum in coinciding and a minimum in non-coinciding solid pixels. The threshold approximating this 'optimum' the best is named the 'optimal' threshold. This 'optimal' threshold is however only valid for unique combination of a selected material, μCT device and acquisition parameters. If one of these settings changes significantly, a new 'optimal' threshold needs to be determined. But since a well defined protocol is followed for each selected material, containing fixed acquisition parameters on a fixed device, the 'optimal' threshold should only be determined once and can be applied in further measurements. The only parameter which can vary for a selected material is the spatial image resolution. Hence, the influence of this parameter on the 'optimal' threshold is assessed.

In comparison to other thresholding methods this method (i) accounts for closed pores and (ii) results in binary images closely representing the real structure since the physical visualization of the structure is taken as a reference. A disadvantage is that it is a global thresholding method and hence it does not account for the local errors present in μCT images. However, since this thresholding method includes a definition of the overlap and mismatch with respect to reality, this error can be quantified.

Experiments, Results and Discussion: The influence of the resolution is assessed using porous titanium structures with heterogeneous architectures (strut size: 20-100μm and pore size: 50-500μm). For each sample, different μCT datasets with varying voxel size (15 - 35μm) are rendered. For the μCT datasets with

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the highest resolution, the 'optimal' threshold is determined as explained above. Ideally, this threshold value should be kept constant for different (lower) resolutions. However, since features with dimensions in the range of the resolution will be visualized with lower grey-values due to the partial volume effect, they are not selected by the 'optimal' threshold. It is also known that, inherently, the lower the resolution, the larger the error in the μCT images will be. If for lower resolution the 'optimal' threshold would be determined as described above, this is not taken into account since the method minimizes the mismatch. Hence, for the images with lower resolution it is decided to keep the overlap percentage equal to that of the highest resolution images, and the threshold representing this percentage is assigned as the new 'optimal' threshold. This approach results in a threshold that decreases linearly with decreasing resolution (for double the voxel size, the threshold decreases by 13.7 ± 4.2 %) and in a non-linear mismatch increase.

Conclusion: A novel threshold method is developed which results not only in an 'optimal' threshold, but also quantifies the μCT image visualization and binarization errors. It is determined that this 'optimal' threshold is influenced by the spatial image resolution. Hence, another method is applied to determine a new 'optimal' threshold for images with lower resolution and to correlate the threshold to the spatial resolution.