

Latest developments in 3D analysis of CT data by Morpho+

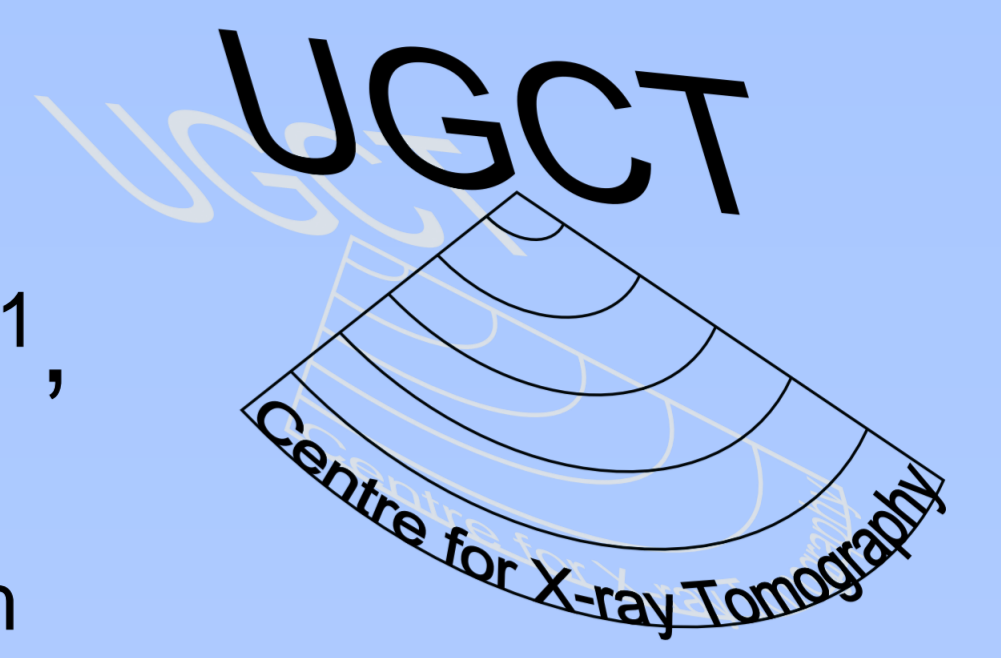


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Abstract

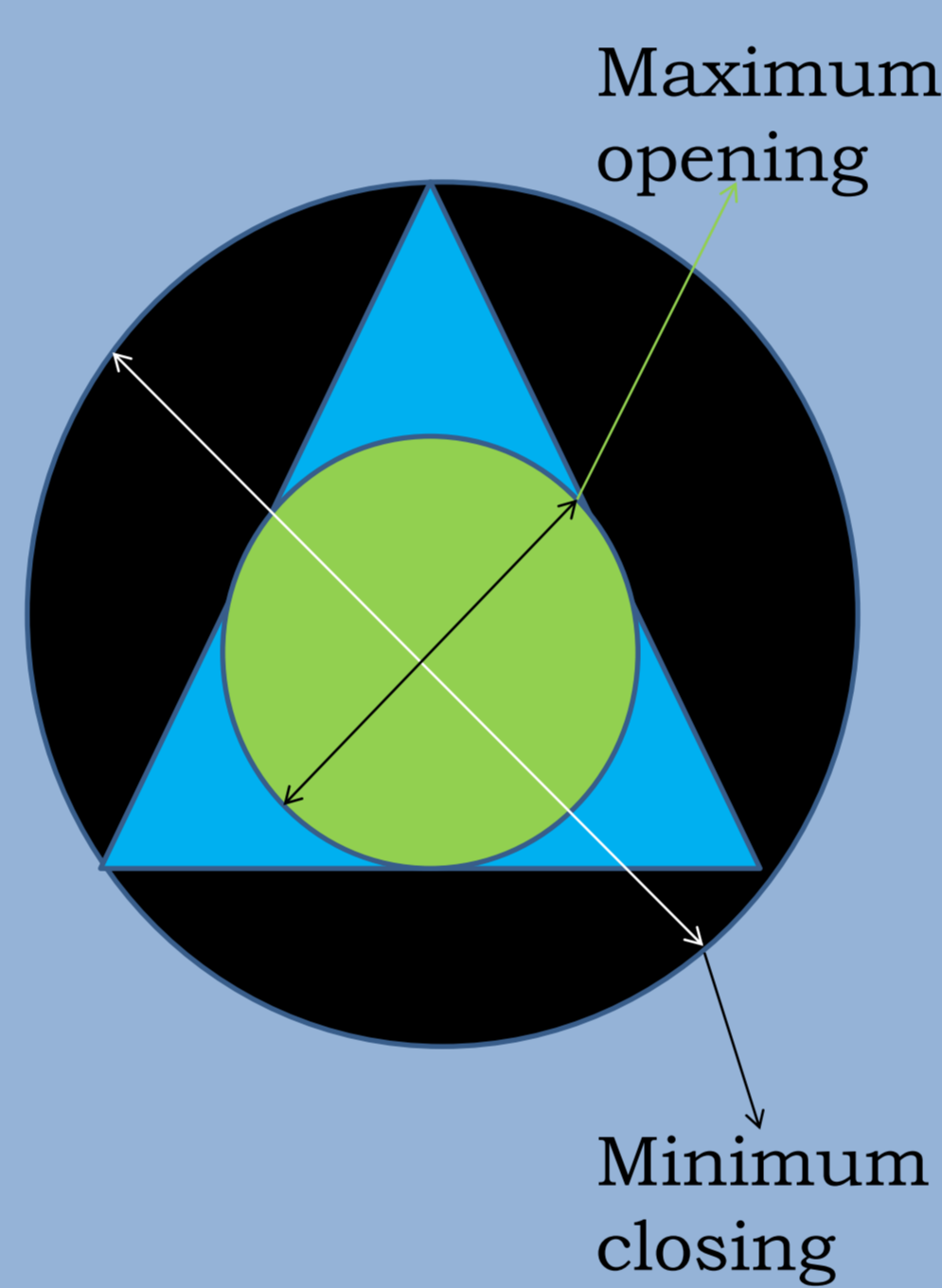
At the Centre for X-ray Tomography of the Ghent University (Belgium) (www.ugct.ugent.be), a lot of progress is being made in hardware development for high-resolution X-ray CT scanners, as well as in the field of software for data reconstruction and 3D analysis. We present the latest developments in the in-house developed package Morpho+, a flexible 3D analysis software program which provides several structural 3D parameters of a scanned sample.

Morpho+ is able to calculate several geometrical parameters for both a complete sample as for specific components of a sample, such as grains or pores. These parameters include the surface, diameter of the maximum inscribed sphere, diameter of the minimum circumscribed sphere, equivalent diameter, orientation and a measure for the sphericity (shape parameter). In addition, total sample porosity (or volume fraction) and partial porosity (radial and longitudinal) can be determined. To measure the connectivity of the sample, a skeletonization algorithm and calculation of parameters such as the Euler Number and the size of bottlenecks of a network are included in the program.

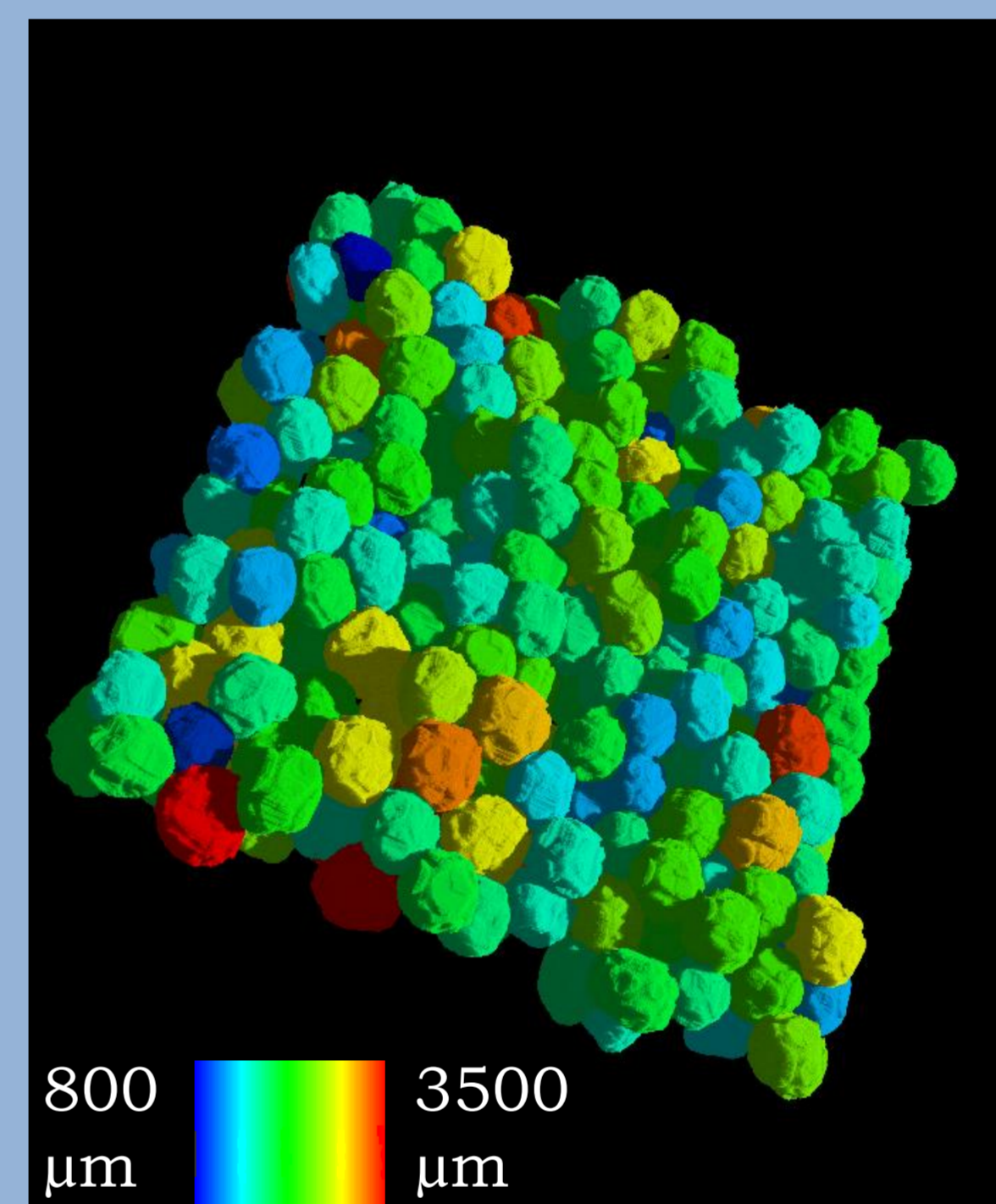
Morpho+ produces a quantitative output, but it is also possible to visualize the different steps of the analysis, enabling easy interpretation of the results. For example different elements in a 3D volume can be colour-labelled based on their size. Furthermore, the surfaces of the analysed components can be saved as an STL-file for easy visualisation or further analysis.

Size and shape

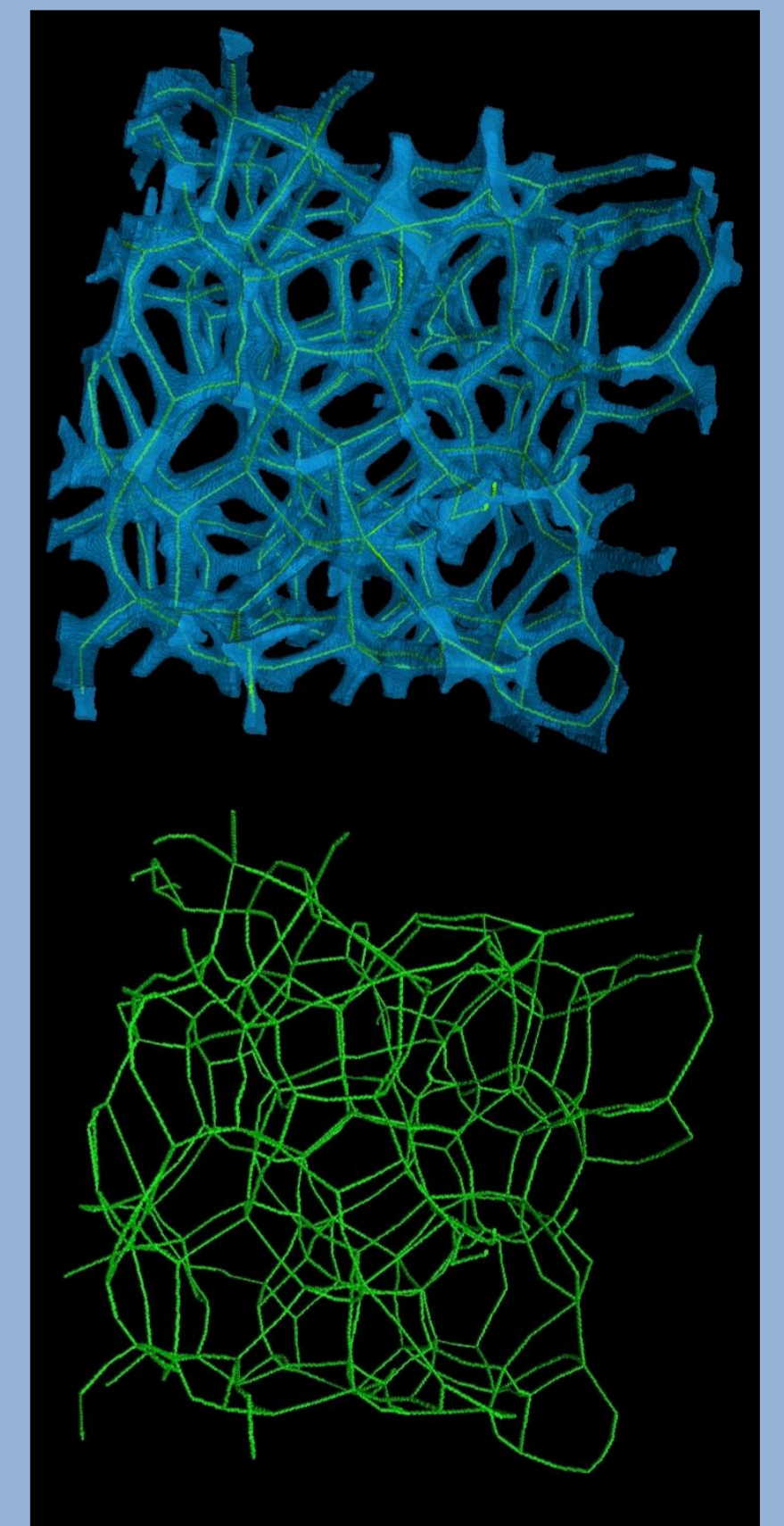
There are several parameters to compare the size and the shape of objects in a volume (such as grains or pores). The equivalent diameter is the diameter of a sphere with the same volume as the object. The maximum opening is defined as the diameter of the maximum inscribed sphere of the object; the minimum closing is the diameter of the minimum circumscribing sphere. Dividing the maximum opening by the minimum closing gives a measure for the sphericity; the object will resemble a sphere if this value is close to one. Additionally, the orientation of the objects can be determined, which can then be visualized in a stereoplot. It is also possible to colour label objects according to their size or shape, or to create a skeleton of the volume.



Maximum opening and minimum closing of a triangle

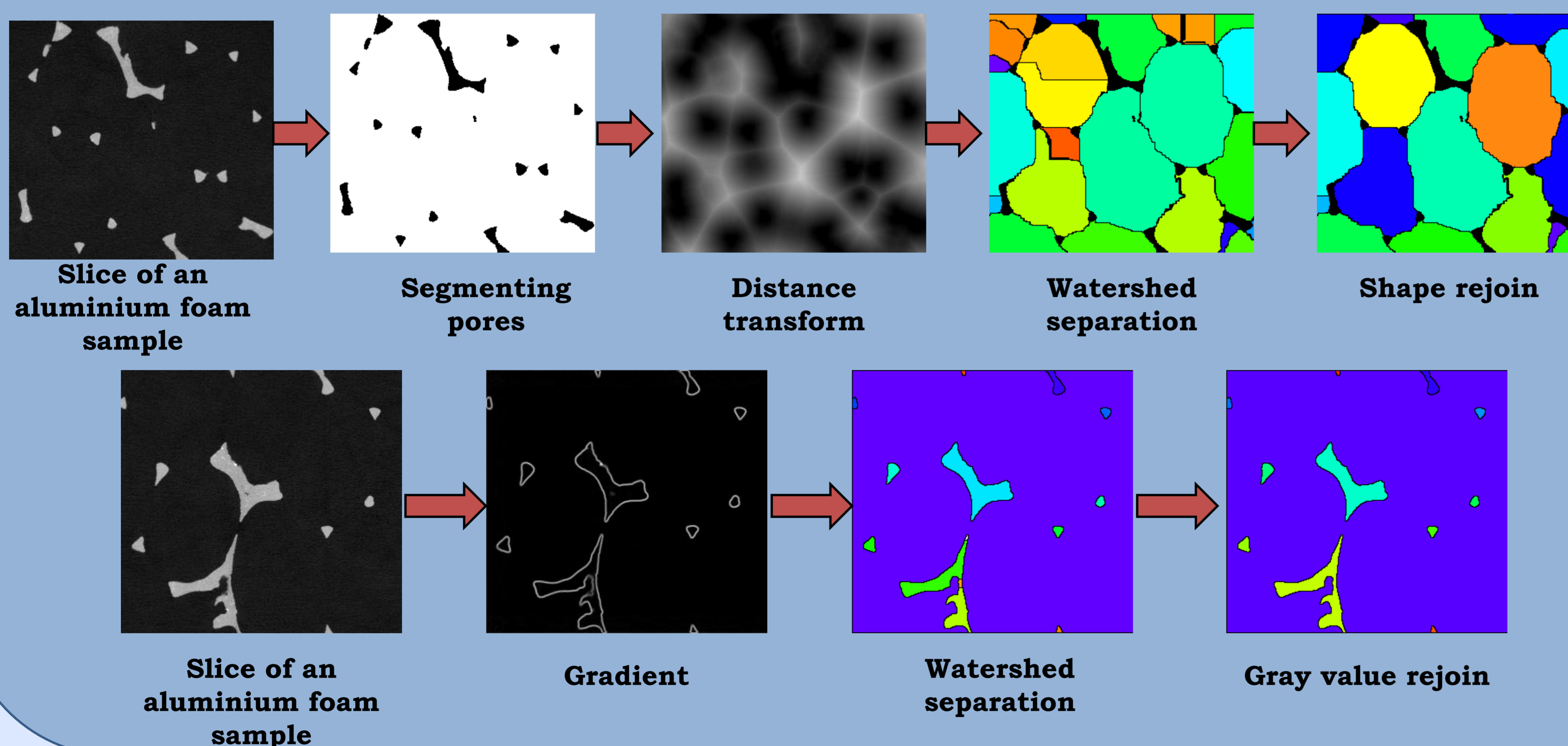


Pores of an aluminium foam colour labelled based on their maximum opening



Skeleton (green) of an aluminium foam (blue)

Segmentation



Several techniques for segmenting the phase of interest in a volume are implemented in Morpho+. A simple gray value based thresholding operation can be performed, or a gradient based watershed separation. To separate objects which are not physically connected, or to separate connected objects inside a volume (e.g. different cells in a network), an additional watershed separation can be performed on the Euclidean distance transform, i.e. the minimal distance to the border of the object for every voxel. To reduce oversegmentation, separated objects can be rejoined if the difference in gray value is small (gray value rejoin) or if the throat separating the objects approximates the maximum opening of the objects themselves (shape rejoin).

