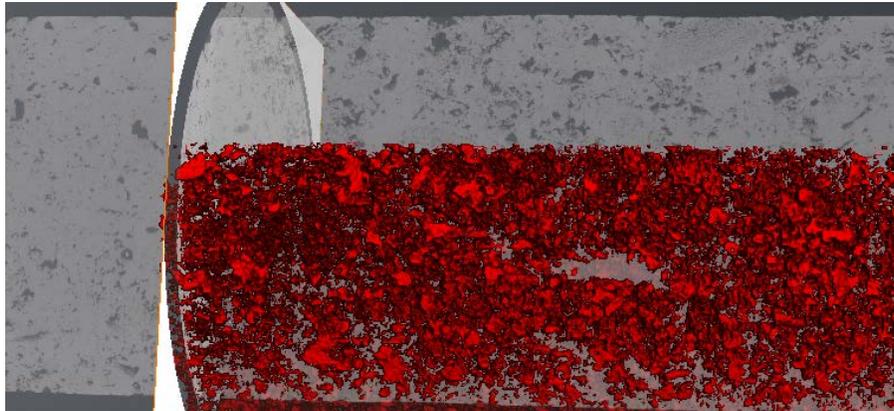


Segmentation tools and workflows in PerGeos

1. Introduction

Segmentation typically consists of a complex workflow involving multiple algorithms at multiple steps. Smart denoising and morphological filters are often included in the segmentation process. Thus, a robust library of versatile, fast and parallelized algorithms with low memory consumption, is mandatory.

At a high level, being able to use proven workflows, and save / re-use custom ones is key to develop a viable and sustainable Digital Rock platform. PerGeos offers both, by using its in-house image processing library-developed since the 90's and constantly being enhanced- and through workflow automation, where a user can add breakpoints and comments in order to provide multiple levels of interaction with the segmentation workflow, generating processes that are easily shared between users and provide a guided user experience for image processing.



2. Tools

Thresholding

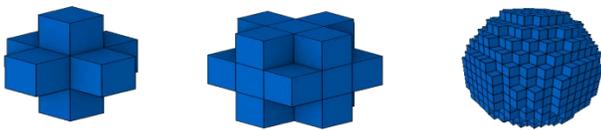
Thresholding can be achieved using multiple approaches:

- Manual
- Automatic (entropy, factorization, iso data, moments)
- Adaptive (based on criterions applied to local histograms)

Morphology and kernels

Many segmentation workflows involve morphological mathematics. Operations such as erosion, dilation, closing, opening, reconstruction from markers, border removal, are the most commonly used.

The kernel used for the operation needs to be flexible (2D, 3D, cubic, spherical, configurable shape and direction).

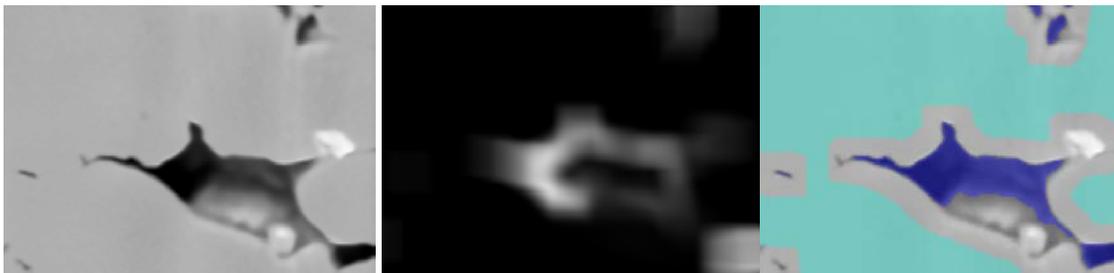


Examples of morphological kernels

Gradients & variances

The gradient of an image is a good indicator of where boundaries exist for features of interest. It is often used in edge recognition mechanisms. Defined as the local deviation at every pixel location, multiple methods can be used (morphological, directional, 2D, 3D).

The variance is also indicating a deviation, but on a larger region around the pixels, by the use of a bigger kernel. It is used in the segmentation of pore-backs in FIB/SEM volumes.



Greyscale image

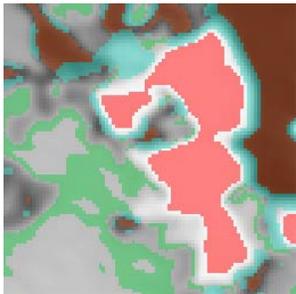
Variance image

Markers for pore back detection

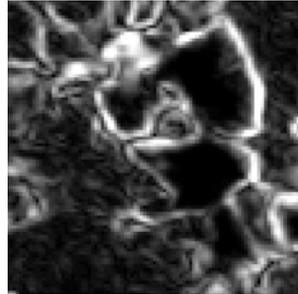
Marker Based Watershed (MBW)

This algorithm is often the main driver in the segmentation process. The boundary between materials is not defined by a user driven algorithm, but by the images/volumes themselves, by using the gradient function (the local deviation) as the delimiter between the different features.

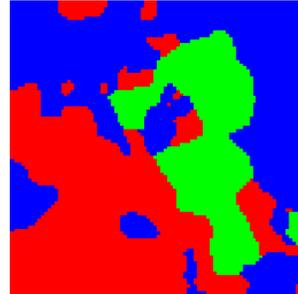
The materials to be segmented are marked with thresholding (automatic or manual), top hat and/or variance. The MBW process then computes the expansion of the markers on a landscape function which is defined by the gradient volume. The result is analogous to the so-called active contours algorithm.



Markers for MBW



3D gradient contour



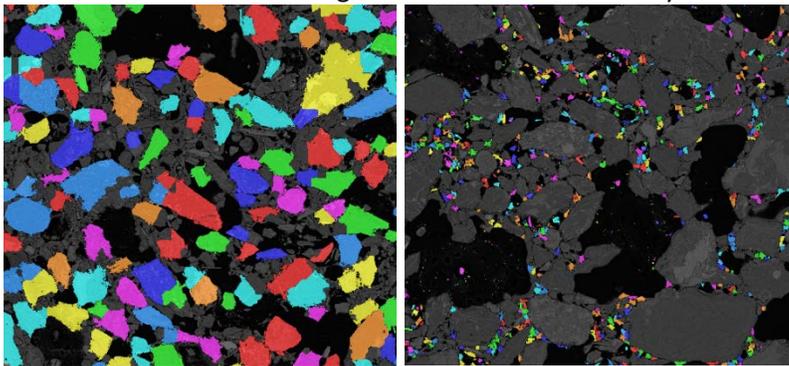
3 Phases segmentation

Separation

Separation can be involved in the segmentation workflow (separation of grains .e.g.). Multiple methods relying on distance maps and/or skeletons to set markers, MBW for the expansion, are available.

Measure-based segmentation

Sometimes segmentation needs to involve analysis of isolated features. Extracting features with .e.g a given volume/orientation/shape is a common example. PerGeos measurement library provides more than 100 characteristics that can both be used for segmentation or intrinsic analysis.

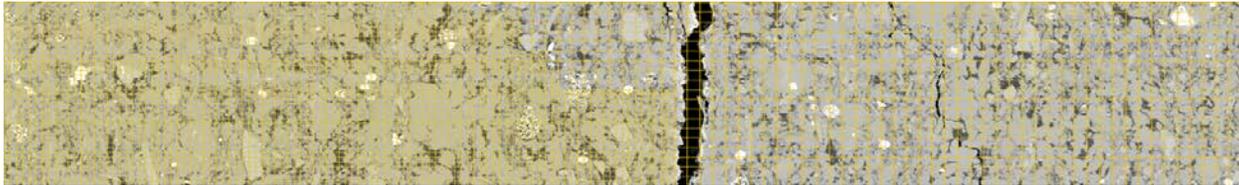


Measure-based segmentation illustration

Examples

Large 2D images

When processing large mosaic images, the graphics engine needs to be able to render large 2D images whose size exceeds the memory of the GPU. PerGeos addresses this by the use of the out-of-core rendering of its graphics engine (FEI Open Inventor API).

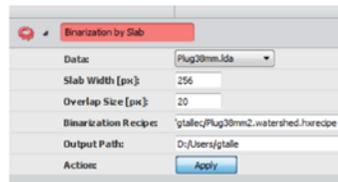


Large 3D volumes

The size of 3D volumes is now commonly more than 60GB in output of high-ends microCTs (FEI Heliscan). A segmentation workflow could use up to 4x the RAM of the volume (gradient volume, MBW, output label data), often larger than the RAM of a single machine, making an out of core processing or a cluster-based solution mandatory.

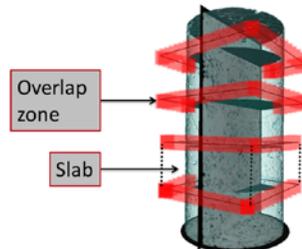
PerGeos allows the out-of-core processing on a single machine, by a high-performance slab mechanism (segmentation by blocks in the Z direction) with customizable overlaps in order to allow block to block information sharing. The output label volume is not loaded in RAM, but written on the disk as a multi resolution out-of-core data (LDM file format).

SLAB Processing



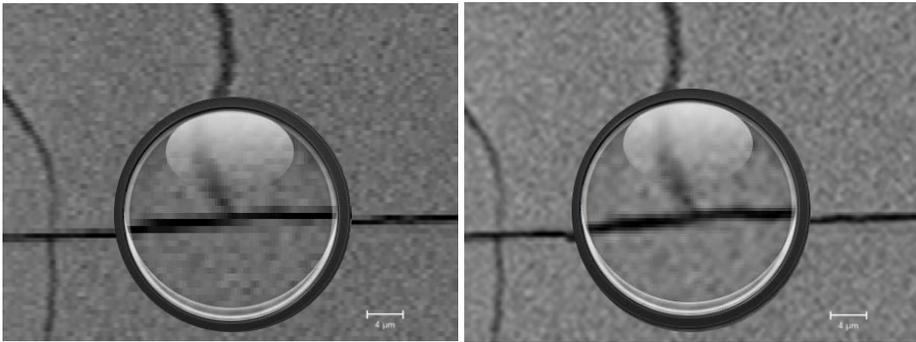
• **Unlimited File size**

- Segmentation :
 - using dedicated recipe (Watershed & TopHat) + TopHat)
- Analysis :
 - Porosity
 - Connected porosity
 - Labeling



CT

Due to the low resolution, cracks are often defined on 1 or 2 voxels in thickness. The best automated approach is to over-sample the volume (thus making cracks being defined on 4-5 voxels), and use the MBW standard workflows.

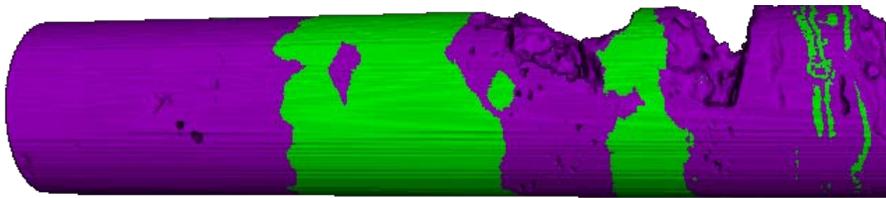


Original Cracks

Oversampled cracks

Whole Cores

By using the CoreProfile extension, whole cores (100GB +) can be segmented in a single workflow often including Beam Hardening correction, denoising and MBW.

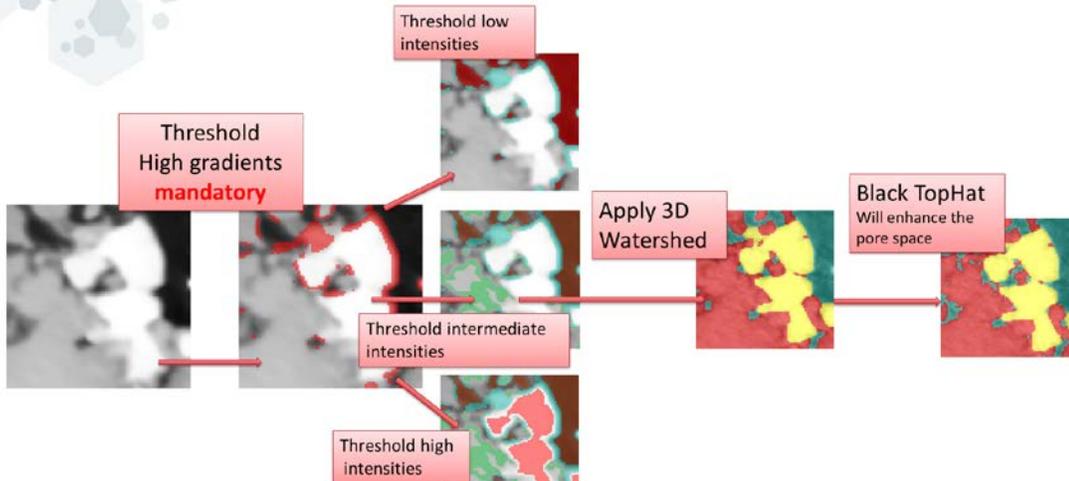


Micro-CT

Multiple workflows relying on MBW have been defined and are commonly used for microCT samples segmentation:

- Porosity
- Grain
- Multiphases

Multiphase Watershed segmentation

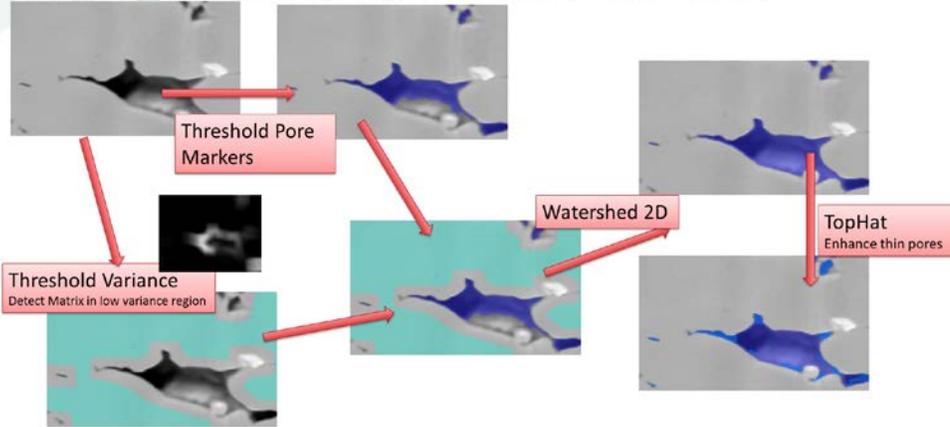


BSEM

The difficulty with BSEM images is that the pixels don't represent a density, but a reflection of the material. The most difficult task is to segment the pore space, and the so-called pore backs, the back side of the pore whose pixels have often the same intensity as the minerals in the sample, due to the reflection of the electrons inside the pore, or re-deposition of material into open pores during milling.

In samples where the matrix is quite homogeneous, markers are positioned using the variance filter, in order to avoid marking inside the pores. Pores and organics are marked with thresholding or top hat. The Markers are then expanded in 2D with a MBW

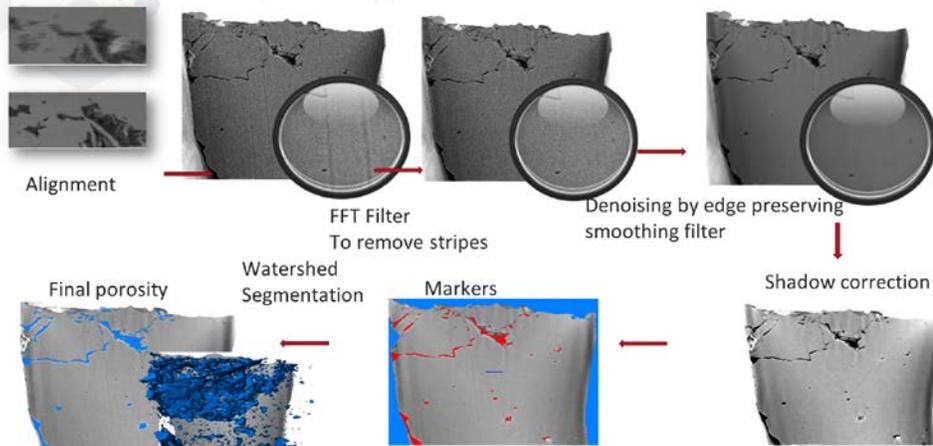
Recipe : SEM Porosity segmentation (Pore-backs)



FIB/SEM

In addition to the BSEM characteristics, FIB/SEM volumes have a whole set of artifacts that needs to be corrected prior to any segmentation workflow (mis-alignment, strong noise, stripes, shadowing). PerGeos includes the necessary artifact removal techniques to clean the data for easier segmentation and more accurate analysis.

FIB/SEM : Pore space segmentation



Classification into regions

Images or volumes are often scanned at big sizes but low resolution due to hardware limitations. A discretization and classification into regions is then needed in order to characterize a particular continuous feature used for sub-resolution extraction and scanning.

The below example shows how porosity can guide sub plugs extraction. This is part of a rock typing workflow.

Classification by porosity

