thermo scientific

PerGeos Software

Digital Rock Analysis

Visualize, Analyze, Simulate

Release notes – PerGeos Software 2019.1

March 2019

This document will inform you of the most important new features, improvements and changes in this version of Thermo Scientific™ PerGeos Software. Please read these Release Notes carefully.

We would appreciate your feedback regarding this version. If you encounter any problems or have any suggestions for improvement, please do not hesitate to contact us at FRBOR.3d_hotline@thermofisher.com.

Thank you in advance for your cooperation.

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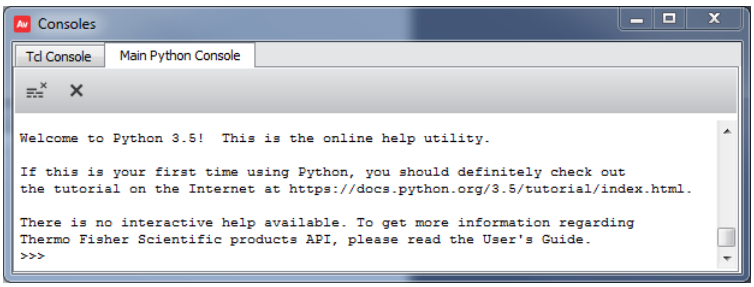
GENERAL ENHANCEMENTS AND CHANGES

PYTHON 3.5

The Python scripting API in PerGeos Software has been upgraded to Python 3.5.2. Python 2.7 support has been discontinued. Some compatibility issues exist between Python 2 and Python 3. The official Python documentation regarding porting to Python 3 can be found here: https://docs.python.org/3.5/howto/pyporting.html.

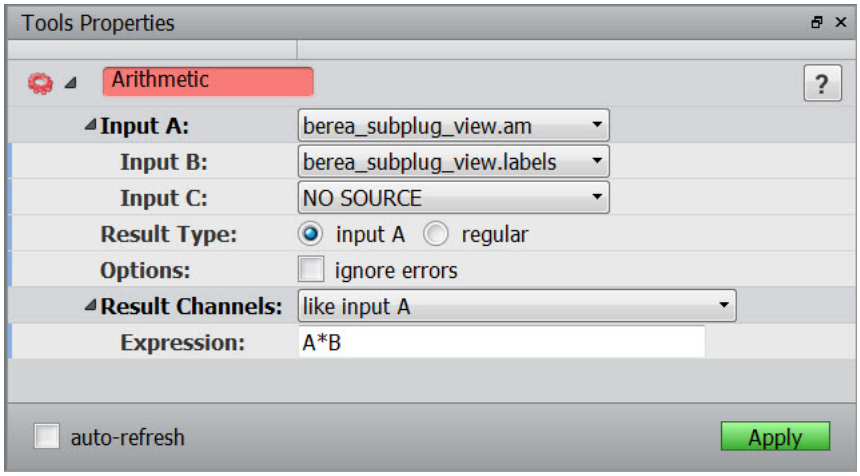


The following are some of the advantages of moving to this new version of Python:

- Compatibility with Matplotlib and PyQt
- OpenCV available in default packages list
- New Deployment Manager (EDM) that allows fast creation of multiple self-contained Python environments

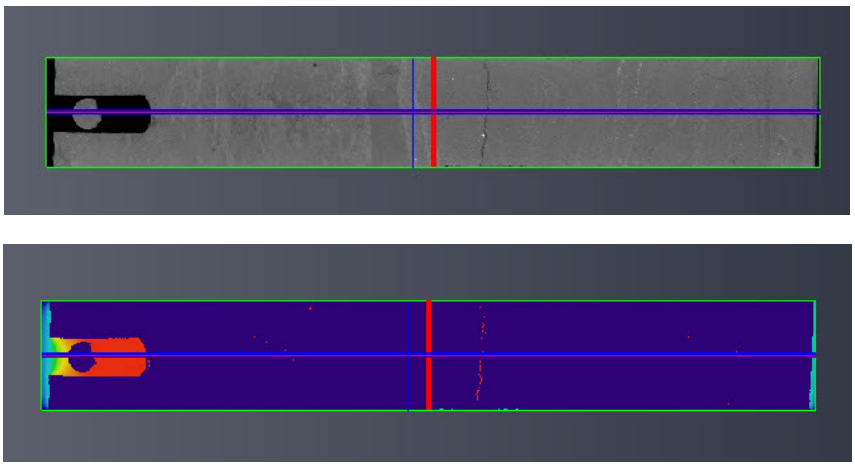
PROPERTIES AREA

All input data ports for a module in the Tools Properties panel are now placed at the top of the panel.



COMPUTE AMBIENT OCCLUSION

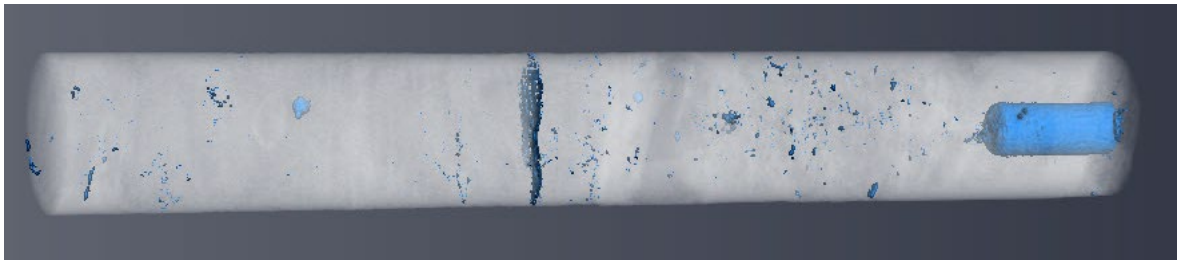
The Compute Ambient Occlusion module allows you to compute an ambient occlusion scalar field from a given label field. The ambient occlusion field is computed by casting rays from each background voxel into all directions until the rays hit the foreground. The ratio of the number of rays that hit the foreground and the overall number of rays define the ambient occlusion value. A value of 0 means that the full light reaches this point; a value of 1 means that no light at all reaches this point.



Grayscale CT image of a core (top). Ambient occlusion image of the core computed on the CT image (bottom).

The ambient occlusion scalar field can be used to detect cavities. Many natural objects contain pores and cavities that are filled with the same material that also surrounds the object. When such objects are imaged using, for example, computed tomography, the pores and cavities cannot be distinguished from the surrounding material by considering gray values and textural properties of the image. In this case, morphological operations are often used to fill the inner region. This is applicable if the pore and cavity structures are small compared to the overall size of the object and if the object is mainly convex; otherwise, the segmentation can be difficult and may result in a lot of noise.

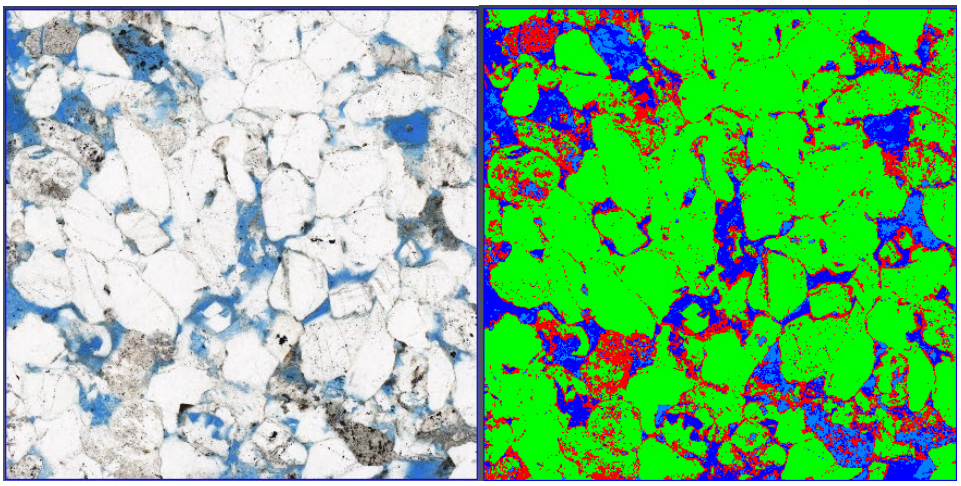
One of the advantages of the ambient occlusion tool for the segmentation of pores and cavities is that it generates smooth scalar fields. Due to this smoothness property, a segmentation based on those fields will result in smooth boundaries at the pore and cavity openings. This is often desired, particularly when dealing with natural objects.



Cavities and fractures segmented using the ambient occlusion image of the core.

INTENSITY AUTO CLASSIFICATION

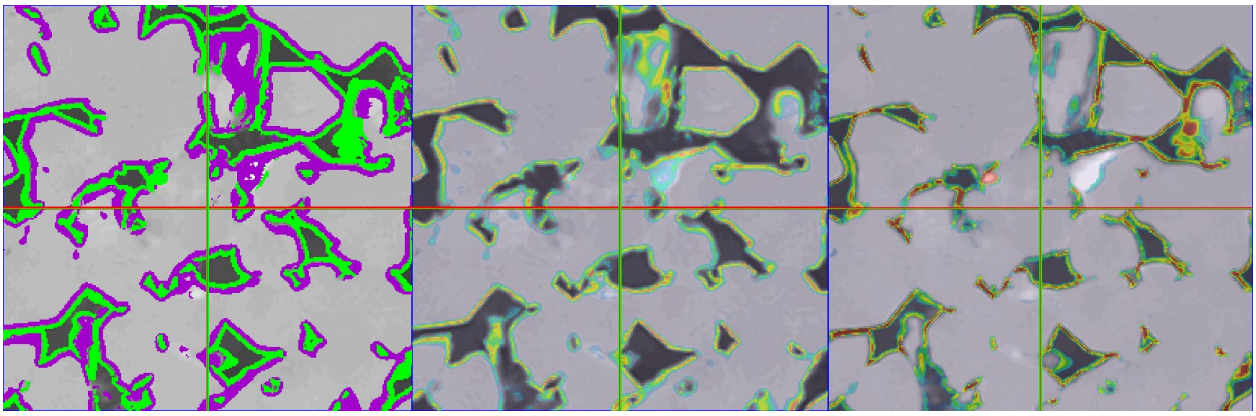
The Intensity Auto Classification module is a non-supervised classification tool that performs an automatic segmentation of gray-scale and multi-channel images into a given number of classes. It is based on a k-means clustering algorithm.



Thin-section color image is automatically segmented into four phases using Intensity Auto Classification. (Image courtesy of Weatherford Labs).

RIDGE ENHANCEMENT

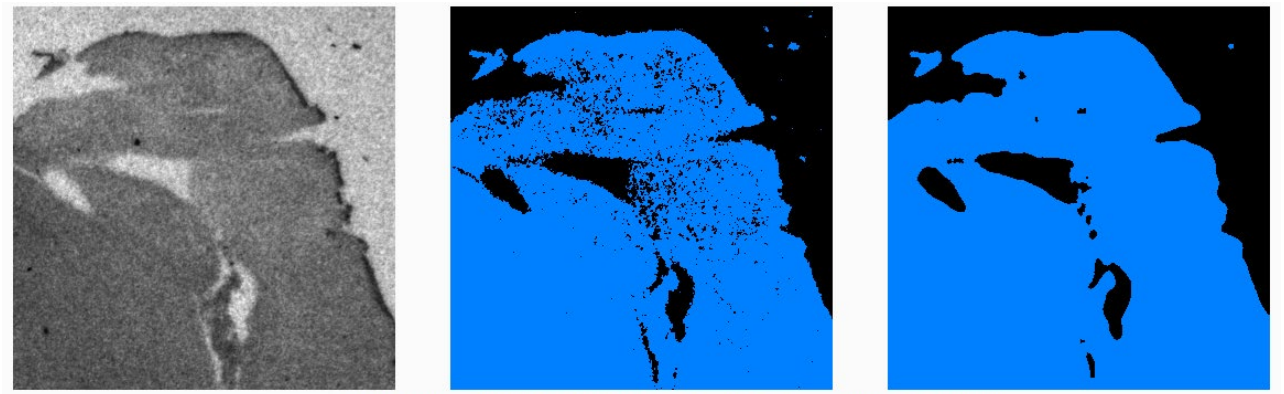
The Ridge Enhancement filter uses the second-order derivative to detect, highlight and enhance dark-to-bright and bright-to-dark transitions in an image. First-order derivative or gradient images have high values at an edge or transition in an image, while the second-order derivative matrix contains information about the nature of the transition. This filter can be used to obtain the pore and grain edges as separate phases.



(From L–R): Berea sandstone data with grain edges (purple) and pore edges (green) overlaid. Berea data blended with ridge enhancement filter output (bright). Berea data blended with ridge enhancement filter output (dark).

BINARY SMOOTHING

Binary smoothing transforms a binary image into another binary image by inspecting the local mean value in a user-specified neighborhood.



Grayscale input image, binary image after thresholding and result of a binary smoothing using a 9x9 window

SELECTIVE MORPHOLOGICAL OPERATORS

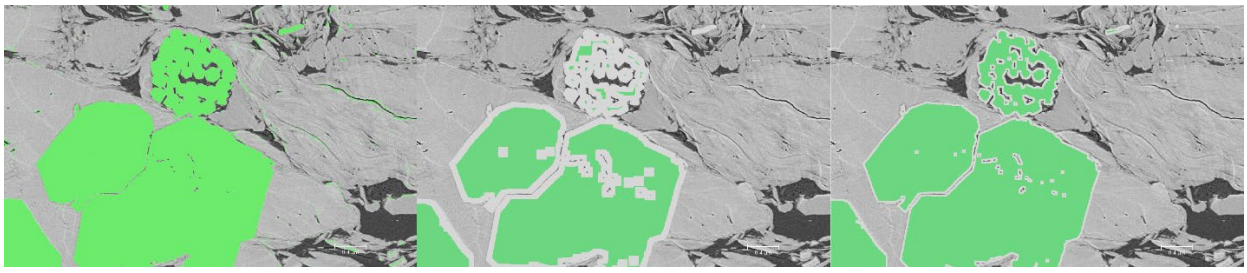
The selective morphology tools take into account the local binary values while performing opening, closing, dilation and erosion. Due to the local binary constraints, selective morphology can be robust to different datasets; hence, these modules can make for excellent candidates to be part of recipes. Selective morphology can also be used to decide on pore-grain boundary pixels to recede or proceed while retaining the underlying shape of the pore or grain.

Selective Opening: This algorithm performs a selective erosion followed by a selective dilation. This operator is smoother than the classic opening and softens the appearance of the structuring element in the filtered image.

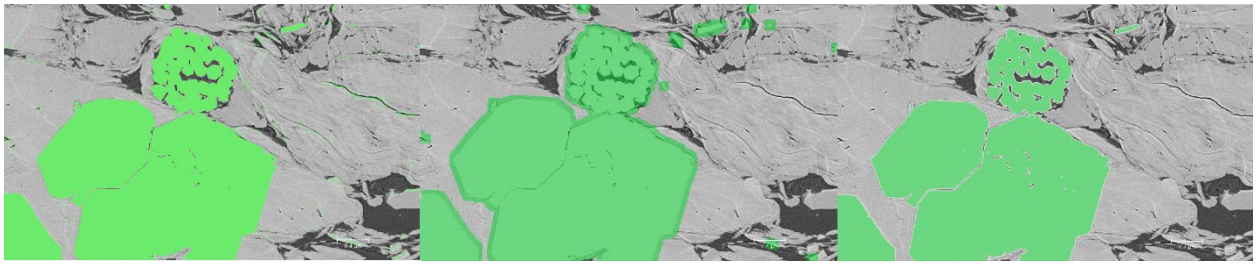
Selective Closing: This algorithm performs a selective dilation followed by a selective erosion. This operator is smoother than the classic closing and softens the appearance of the structuring element in the filtered image

Selective Erosion: This algorithm erodes objects conditionally to a local constraint. This operator is smoother than a standard erosion and softens the appearance of the structuring element in the filtered image.

Selective Dilation: This algorithm dilates objects conditionally to a local constraint. This operator is smoother than a standard dilation and softens the appearance of the structuring element in the filtered image.



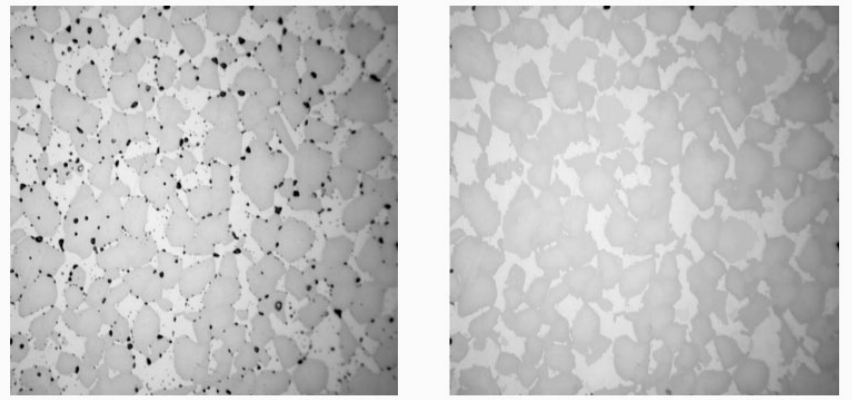
(From L–R): Auto-thresholded result for bright phase on the Barnett dataset. Regular erosion applied recursively five times with a kernel size of 5. Selective erosion applied five times recursively, three iterations each, with a threshold of 5.



(From L–R): Auto-thresholded result for bright phase on the Barnett dataset. Regular dilation applied recursively five times with a kernel size of 5. Selective dilation applied five times recursively, three iterations each, with a threshold of 5.

GRAYSCALE FILL HOLES

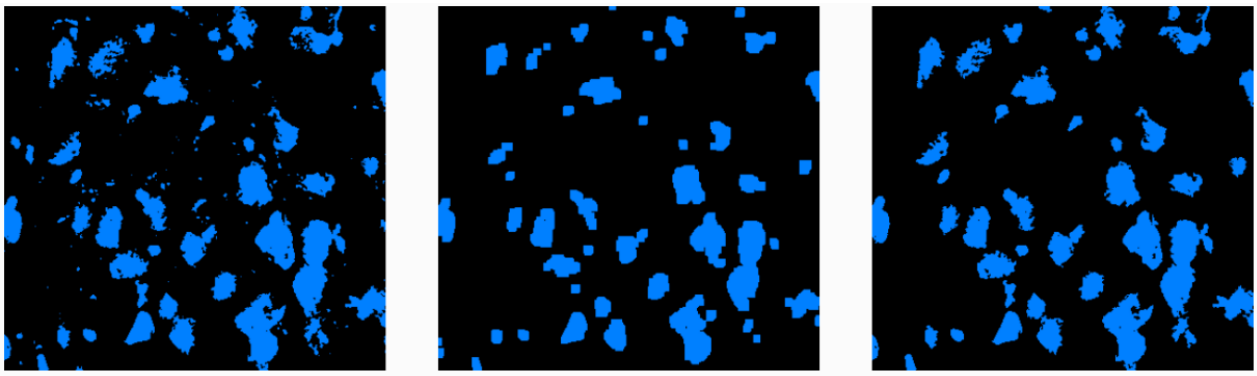
The Grayscale Fill Holes module fills darks areas that are not connected to the image borders with the maximal gray level surrounding them.



Original image, gray hole fill result (hole level = image maximum)

OPENING/CLOSING BY RECONSTRUCTION

An opening/closing by reconstruction consists of applying an erosion/dilation followed by a morphological reconstruction. Different structuring element geometry can be selected.



Binary input image, binary opening of size 3 and binary opening by reconstruction of size 3

REORDER LABELS

When a label image has some missing values in its histogram, it is not possible to automatically reassign some consecutive labels by using the Labelling module, which assigns a unique value to each connected component.

The Reorder Labels module fills the missing values of the histogram while preserving the original connectivity of the input labels.

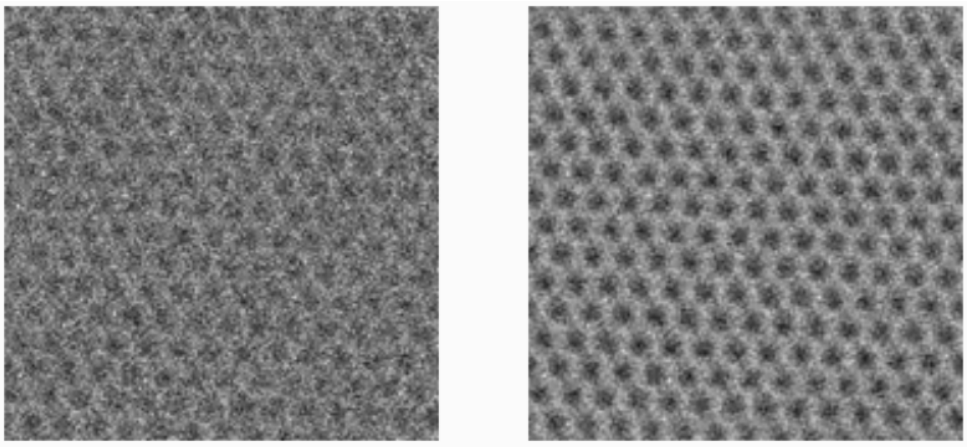
Input label image, output of the Labeling module and output of the Reorder Labels module

PRUNING

The Pruning module removes, from a 3D binary image, all object voxels having only one neighbor. It can be applied either by specifying a number of iterations or until convergence. This feature can be used for removing terminal branches from a skeleton.

RADIAL FREQUENCY FILTER

The Radial Frequency Filter module applies a radial background correction in the Fourier domain, then eliminates the high frequencies by applying a circular mask before reverting to the spatial domain. This filter is especially useful for highlighting periodic structures such as crystalline material in high-resolution electron microscope images.

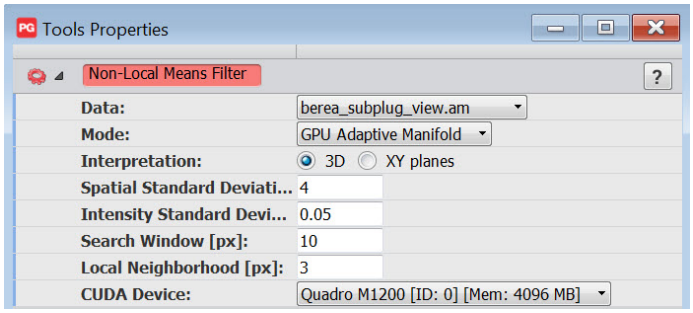


Input image and result of radial frequency filter

IMAGE PROCESSING: ENHANCED FEATURES

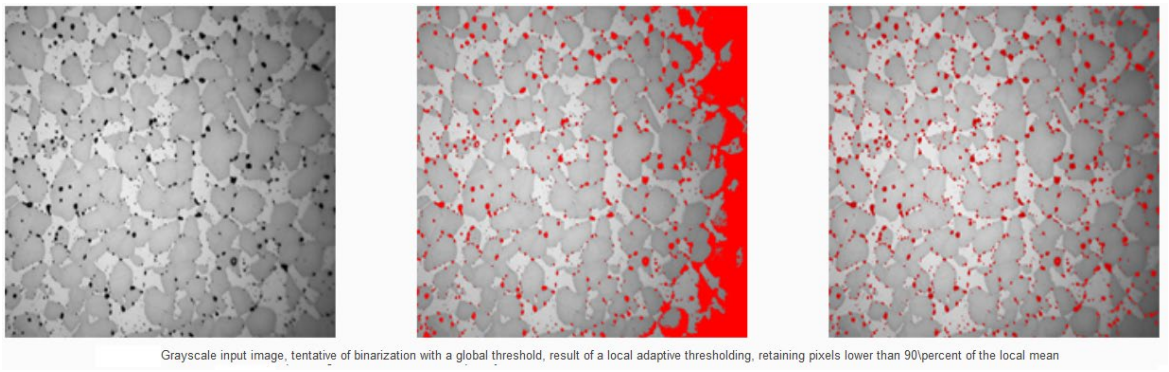
NON-LOCAL MEANS FILTER

The Non-Local Means Filter module has been enriched with a new GPU Adaptive Manifold mode, providing a substantial performance improvement, especially in 3D mode. A new CPU mode replaces the previous one. The prior GPU mode is still available.



ADAPTIVE THRESHOLDING

The Adaptive Thresholding module has been enhanced. This module performs a binarization by applying a threshold that is automatically adapted relative to the mean intensity of a sliding window. The former Adaptive Thresholding module has been renamed to **Feature Adaptive Thresholding**.

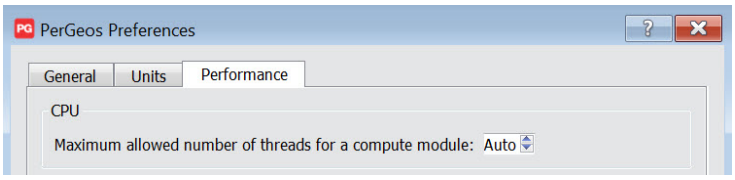


GAUSSIAN FILTER

The Gaussian Filter module has been reimplemented by replacing legacy algorithms with a separable Finite Impulse Response (FIR) filter and an Infinite Impulse Response (IIR) filter modes. Depending on kernel size, both new modes offer greatly improved performance.

SET NUMBER OF THREADS USED BY VISILOG

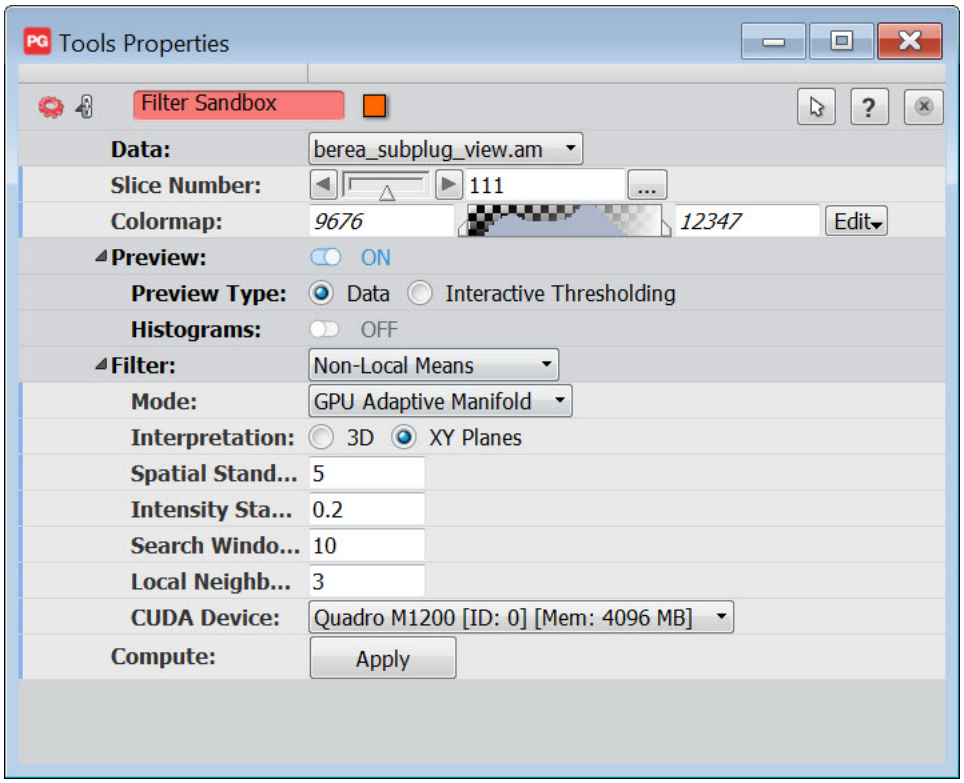
The underlying image processing library (Visilog) implements various multi-threaded algorithms. The number of threads can now be controlled by setting the preference in the Performance tab of the Preferences dialog. With previous versions, this preference was used only by certain modules that were outside the image processing library.



FILTER SANDBOX

The Filter Sandbox tool now uses the new GPU Adaptive manifold mode for the Non-Local Mean filter with significant performance improvements, especially in 3D mode, but which is potentially slower in 2D.

The ergonomics of this module has also been completely revamped in order to expose for each filter the same parametrization as the corresponding image filter module.



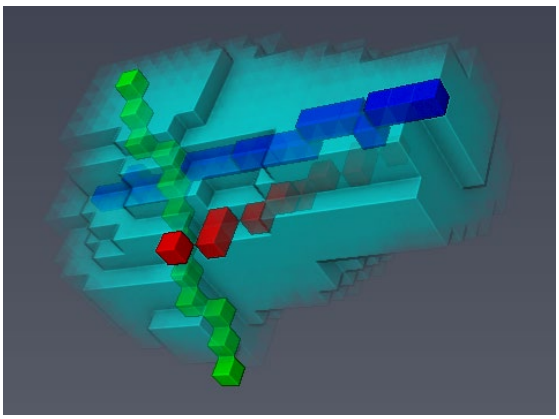
Projects saved prior to this version containing a Filter Sandbox will be reloaded in this version, but the old Filter Sandbox will be created. There will be error messages on reload of the old projects that you can ignore. The new Filter Sandbox tool can be replaced manually. In order to obtain a similar performance to the previously saved project, it is recommended that you set the Interpretation to 3D mode, which is faster in this version.

IMAGE ANALYSIS: NEW MEASUREMENTS

FERET MEASURES

The Length3d, Width3d, Breadth3d and Thickness3d measurements return specific axis lengths based on the Ferret diameters. In previous versions, it was impossible to visually control the locations of these axes. For each axis, six new measurements have been added in the Feret category. These measurements return the coordinates of the extremities of each axis. For instance:

- Length3dInputX, Length3dInputY, Length3dInputZ are the coordinates of the first end of the Length3d axis.
- Length3dOutputX, Length3dOutputY, Length3dOutputZ are the coordinates of the other end of the Length3d axis.

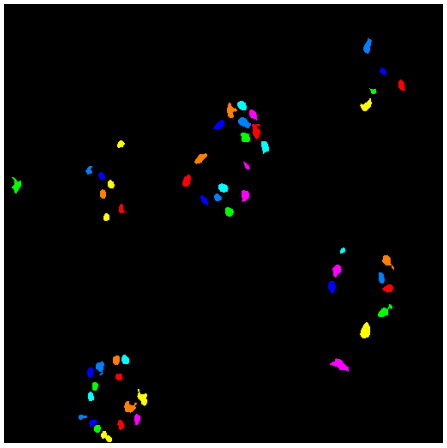


Representation of Length3d (blue), Breadth3d (green) and Thickness3d (red)

INTENSITYCOUNT

The new measurement, IntensityCount, returns the number of different gray levels in the intensity image associated with each object of the label image. It is particularly useful for counting the number of markers in an image under a mask defined in another image.

Input label image



Input intensity image

	IntensityCount
1	5
2	16
3	7
4	1
5	9
6	15

IntensityCount result

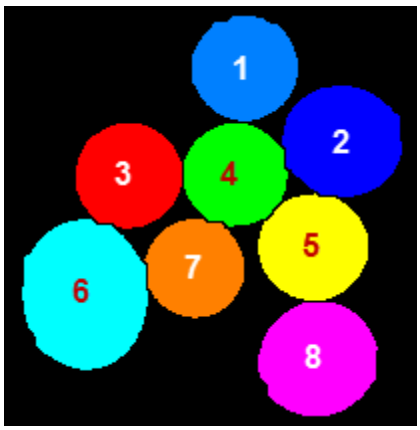
THICKNESS ORIENTATION PHI – THICKNESS ORIENTATION THETA

Angle Phi/Theta of the Thickness 3D diameter over a range of angles [0,+90].

NEIGHBOR COUNT

The new measurement NeighborCount returns the number of objects close to the current label. This measurement is useful for identifying particles belonging to a cluster. It has 3 attributes:

- Distance unit indicates if the cut-off distance is expressed in pixels (0) or in spatial unit (1). Default value is 0.
- Cut-off distance represents the distance to the current label boundaries where neighbors are searched. Default value is 5.
- Minimal overlap indicates the minimal percentage that should represent the volume overlapping the searched neighborhood to be counted as neighbor or not. Default value is 0, which means any neighbor having at least one voxel in the searched area is retained.



Input label image

	NeighborCount
1	1
2	2
3	2
4	5
5	3
6	2
7	2
8	1

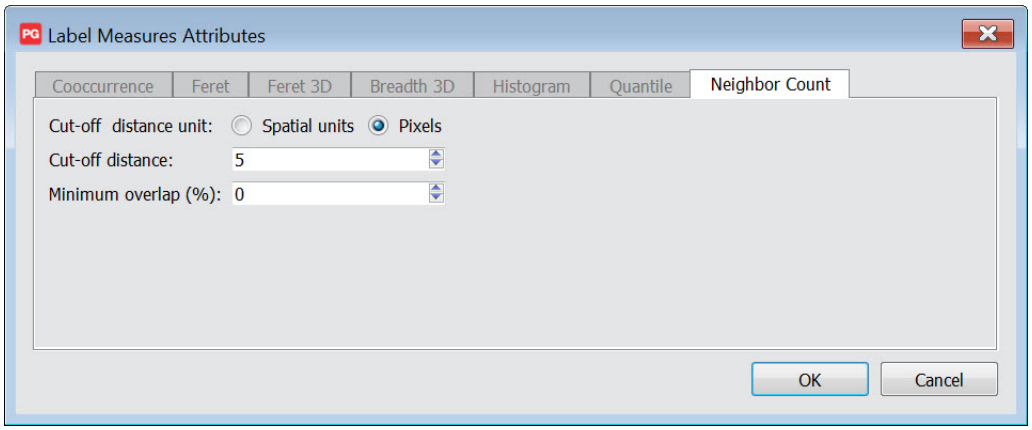
NeighborCount results with default parameters (distance = 5 pixels, overlap = 0%)

	NeighborCount
1	2
2	3
3	3
4	5
5	4
6	2
7	4
8	1

NeighborCount results with distance = 10 pixels, overlap = 0%

	NeighborCount
1	1
2	2
3	2
4	4
5	1
6	1
7	1
8	0

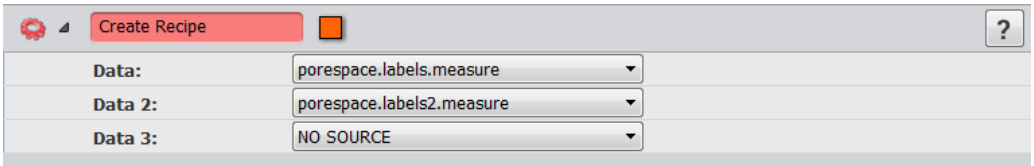
NeighborCount results with distance = 10 pixels, overlap = 5%



RECIPE ENHANCEMENTS AND NEW FEATURES

RECIPE FROM MULTIPLE OUTPUTS

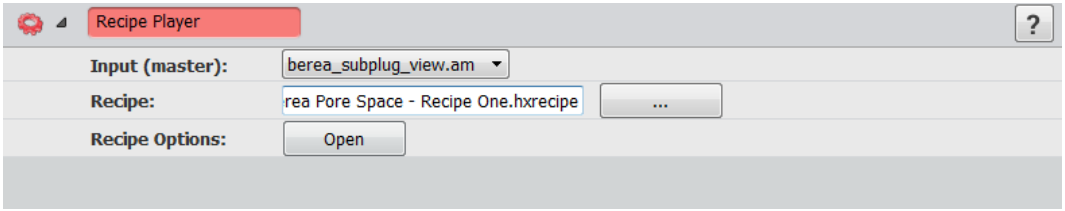
The functionality to create a recipe from multiple outputs is now available. A create recipe tool is introduced that enables you to provide multiple data files for generating a single recipe. You can now make a workflow with multiple output files, which may be generated through independent paths, into a single recipe, thus eliminating the need to run multiple recipes.



RECIPE INSIDE A RECIPE

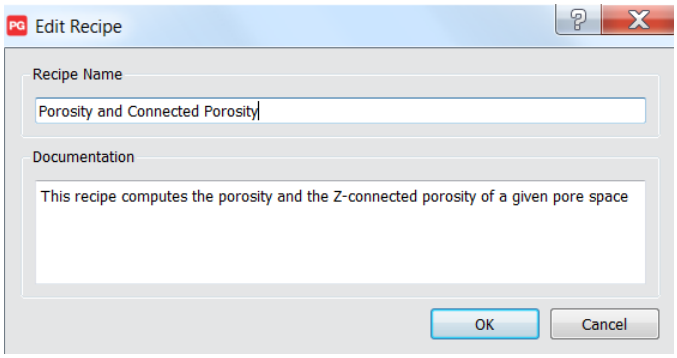
Complex digital rock analysis workflows consist of many of steps that can be bundled into multiple categories. Some of these subsets of the workflow are often repeated and can be re-used in other workflows. A recipe inside a recipe functionality is introduced that enables you to include a recipe as a step of a new recipe. When you run a recipe on a

dataset using the Recipe Player tool, and then you create a new recipe based on the resulting data, the original recipe is embedded as a step of the new recipe.



RECIPE DOCUMENTATION

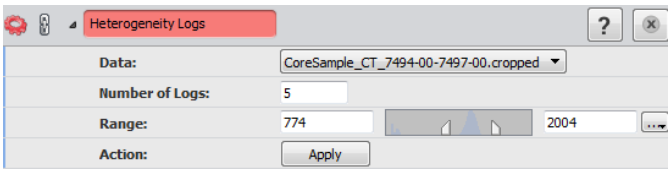
In the Recipes panel, a new functionality enables you to write a description of the recipe. This is triggered by clicking on the Edit Recipe button next to the name of the recipe. A new windows opens that allows you to write a description of the recipe.



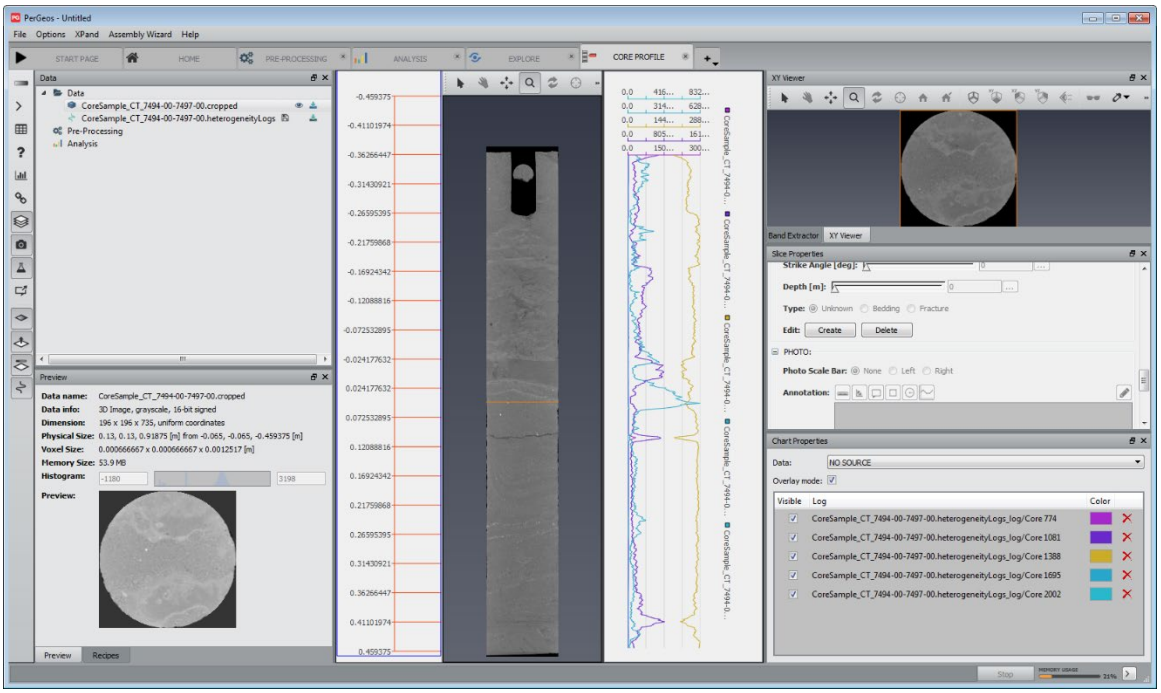
CORE PROFILE ENHANCEMENTS AND NEW FEATURES

HETEROGENEITY LOGS

The Heterogeneity Logs tool is introduced in this release. This tool generates a number of logs based on the intensity histogram of the input grayscale image. You can specify the number of logs to be generated.



The generated logs are loaded as a single data file and displayed in the Core Profile workspace. The variations in the logs provide an insight into the amount of heterogeneity in the core.



Heterogeneity logs are displayed alongside the CT image of the core in Core Profile.

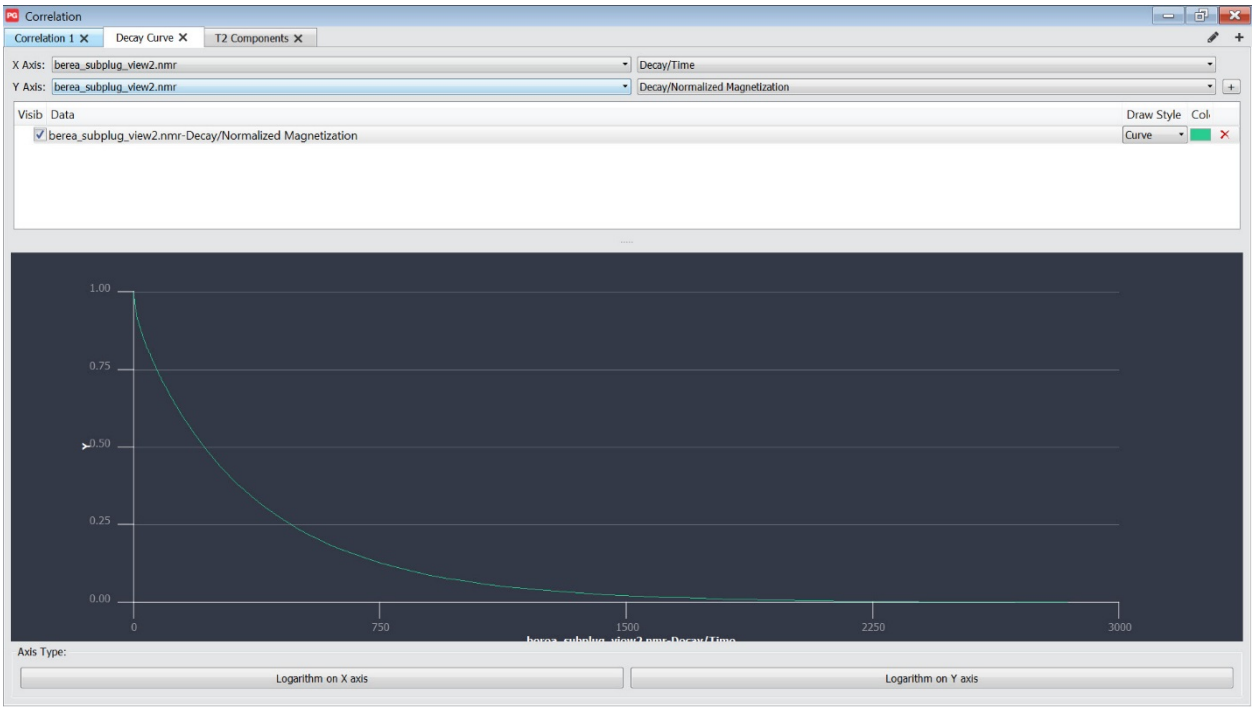
PETROPHYSICS ENHANCEMENTS AND NEW FEATURES

NUCLEAR MAGNETIC RESONANCE (NMR)

The NMR tool simulates the decay of the magnetic resonance of the nuclei of hydrogen-1 atoms of the fluids in the pore-space of the rock. It uses the random walk technique. A multi-phase segmented image of the rock is used as input. A label mapping section is available, where you can associate the labels with different materials. You can assign different relaxation strengths to the materials in the sample. The computation is done in parallel, and you can set the number of processors.

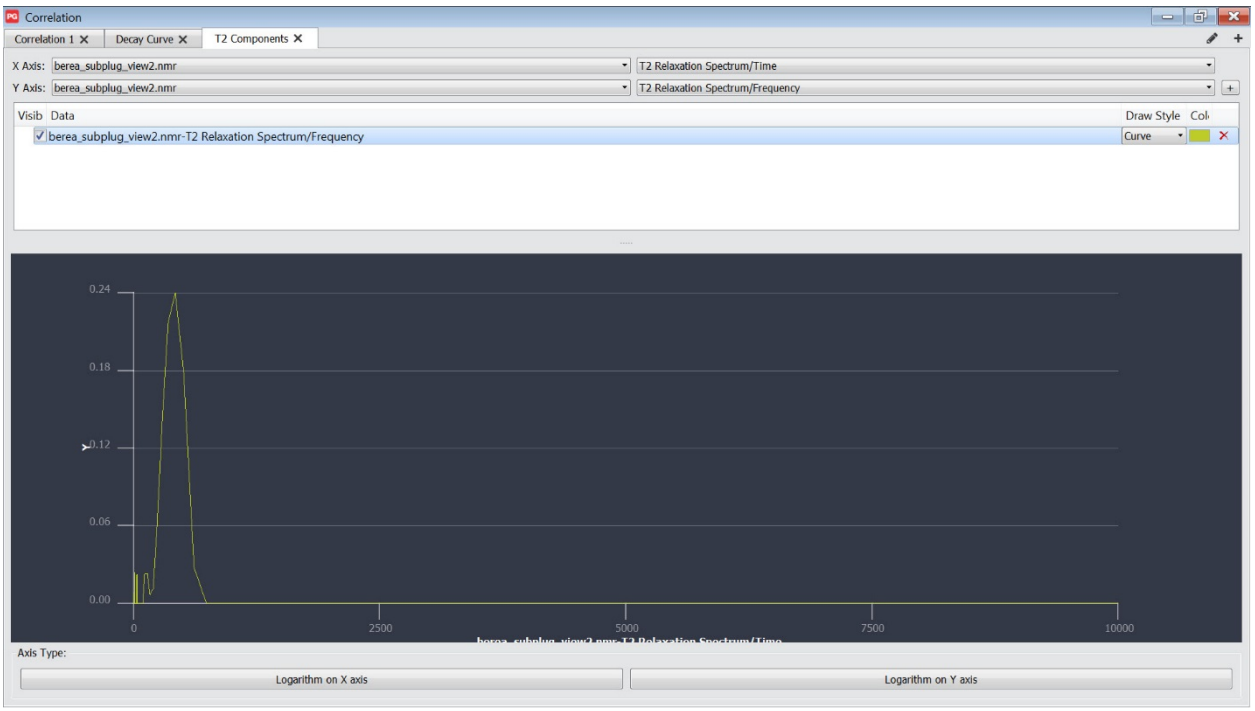
$$M(t) = \sum_i A_i \exp(-\frac{t}{T_i})$$ Sum of decaying exponential functions

The magnetization is calculated as a function of the relaxation time and is plotted in the Decay Curve. In addition, the sum of decaying exponential functions is used to characterize the magnetic relaxation data. As a result, the T2 relaxation spectrum is calculated, and its histogram is plotted.



Normalized magnetization as a function of relaxation time.

You can use the NMR tool to compare the results of magnetic relaxation against the NMR logs acquired in the lab or downhole in the field. The NMR tool also provides an alternative method for characterizing the behavior of the pore-size distribution of your rock without performing pore-separation and individual label measurements.



T2 relaxation histogram demonstrating a bi-modal distribution.

EXPERIMENTAL ENHANCEMENTS AND NEW FEATURES

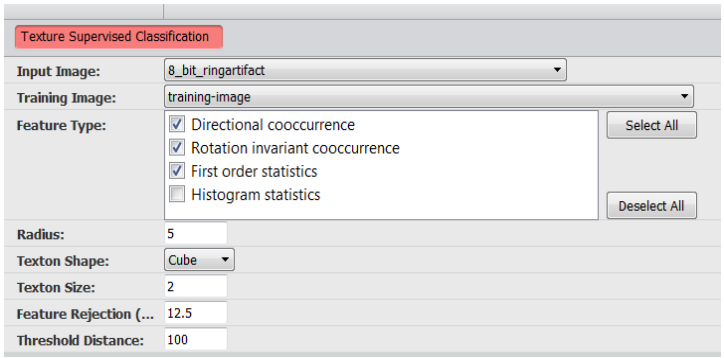
Experimental modules are made available upon request and are not part of the supported modules. They are provided as likely technology to be integrated in future versions of the application without any warranty of permanence. These modules have not reached productization standards and are available for testing purposes only.

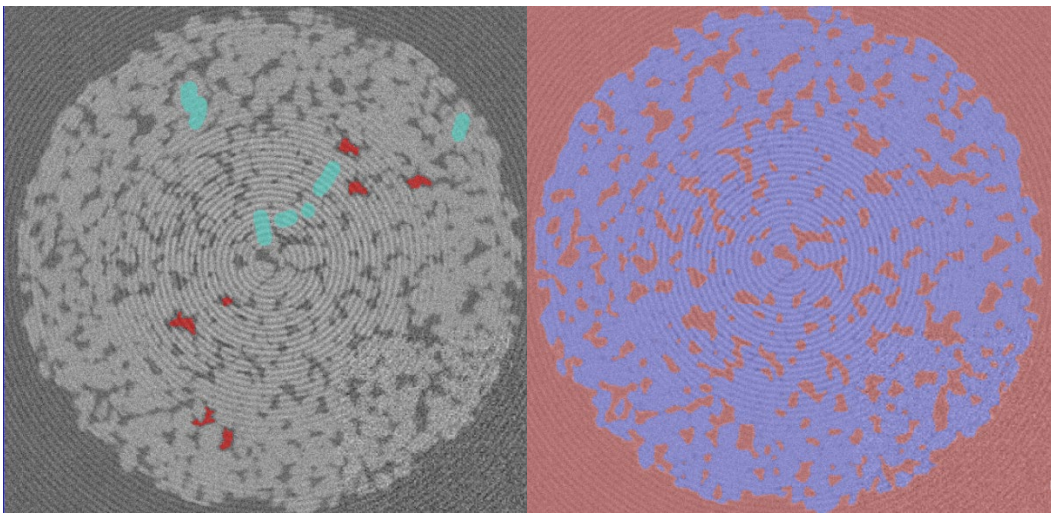
TEXTURE SUPERVISED CLASSIFICATION

From a grayscale image, a label image and a set of measures, this new experimental module computes a classification object and then performs supervised classification at the pixel level:

- Feature extraction
- Training
- Segmentation

This is an image segmentation tool intended for extracting phases based on textural information. This tool can be applied to segmentation workflows that require distinguishing materials with similar compositions but different spatial distributions. Examples of these types of materials include depositional features or structures compared to diagenetic features in images of mudrocks. Texture-based classification is also useful for segmenting phases based on data containing image acquisition artifacts.





Texture Supervised Classification tool used to segment pores and grain in a micro-CT image with sever ring artifacts. Image courtesy of Royal Dutch Shell (S*. Berg, N. Saxena, M. Schaik, C. Pradhan, Generation of Ground Truth Images to Validate Micro-CT Image Processing Pipelines, The Leading Edge 37(6), 412-420, 2018*.)

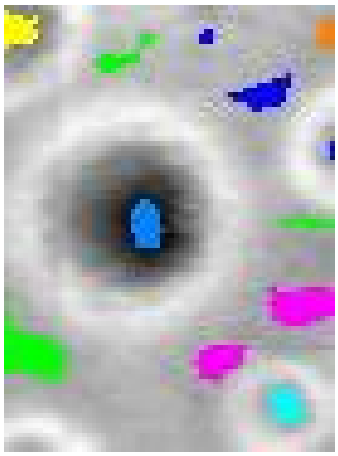
FUTURE DEPRECATIONS

This section documents the features that will be deprecated or removed from the next PerGeos Software version.

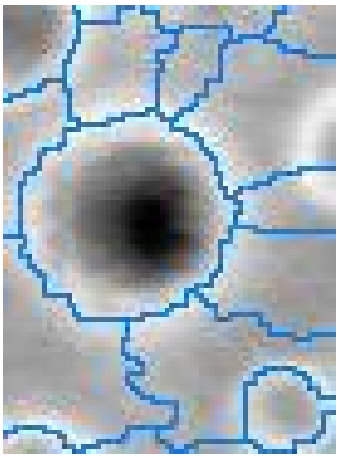
In PerGeos Software 1.0.1, the properties area had been redesigned and many tools ports had been modified. Projects created prior to PerGeos 1.0.1 using the modified ports could still be loaded in the following versions, raising warnings about the deprecated ports in the application console. Starting from the 2019.2 version, those deprecated ports will be removed. If you are still using projects saved prior to PerGeos Software 1.0.1 raising deprecated ports warnings, reload and save those projects in the current version to make them compatible with the 2019.2 version.

COMPATIBILITY NOTES

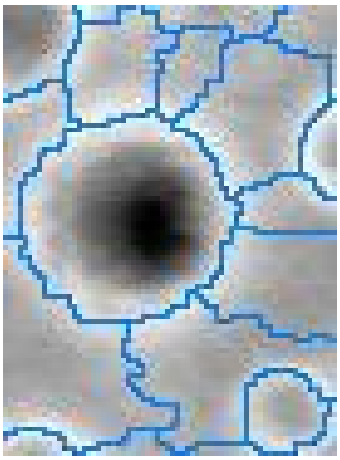
The default behavior of the watershed algorithm has been changed to consider markers located on the image bounding box. Consequently, the results of the following tools will change when using markers being only made up of pixels on image borders: Marker-Based Watershed, Separate Objects, Watershed Segmentation.



Input image and markers



Former watershed result



New watershed result

gcc 4.4.x and Red Hat Enterprise Linux 6 are no longer supported. Supported Linux distribution is Red Hat Enterprise Linux 7 with gcc 4.8.x.

OPERATING SYSTEMS

PerGeos Software 2019.1 runs on:

- Microsoft Windows 7/8/10 (64-bit).
- Linux x86 64 (64-bit). Supported 64-bit architecture is Intel64/AMD64 architecture. Supported Linux distribution is Red Hat Enterprise Linux 7.

In order to add custom extensions with PerGeos Software XPand, you will need:

- Microsoft Visual Studio 2013 (VC12) Update 4 on Windows
- gcc 4.8.x on Red Hat Enterprise Linux 7

SOLVED ISSUES

PerGeos Software 2019.1 release provides various enhancements and solutions to known problems, including:

Filter Sandbox	**66559**	**In the Filter Sandbox module, when using the Anisotropic Diffusion Filter, the initialization of the Diffusion Stop Threshold parameter has been improved.**
Non-Local Means Filter	63622	The Non-Local Means Filter module has been enriched with a new GPU Adaptive Manifold mode with a huge performance improvement, especially in 3D mode
Pore Network Model	72200	Limitation of PNM functionality documentation updated.
Stereo	59489	Using 2 Volume rendering in Red/Cyan stereo mode could generate an incorrect output; this has been fixed.

Our team is focused on solving as many issues as possible to make your experience using PerGeos Software as satisfactory as possible. We would appreciate your feedback regarding this version. If you encounter problems or have suggestions for improvement, please report them to FRBOR.3d_hotline@thermofisher.com.