DRAGONFLY RELEASE NOTES

VERSION 4.0

ORS | OBJECT RESEARCH SYSTEMS

Title	Dragonfly Release Notes
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Release Notes
Version 4.0

This document describes the new features, product enhancements, and other improvements implemented in the Dragonfly and Dragonfly Pro 4.0 software release. You should read these release notes carefully before you install this new version.

Object Research Systems

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New Features

The 4.0 software release for Dragonfly and Dragonfly Pro provides the following new features. For information about deep learning enhancements — as well as improvements for registering datasets, sampling, creating animations, and other changes — see Product Enhancements on page 49.

Official Linux Release

This software release marks the official release of the Linux versions for Dragonfly and Dragonfly Pro.

Dragonfly Organizer

Dragonfly's new Organizer provides an easy way to organize, manage, and share your data and analysis results. The Organizer is equipped with drag-and-drop features so that you can readily add objects — such as image data, regions of interest, multi-ROIs, meshes, screen captures, session files, and more — to a project.

Dragonfly Organizer dialog
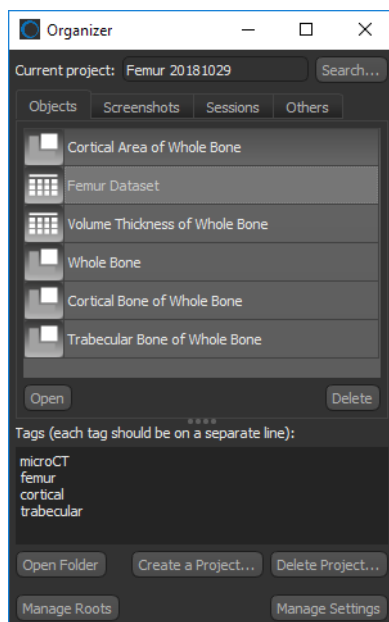
With Dragonfly's new Organizer you can:

- Organize data in a variety of ways, add tags to a project and saved objects for easy searching, as well as move, rename, merge, and delete projects.
- Create root folders that can hold multiple project folders.
- Search local drives and remote servers for matching tags and data types, or by date.
- Protect your private data while sharing your public projects with other users.

NOTE The Organizer is a separately licensed feature for Dragonfly. Contact Object Research Systems to request pricing for this module and availability.

Bone Analysis

The Bone Analysis module for Dragonfly 4.0 lets you discover new productivity for your bone image analysis needs. With the unique pairing of robust quantification with options to map and analyze trabecular anisotropy by orientation, Dragonfly's Bone Analysis module lets you better understand complex metabolic bone diseases to help develop new therapies and treatments. The benefits of Bone Analysis include the following:

• Computation of common bone morphometric measurements, as described by *Bouxsein et al.* 2010. JBMR 25(7):1468-86, from segmented bone regions that provide quantitative descriptions of bone microarchitecture.

• Computation of anisotropy with surface orientation of trabecular bone.

• Mapping of orientation and value — from a mesh and from an ROI — colorized according to the orientation of the vectors.

NOTE Bone Analysis is a separately licensed feature for Dragonfly 4.0. Contact Object Research Systems to request pricing for this module and availability.

Bone Analysis results
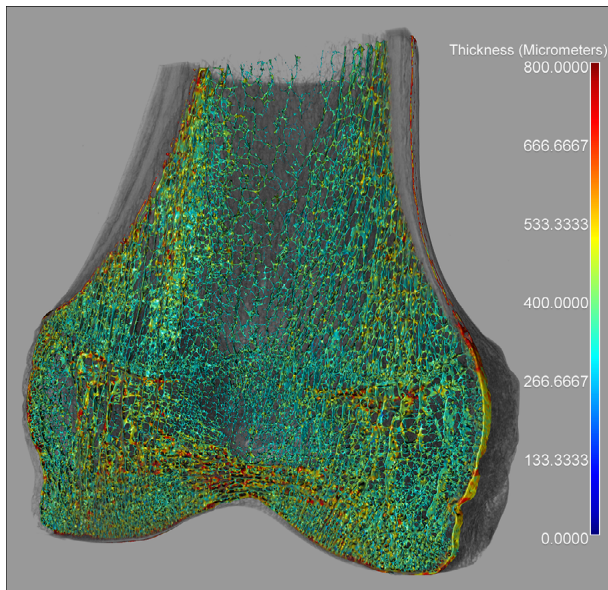
Mapping of trabecular bone thickness
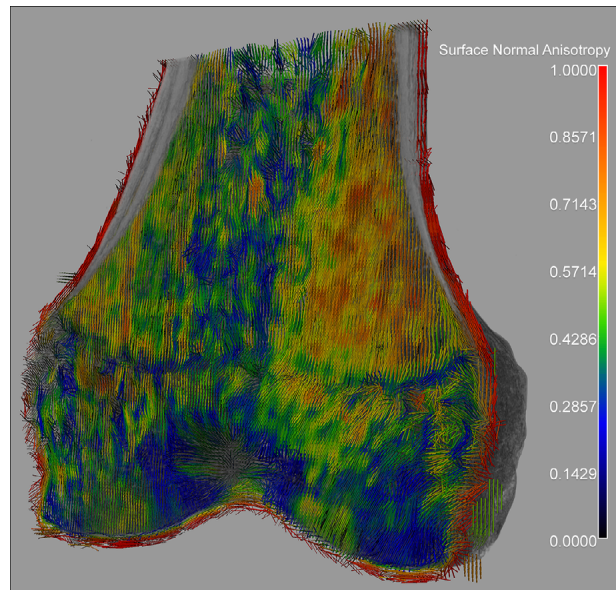
Mapping of surface normal anisotropy

NOTE The Bone Analysis module is a pre-clinical research application designed to facilitate the analysis of high-resolution micro–computed tomography (micro-CT) images. You should note that currently available micro-CT scanners can achieve an isotropic voxel size of as low as a few micrometers, which should be sufficient for investigating structures such as mouse trabeculae that have widths of approximately 30 to 50 micrometers. You should also note that measurement error will decrease as the ratio of voxel size to object size decreases, regardless of scale.

Dragonfly's Bone Analysis module can separately segment and identify cortical and trabecular bone in whole-bone specimens. The calculation of common bone morphometric measurements from these segmented regions then provide quantitative descriptions of bone microarchitecture.

To start an analysis, choose **Bone Analysis** in the Tools menu. Automated segmented routines, cortical and trabecular measurements, as well as mappings of anisotropy, are available in the Bone Analysis dialog shown in the following screen capture.

Bone Analysis dialog
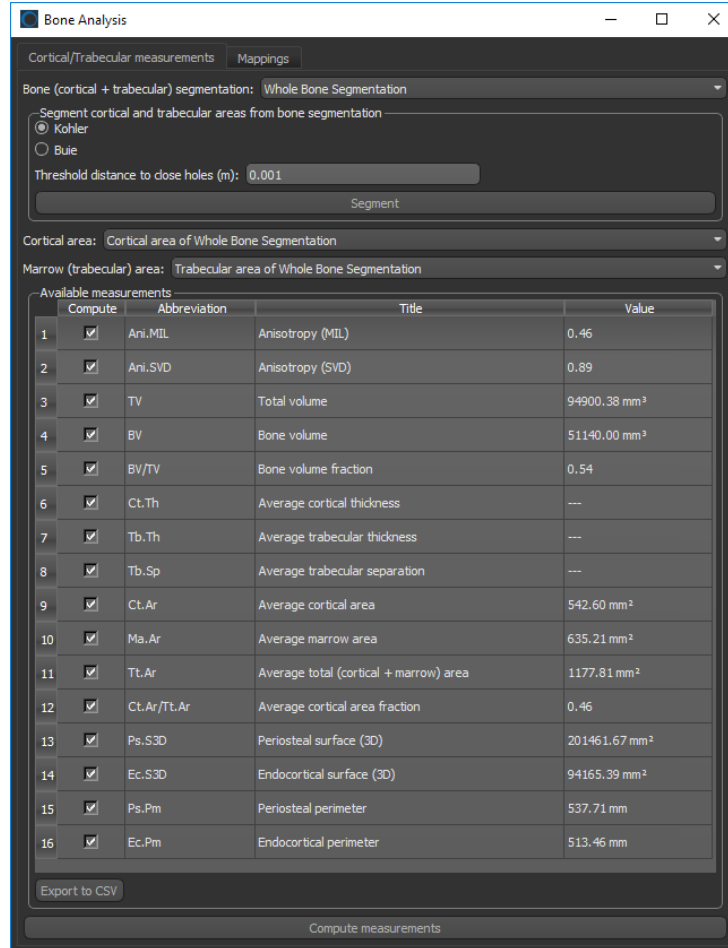
Global measurements for segmented cortical and trabecular areas

Abbreviation	Measurement	Description
Ani.MIL	Anisotropy (MIL)*	A measurement of the orientation of trabecular architecture that uses the mean intercept length (MIL) method.
		The MIL method (Whitehouse, 1974; Harrigan and Mann, 1984; Cowin, 1986) uses the mean distance between material intersections (bone–marrow interfaces) along linear traverses over a range of orientations. Because MIL traverses cross both materials, the result is a combined measure that incorporates features of both materials.

Abbreviation	Measurement	Description
Ani.SVD	Anisotropy (SVD)*	A measurement of the orientation of trabecular architecture that uses the star volume distribution (SVD) method (Cruz-Orive et al.,1992; Karlsson & Cruz-Orive, 1993).
		In this method, the distribution is determined by placing a series of points within the material of interest, and measuring the lengths of the lines emanating from them in various directions until they encounter a boundary. These lines are considered infinitesimal cones, with their vertex at the origin and subtending a solid angle as they approach the material interface.
TV	Total volume	Volume of the entire region of interest.
BV	Bone volume	Volume of the region segmented as bone, calculated in the same manner as TV.
BV/TV	Bone volume fraction	Ratio of the segmented bone volume to the total volume of the region of interest.
Ct.Th	Average cortical thickness**	Mean thickness of cortical bone.
Tb.Th	Average trabecular thickness**	Mean thickness of trabeculae.
		Calculated by fitting maximal spheres within the trabecular structure. The diameters of the spheres within the bone and the marrow regions provide estimates of Tb.Th and Tb.Sp.
Tb.Sp	Average trabecular separation**	Mean distance between trabeculae.
Ct.Ar	Average cortical area	Cortical bone area, computed as:
		cortical volume (Ct.V) / (number of slices x slice thickness).
Ma.Ar	Average marrow area	Medullary (or marrow) area.
Tt.Ar	Average total area (cortical + marrow)	Total cross-sectional area inside the periosteal envelope.
Ct.Ar/Tt.Ar	Average cortical area fraction	Cortical area fraction.
Ps.S3D	Periosteal surface (3D)	Total surface area of the periosteum, which is the membrane that lines the outer surface of all bones, except at the joints of long bones.
Ec.S3D	Endocortical surface (3D)	Total surface area of the endocortex, which lines the inner surface of all bones.
Ps.Pm	Periosteal perimeter	Total perimeter of the periosteum.
Ec.Pm	Endocortical perimeter	Total perimeter of the endocortex.

* The orientation of trabecular architecture can affect mechanical behavior and is often associated with disease and aging.

** Assessed using direct 3D methods.

In addition to the global parameters available in the Bone Analysis dialog for volumes, areas, and perimeters, per slice measurements in any oblique for segmented cortical and trabecular areas are available in the Slice Analysis panel, as shown below.

Slice Analysis panel
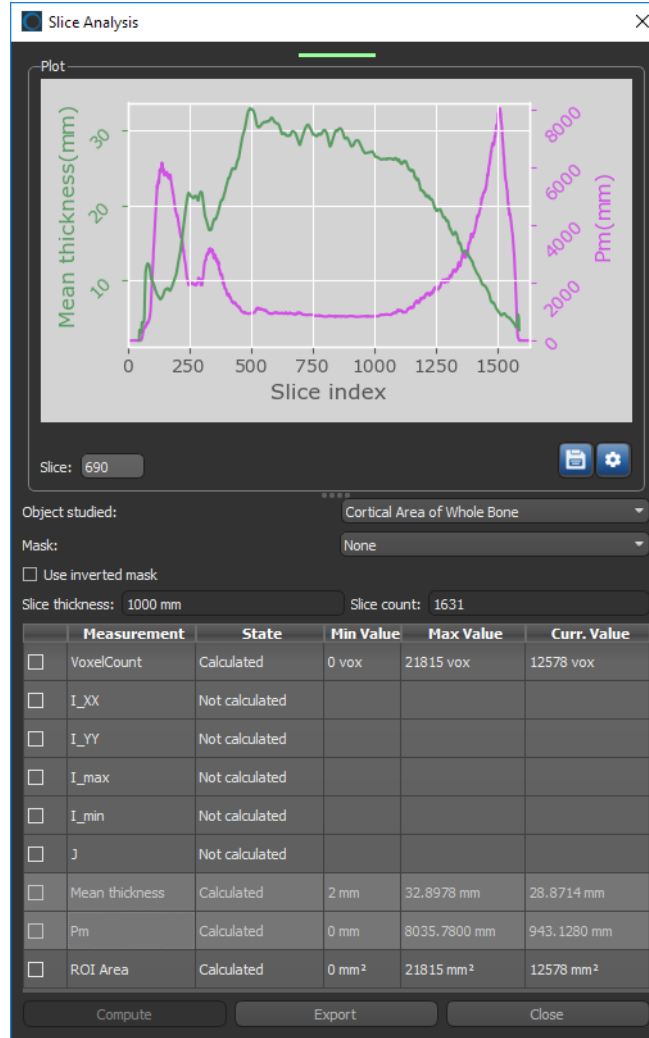
Per slice measurements for segmented cortical and trabecular areas

Abbreviation	Measurement
Voxel Count	Number of voxels contained in the selected region of interest.
I_{XX}	Moment of inertia (XX).
I_{YY}	Moment of inertia (YY).
I_{max}	Maximum moment of inertia.
I_{min}	Minimum moment of inertia.
J	Polar moment of inertia.
Th	Mean thickness.
Pm	Perimeter.
ROI Area	Area of the labeled voxels contained in the selected region of interest.

Image Stitching

Dragonfly's powerful new Image Stitcher provides automated and manual alignments to precisely combine, or *stitch*, overlapping 2D or 3D image tiles to create a single high-resolution image. The coordinates of the tiles in a dataset can be taken directly from a configuration file or a grid layout can be selected in the Layout Editor to position the tiles in the Stitching workspace. However, the real advantage of Dragonfly's Image Stitcher can be found in the automated alignment methods that can correct both systematic and non-systematic collection errors.

NOTE The Image Stitcher is a separately licensed feature for Dragonfly and is currently available as *beta* for evaluation purposes. Contact Object Research Systems to request pricing for this module and availability.

Right-click the dataset with the image files that you need to stitch in the Data Properties and Settings panel and then choose **Image Stitching** in the pop-up menu to open the Stitching contextual window, shown below.

Stitching window
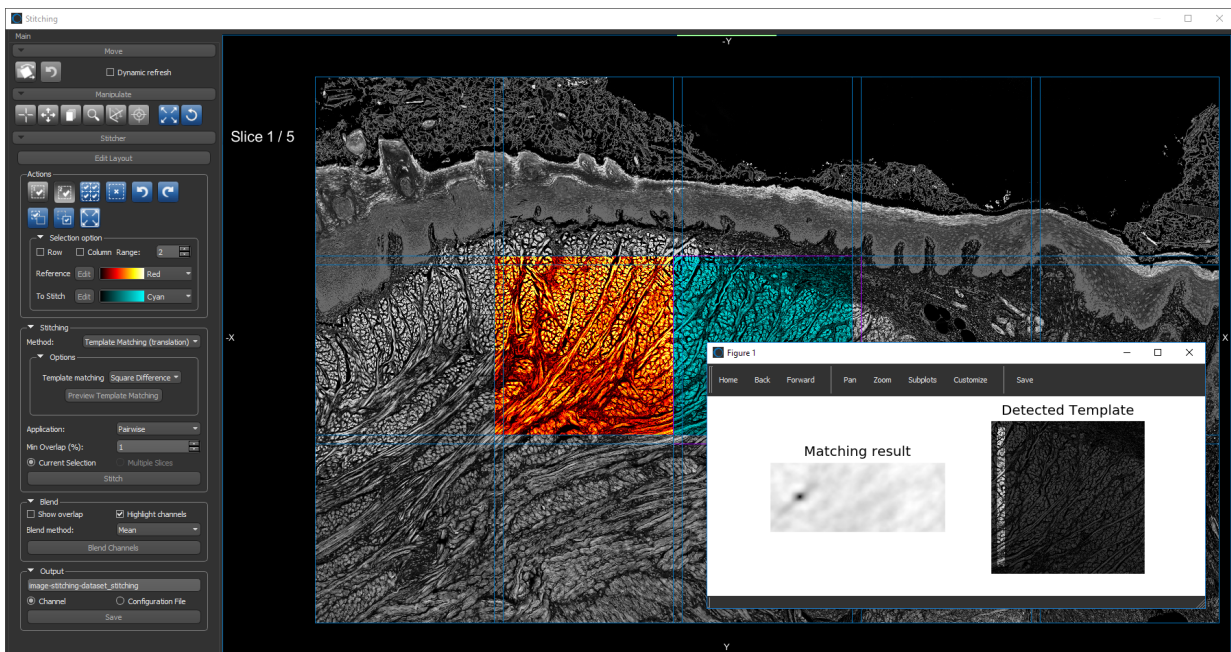
The workspace contains a view of the image tiles arranged in the selected grid layout. You can apply different LUTs to your *Reference* and *To Stitch* selections, as well as outline the images that are contained within the mosaic.

Stitcher panel... Options and controls for automatically and manually aligning overlapping 2D and 3D tiled images and stitching the result into a single high-resolution image are available in the Stitcher panel. Additional options let you blend overlapping regions to create a seamless result, as well as to save a configuration file of the coordinates of each image tile in the stitched result.

Stitcher panel
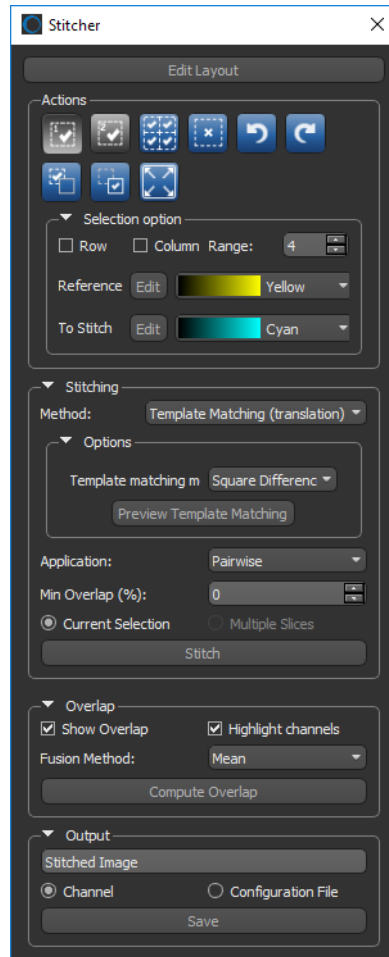
NOTE You can also translate and rotate the currently selected image tile(s) with the Translate and Rotate tools to position image tiles within a mosaic.

Preview windows... Preview windows are available for evaluating the Feature Base and Template Matching methods. You can pan, zoom, and customize the window, as well as save the figure. The example below illustrates how the best matches within two overlapping images are mapped to each other in the Feature Base preview window.

Feature Base preview window
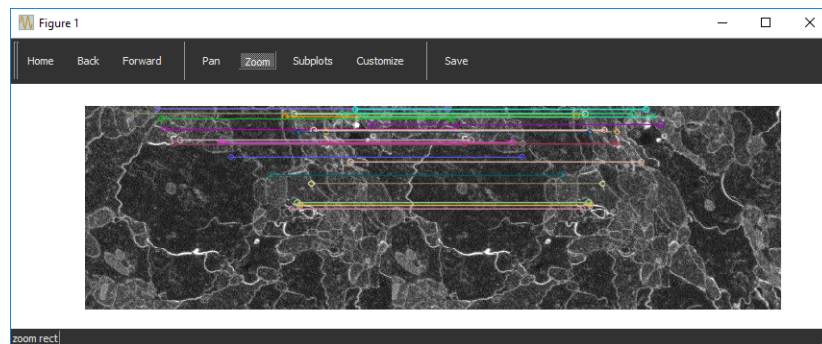
Stitch 3D Datasets

The new Stitch 3D Datasets feature lets you combine, or *stitch*, multiple volumetric datasets into a single 3D dataset. Select one or more of the datasets you plan to stitch in the Data Properties and Settings panel, right-click, and then choose **Stitch 3D Datasets** in the pop-up menu to open the Stitch 3D Datasets dialog, shown below.

Stitch 3D Datasets dialog
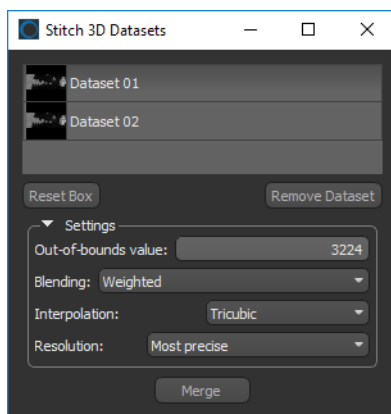
The options for stitching let you assign data values to voxels that are *out-of-bounds*, as well as choose a blending method, interpolation type, and resolution for the output. The dimensions of the stitched dataset can be constrained to the referenced box.

Create 4D Datasets

You can create a 4D, or *time-enabled*, dataset from multiple volumetric datasets with the new Create 4D Dataset feature. Select one or more of the datasets you plan to include in your new 4D dataset, right-click, and then choose **Create 4D Dataset** in the pop-up menu to open the Create 4D Dataset dialog, shown below.

Create 4D Dataset dialog
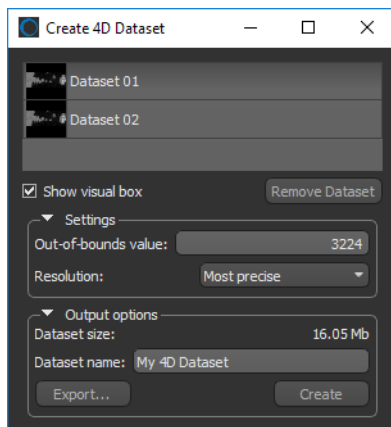
The options in the Create 4D Dataset dialog let you assign data values to voxels that are *out-of-bounds*, as well as to choose a target resolution for the output. The dimensions of the 4D dataset can be constrained to the referenced box.

TM021-A-05

Macro Builder

This Dragonfly release adds a new Macro Builder that provides an intuitive, visual way to build and edit complex macros or to combine multiple macros for batching. Based on Google's Blockly, which uses interlocking, graphical blocks to represent code concepts like variables, logical expressions, iterations, and more, the Macro Builder lets you apply programming principles without having to worry about syntax or the intimidation of a blinking cursor on the command line.

Macro Builder
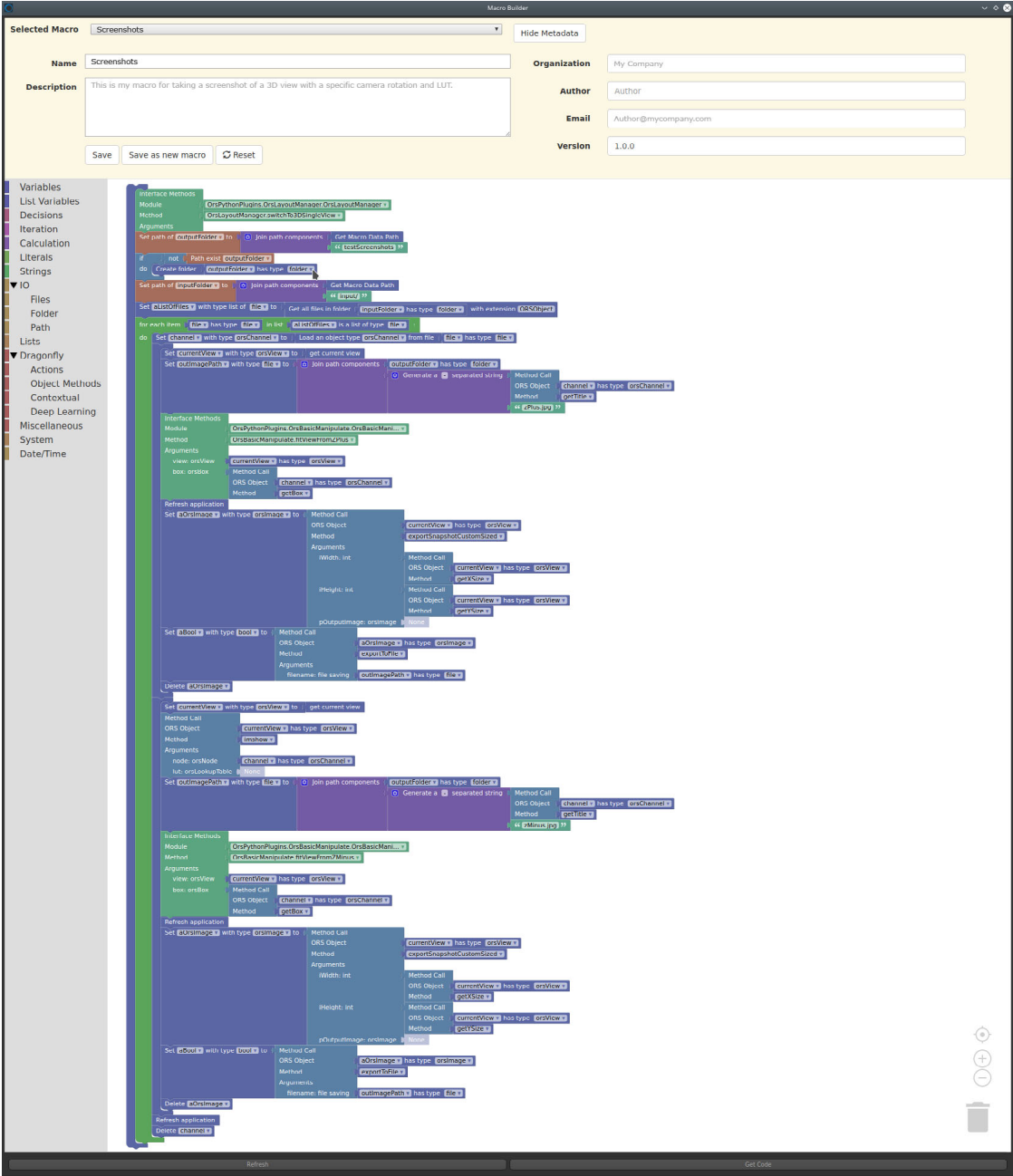
Hyper-Dimensional Imaging

This release introduces a beta version of Dragonfly's *Hyper-Dimensional Imaging* module that facilitates the interactive visualization, manipulation, and data analysis of multi-dimensional datasets. You can exploit the multi-dimensionality of a dataset — with the goal of finding objects, identifying materials, and detecting processes — by applying dedicated analytical tools that operate on individual signals.

Choose **Tools > HyperChannel Manager** on the menu bar to open the Hyper Channel tab on the left sidebar.

Visualization of multi-dimensional image
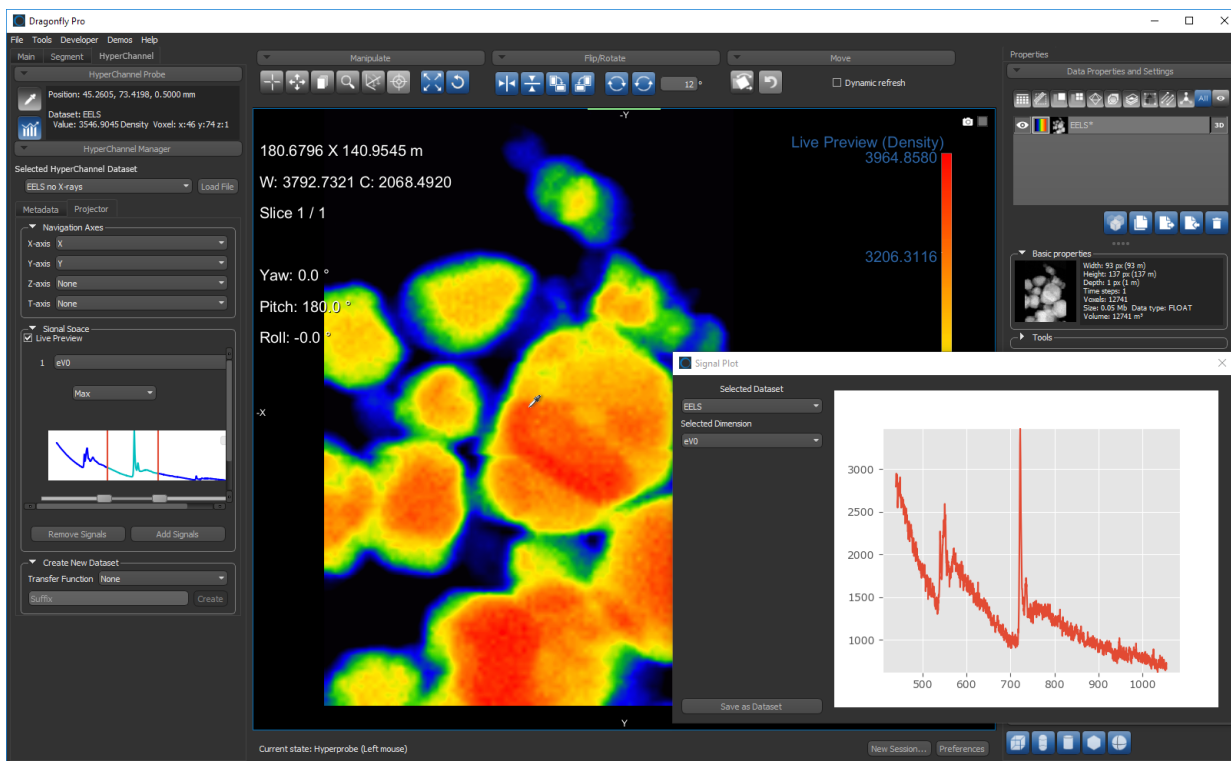
Plugin Toolbar

The new Plugin Toolbar, shown below, lets you quickly access any of the available Dragonfly plugins — such as the Organizer, Bone Analysis, Deep Learning, and Active Contour modules, as well as the Infinite Toolbox. The Plugin Toolbar is available by default on the left sidebar.

Plugin Toolbar panel
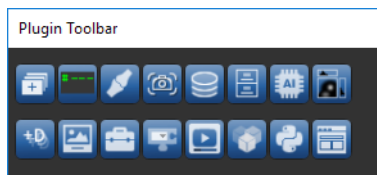
Feret Diameter Measurements

This software release includes Feret diameter measurements for regions of interest, multi-ROIs, and meshes. The measurements of the minimum, mean, and maximum Feret diameters are available in the Statistical properties and Information boxes on the Data Properties and Settings panel for regions of interest and meshes and in the Object Analysis dialog for multi-ROIs.

Feret Diameters Definition

The Feret diameter, or Feret's diameter, is a measure of an object's size in an arbitrary direction. This measurement, which can be defined as the distance between the two parallel planes restricting the object perpendicular to that direction, is also sometimes called the caliper diameter as it can refer to the measurement of object size with a caliper. This measure is often used in the analysis of particle sizes in microscopy, where the minimum Feret diameter can be used as the equivalent diameter in a sieve analysis.

Feret diameters computed for a multi-ROI and filtered in the Measurement Inspector
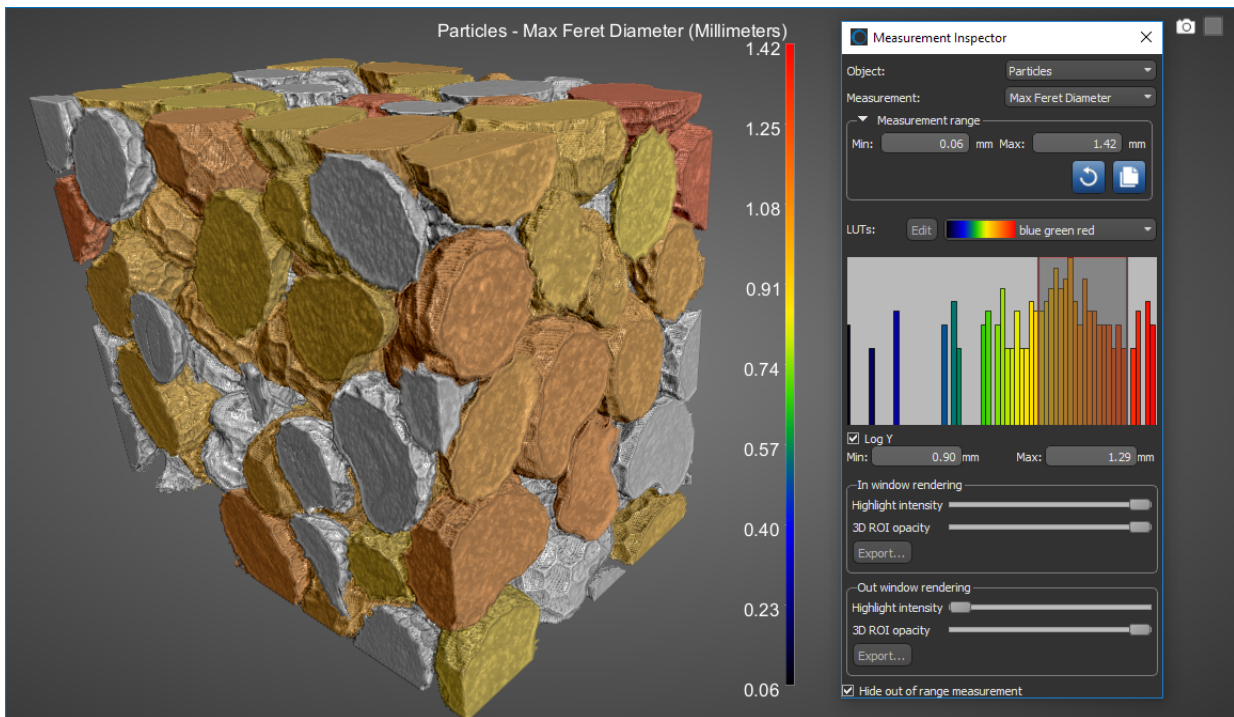
Min Feret diameter... The shortest distance between any two points along the object boundary at an arbitrary angle, also known as minimum caliper diameter.

Mean Feret diameter... The mean value of the Feret diameters over a sufficient number of orientations. In Dragonfly, measurements for the mean Feret diameter are taken every 5 degrees.

Max Feret diameter... The longest distance between any two points along the object boundary at an arbitrary angle, also known as maximum caliper diameter.

Feret Diameter Measurements for ROIs and Meshes

Feret diameter measurements for ROIs and meshes are available in the Statistical properties and Information boxes on the Data Properties and Settings panel, respectively. Click the **Compute Feret Diameter** button in the Statistical properties box to compute Feret lengths for a selected region of interest. For meshes, check the **Feret diameter** option in the Information box and then click the **Refresh** button.

Feret diameter measurements for ROIs and meshes

Statistical properties for ROIs

Information for meshes

Feret Diameter Measurements for Multi-ROIs

Feret diameter measurements for all connected components in a multi-ROI, which can examined in table and histogram views, are available as a selectable statistical property (see Statistical Properties on page 34).

Feret diameter measurements for multi-ROIs

New Image Filters

The following new filters are available in this software release for processing image data and for training deep learning models and classifiers for trainable segmentation.

Artifact Removal

Vertical, horizontal, and arbitrary angle destriping filters are available in Dragonfly 4.0 for cases in which striped artifacts appear on images. The destriping filters work by adding a pattern that interferes with the image to remove stripes, as shown in the example below for vertical destriping.

Original data (left) and preview after vertical destriping (right)
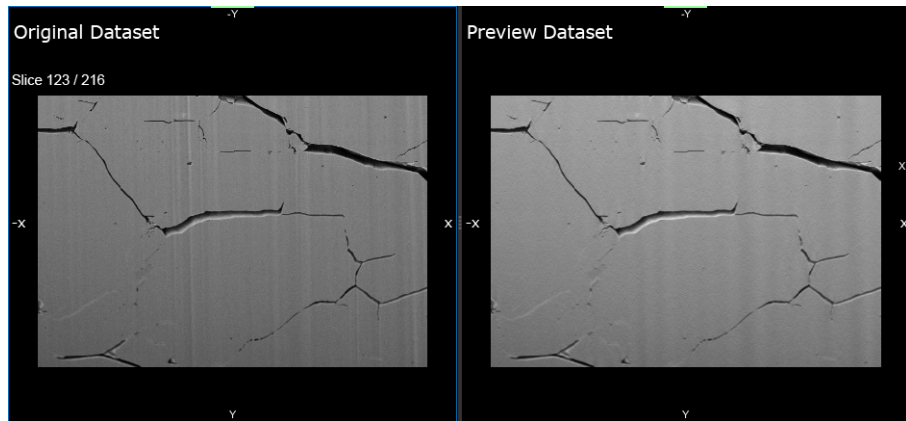
NOTE Striping can be caused by opaque or scattering parts of a sample that block part of the illumination beam during acquisition.

Comprehensive

This software release features the option to process image data directly in the Image Processing toolbox with deep learning models trained for tasks such as denoising, segmentation, and image enhancement. You should note that a selection of trained and untrained deep learning models are available for download in the Infinite Toolbox (https://infinitetoolbox.theobjects.com/). You will need to download at least one model before you can access the comprehensive filters.

Original data (left) and after denoising with comprehensive filtering
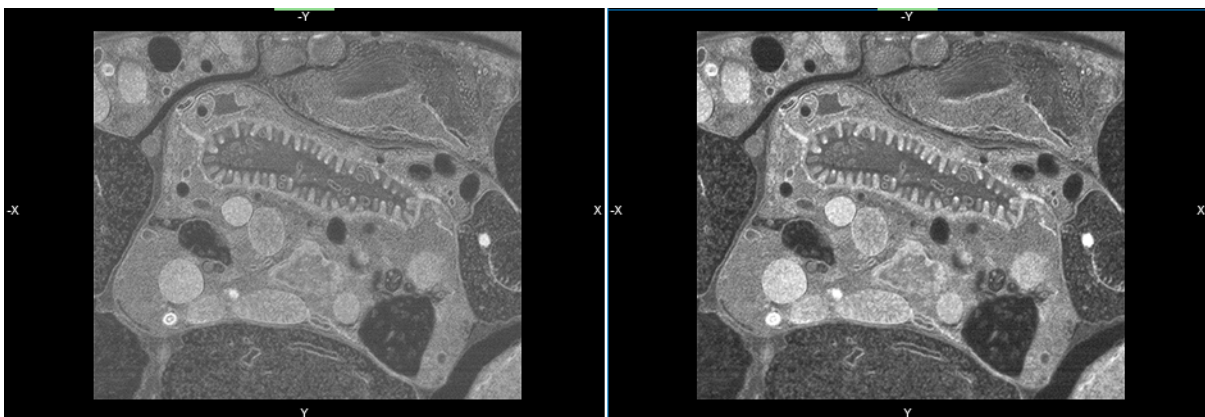
TM021-A-05

Original data (left) and after membrane detection with comprehensive filtering
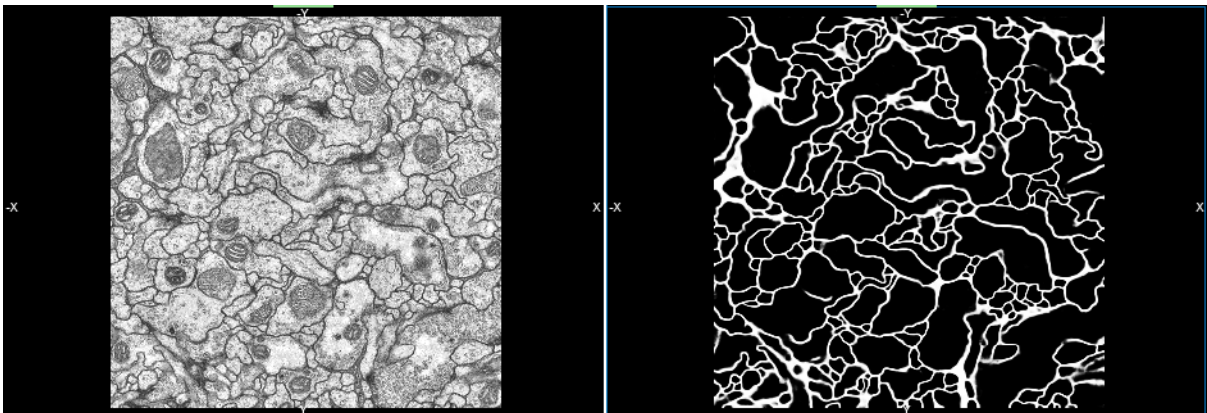
Original data (left) and after segmentation with comprehensive filtering
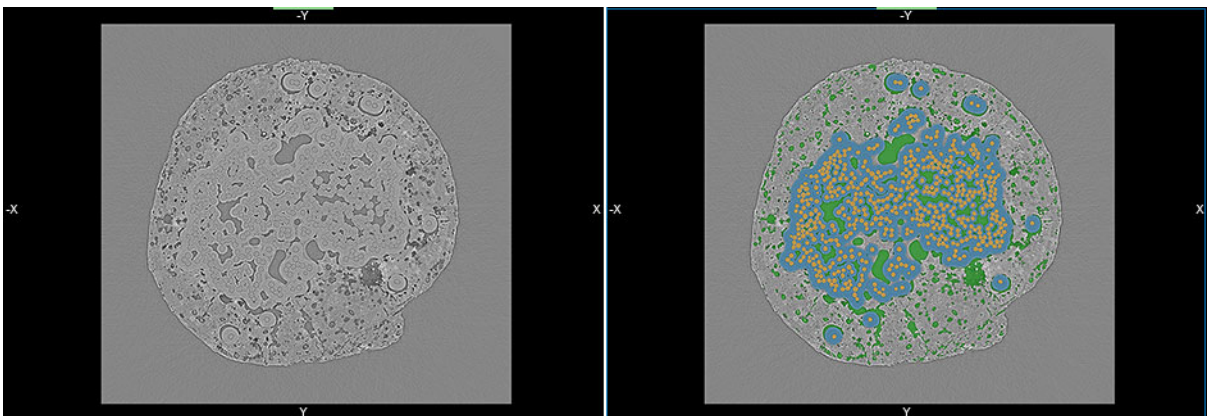
You should note that downloaded models, as well as models that you created and trained for processing image data, are available in the Options box of the Image Processing panel, circled below, when you choose either **Deep Learning** or **Deep Learning Denoiser** as a comprehensive filter.

Options for Deep Learning filters
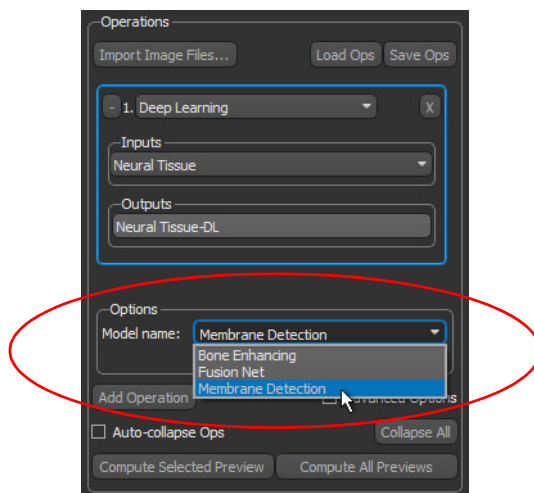
NOTE Deep Learning Denoising requires two inputs — the original data that you need to process and a variation of the original data that was processed with a comparable smoothing filter, such as a Gaussian or mean filter.
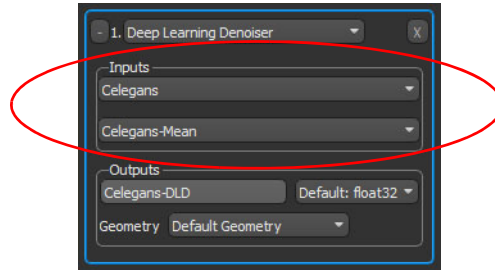
You should also note that the second input must be the same shape as the first.

Segmentation

A number of new image segmentation filters — *K-Means* and *Mini-Batch K-Means* — are available in this software release to partition images into meaningful regions.

Original data (left) and preview after K-Means clustering (right)
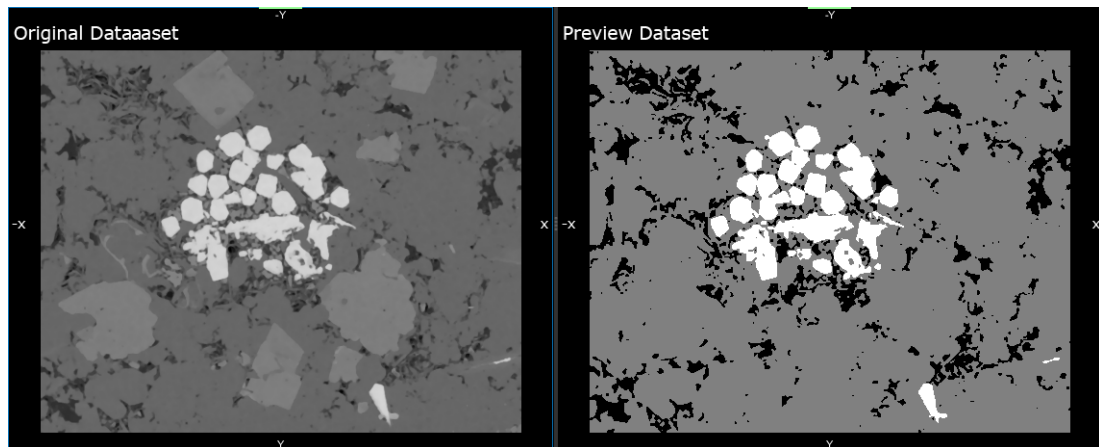
K-Means... The K-Means algorithm clusters data by trying to separate samples in *n* groups of equal variance, minimizing a criterion known as the inertia or within-cluster sum-of-squares. This algorithm requires the number of clusters to be specified and has been used across a large range of application areas. Refer to https://scikit-learn.org/stable/modules/clustering.html for more information about K-Means clustering.

Mini-Batch K-Means... The Mini-Batch K-Means option is a variant of the K-Means algorithm which uses mini-batches to reduce computation times, while still attempting to optimize the same objective function. Mini-batches are subsets of the input data, randomly sampled in each training iteration. In contrast to other algorithms that reduce the convergence time of K-Means, Mini-Batch K-Means produces results that are generally only slightly inferior to the standard algorithm. Refer to https://scikit-learn.org/stable/modules/clustering.html for more information about this variation of the K-Means clustering.

Smoothing

Additional filters to help reduce the amount of noise in an image include *Anisotropic Diffusion*, *Kuwahara*, and *Lipschitz*.

Anisotropic Diffusion... Is a technique aimed at reducing image noise without removing significant parts of the image content, typically edges, lines or other details that are important for the interpretation of the image. Anisotropic diffusion is a generalization of this diffusion process as it produces a family of parameterized images, but each resulting image is a combination between the original image and a filter that depends on the local content of the original image. As a consequence, anisotropic diffusion is a non-linear and space-variant transformation of the original image. Anisotropic diffusion generally preserves the sharpness of edges better than Gaussian blurring.

Original data (left) and after anisotropic diffusion filtering (right)
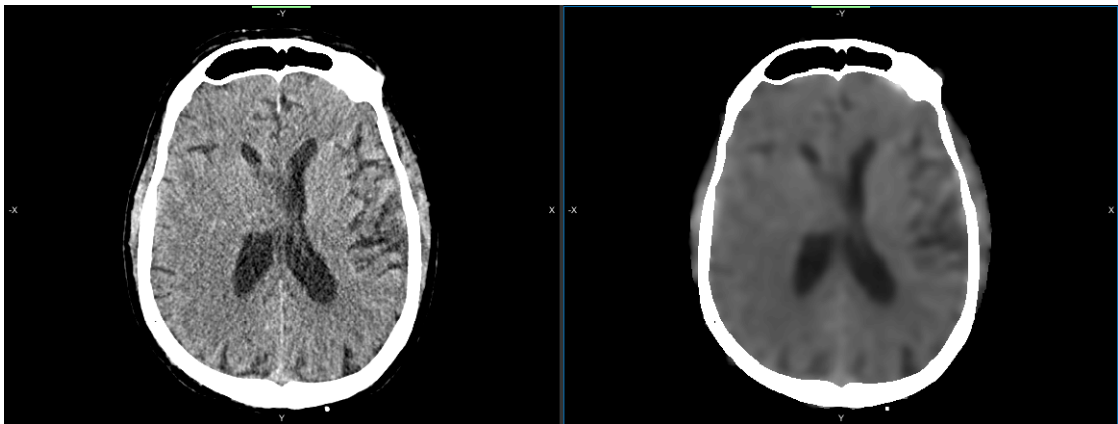
Kuwahara... Provides non-linear smoothing for adaptive noise reduction. Most filters that are used for smoothing are linear low-pass filters that effectively reduce noise, but can also blur out the edges. However, the Kuwahara filter is usually able to apply smoothing on the image while preserving its edges.

Lipschitz... Implements a Lipschitz cover of an image that is equivalent to a grayscale opening by a cone. The Lipschitz cover can eliminate slowly varying image backgrounds by subtraction of the lower Lipschitz cover, which is a top-hat procedure.

Texture Analysis

New texture analysis filters that can characterize the texture of a region by quantifying spatial variation in pixel intensities include the following:

Membrane Projections... Enhances membrane-like structures of an image through directional filtering.

Thresholding

Additional thresholding filters, which output an image composed of basic classes and can be used as masks for segmentation purposes or other image processing tasks, include the following:

Adaptive Gaussian... The threshold value is the weighted sum of neighbourhood values where weights are a Gaussian window.

Additional Options for Image Data

This software release includes additional options for working with image data, as described below. See Image Stitching on page 12, Stitch 3D Datasets on page 14, and Create 4D Datasets on page 14 for information about Dragonfly's new comprehensive image processing plugins.

Add Gaussian Noise

This Dragonfly release provides the option to artificially add Gaussian noise to an image. Deliberately corrupting an image with noise may be useful in cases in which you need to test the resistance of an image processing operator to noise or to assess the performance of various noise filters.

To add Gaussian noise to an image, right-click the required dataset and then choose **Add Gaussian Noise** in the pop-up menu. You can select the level of noise required in the Standard Deviation dialog.

Extract ROIs

Available from the Data Properties and Settings pop-up menu, the **Extract ROIs** item automatically creates a new region of interest for each intensity value in the selected dataset.

Overwrite Dataset

If required, you can overwrite the values of a dataset with the intersecting values of a reference dataset. To overwrite dataset values, right-click the reference dataset and then choose **Overwrite Dataset** in the pop-up menu. The dataset that will be overwritten is selectable in the Choose a Dataset to Overwrite dialog, shown below.

Choose a Dataset to Overwrite dialog
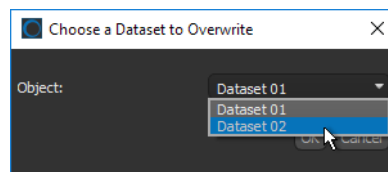
NOTE The reference dataset and the dataset to overwrite must be of the same data type — UBYTE, SHORT, UINT, or FLOAT. For best results, the datasets should also be within the same value range. If required, you can convert or normalize data within a selected range with the Dataset Tools.

New Options for ROIs

A number of new features and options are available in Dragonfly 4.0 for working with regions of interest — including graphing, computing volume thicknesses, removing unwanted objects, and creating geodesic distance maps. These new features and options are described in the following topics.

Graphing for ROIs

The graphing option for regions of interest can provide a ready-made framework for performing a wide range of pore network simulations to better understand how porous materials behave and how to improve them. For example, to create a graph of a region of interest that describes a void space, right-click the ROI in the Data Properties and Settings and then choose **Create Graph from ROI** in the pop-up menu. Graphs of regions of interest can be examined in 3D views, as shown below.

Graph of connected and non-connected porosity
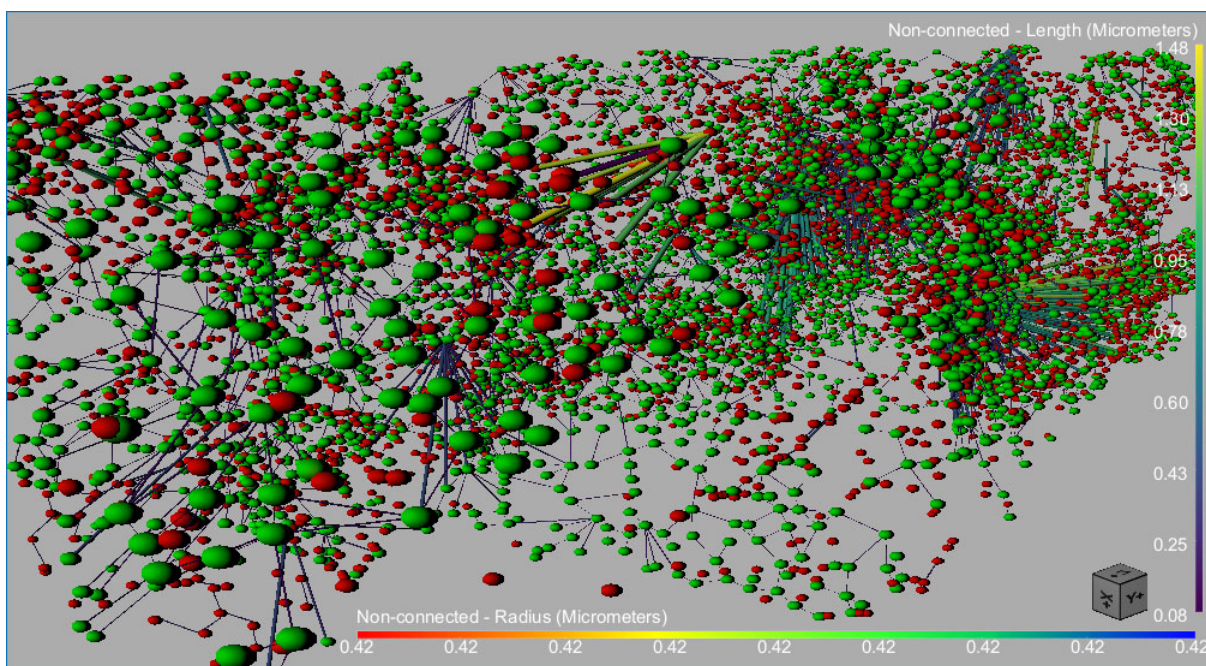
Graph settings, as well as information about the graphed objects, are available on the Data Properties and Settings panel and in the Measurement Inspector, as shown in the following screen captures.

Data Properties and Settings panel and Measurement Inspector
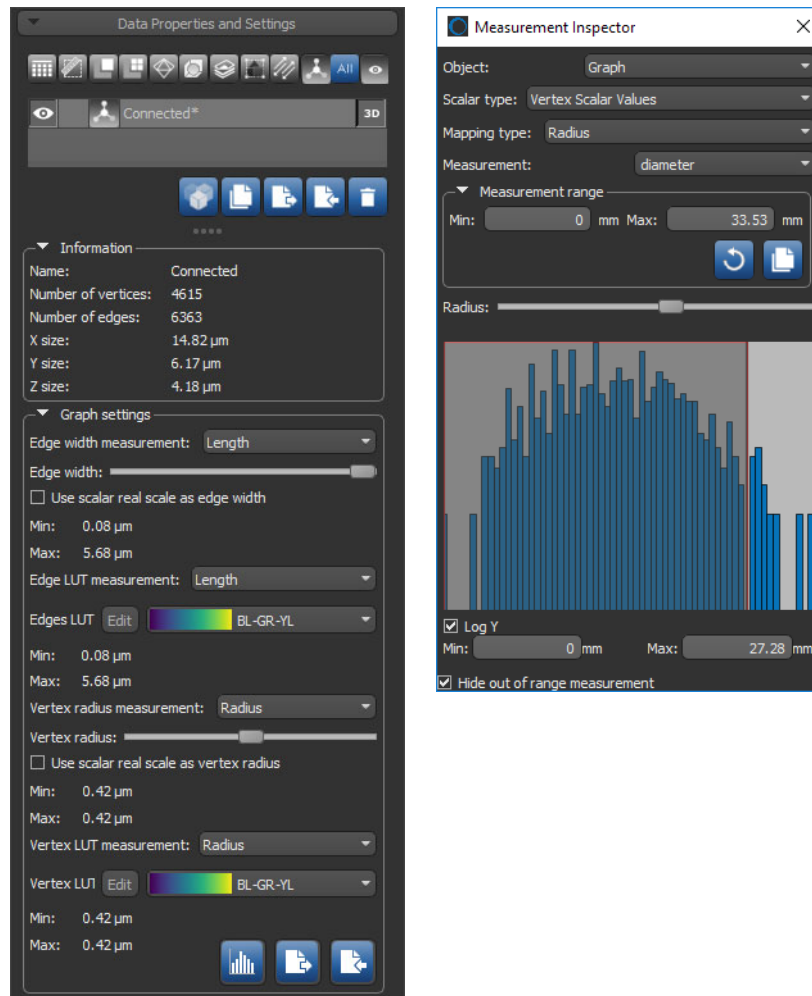
You can do the following in the Data Properties and Settings panel and in the Measurement Inspector:

- Adjust the radius of spheres representing pores or nodes, as well as their connectors.
- Apply different LUTs to ports and adjust measurement ranges by filtering minimum and maximum values in the Measurement Inspector.

- Plot histograms of selected measurements, as shown below.
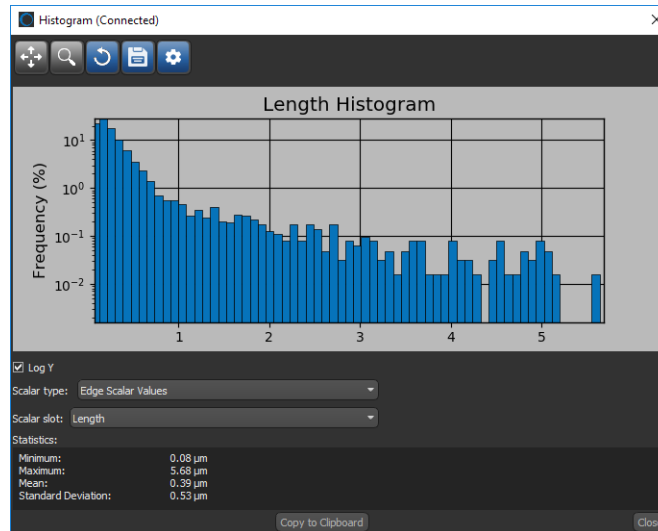
- Export results to a CSV file for additional analysis.

Label Edges of Graph of ROI

This option lets you automatically create a multi-ROI in which the segments contained within the selected region of interest are labeled as separate connected components. You should note that segments are determined by first skeletonizing the region of interest, applying a watershed, and then expanding the ROI and assigning a label to each branch.

To label the edges of a selected region of interest, right-click, and then choose **Label Edges of Graph of ROI** in the pop-up menu. The computed multi-ROI will appear as a new item in the Data Properties and Settings panel.

Statistical Properties

This software release provides additional statistical properties for selected regions of interest.

Interpolated Surface... Provides a more robust method — known as *Fast Marching* — for calculating the surface of a selected region of interest than what was available previously with the pixel-wise computation.

Feret diameters... Provides measurements of the minimum, mean, and maximum Feret diameters contained in the selected region of interest (see Feret Diameter Measurements for ROIs and Meshes on page 18).

Volume Thickness

Measurements of volume thickness that are based on the *sphere-fitting* method are available in this software release for evaluating structures fully described by a region of interest. You should note that one of the key advantages of local thickness measurements is that the bias from the 3D orientation of the structure is kept to a minimum.

To create a volume thickness map, as shown below, right-click a region of interest and then choose **Create Volume Thickness Map** in the pop-up menu. The new dataset will appear in the Data Properties and Settings panel.

Volume thickness of a bone segmentation
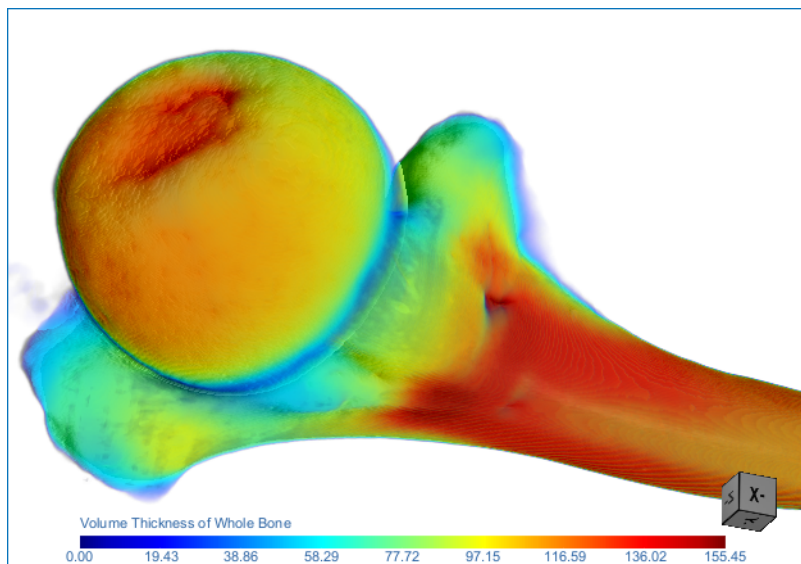
You should note that local thickness for a point in solid is defined as the diameter of the largest sphere which fulfils two conditions:

- The sphere encloses the point, but the point is not necessarily in the center of the sphere.
- The sphere is entirely bounded within the solid surfaces.

Interfacial Surface Computations

This software release offers the opportunity to compute the interfacial surface between two regions of interest. For example, between regions of interest describing oil droplets and water. You should note that computations are performed in 3D with interpolated surfaces that are not limited by pixel-wise methods.

Selectable Connectivity for Processing

This software release lets you choose the level of connectivity — *6-connected* or *26-connected* — that determines how voxels in a region of interest are labeled as separate components in generated multi-ROIs and when removing unwanted objects. You should note that a set of voxels in an image which are connected to each other is called a *connected component*. Finding all connected components in an image and marking each of them with a distinctive label is usually referred to as *connected component labeling*.

Connectivity is selectable for creating multi-ROIs, and processing islands, as shown in the following illustration and explained below. You should note that 18-connected is not available as an option in Dragonfly and is included here for reference purposes only.

6-connected versus 26-connected

Region of interest

6-connected

18-connected
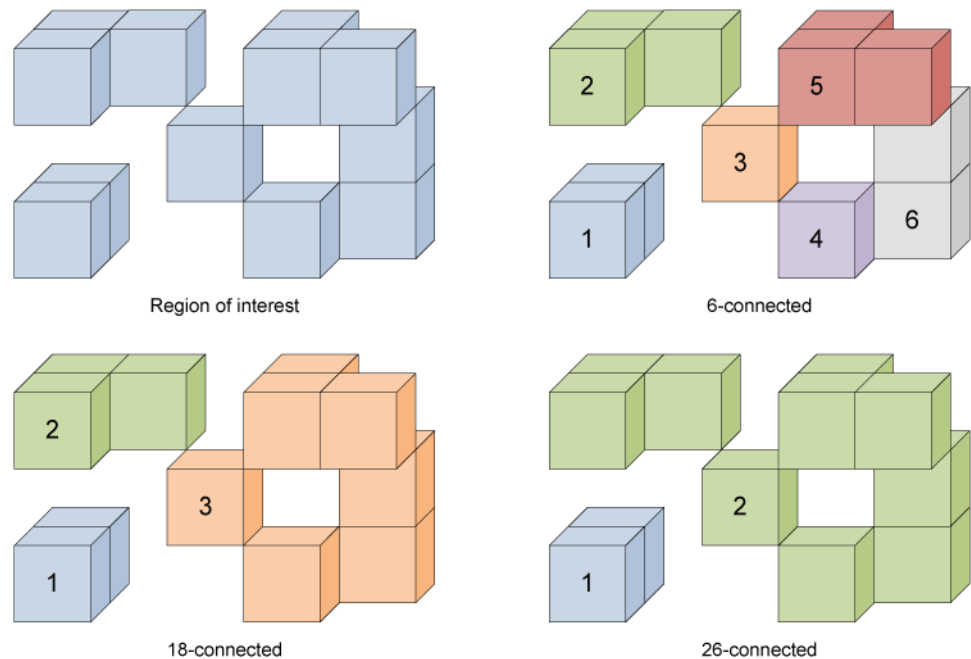
26-connected

6-connected... Propagation is done by strictly using the 6 faces adjacent to the current seed. This was the default mode in previous Dragonfly versions, and will result in the maximum number of labeled objects.

18-connected... Propagation is done using the 6 faces and 12 edges adjacent to the current seed. Will result in fewer connected components than 6-connected. You should note that this option is currently not available in Dragonfly.
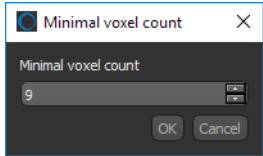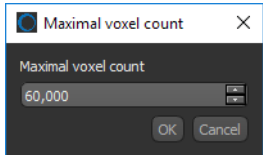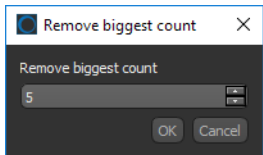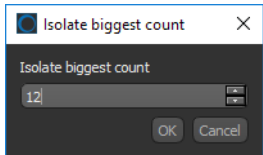
26-connected... Propagation is done in all directions, using the 6 faces, 12 edges and 8 corners adjacent to the current seed. Will result in the fewest connected components, but computation times may increase.

Remove Unwanted Objects (Process Islands)

In cases in which you need to refine thresholded segmentation results or isolate objects of a certain size, this Dragonfly release provides options to remove small objects from a region of interest, as well as to isolate larger objects.

Right-click a region of interest in the Data Properties and Settings panel and then choose **Process Islands** in the pop-up menu. You can then choose to remove or keep objects as described in the following table.

Process Islands options

	Description
Remove (6-connected)	Removes all objects, as determined by the 6-connected* method, that have a voxel count lower than a selected threshold. Voxel counts can be selected in the Minimal Voxel Count dialog, shown below.
Isolate (6-connected)	Keeps all objects, as determined by the 6-connected* method, that have a voxel count higher than a selected threshold. Voxel counts can be selected in the Maximal Voxel Count dialog, shown below.
Remove (26-connected)	Removes all objects, as determined by the 26-connected* method, that have a voxel count lower than a selected threshold. Voxel counts can be selected in the Minimal Voxel Count dialog.
Isolate (26-connected)	Keeps all objects, as determined by the 26-connected* method, that have a voxel count higher than a selected threshold. Voxel counts can be selected in the Maximal Voxel Count dialog.
Remove (6-connected) nth First Biggest	Removes a selected number of the largest connected components, as determined by the 6-connected* method and as ranked by voxel count**. For example, if 5 is selected as the threshold, then the largest 5 connected components will be removed from the selected region of interest. The number of components to remove can be selected in the Remove Biggest Count dialog, shown below.
Isolate (6-connected) nth First Biggest	Keeps a selected number of the largest connected components, as determined by the 6-connected* method and as ranked by voxel count**. For example, if 12 is selected as the threshold, then all connected components except for the 12 largest will be removed from the selected region of interest. The number of components to retain can be selected in the Isolate Biggest Count dialog, shown below.
Remove (26-connected) nth First Biggest	Removes a selected number of the largest connected components, as determined by the 26-connected method* and as ranked by voxel count**. The number of components to remove can be selected in the Remove Biggest Count dialog.
Isolate (26-connected) nth First Biggest	Keeps a selected number of the largest connected components, as determined by the 26-connected* method and as ranked by voxel count**. The number of components to retain can be selected in the Isolate Biggest Count dialog.

* See Selectable Connectivity for Processing for information about how connected components are computed.

** Objects with an identical voxel count will be considered as unique objects when ranked.

Create ROIs Using Neighbor Counts

This new option for regions of interest lets you create a new ROI that contains only voxels with an original neighbor count greater than or equal to a selected threshold. Thresholds are selectable in the Neighbor Count dialog, shown below. To open the dialog, select the required region of interest, right-click, and then choose **Create ROI Using Neighbor Count** in the pop-up menu.

Neighbor Count dialog
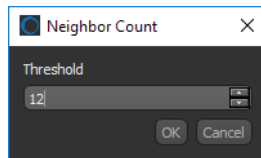
NOTE This option can be applied to facilitate the topological analysis of skeletons, for example.

Smoothing for Thickness Mesh Export

In this software release, smoothing is selectable when regions of interest are exported to normal and sampled thickness meshes from the ROI Tools panel on the Segment tab.

Export options for regions of interest
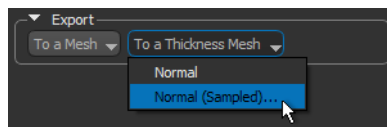
Two methods — *Laplacian Smoothing* and *Hamming Windowed Smoothing* — are available for smoothing in the **Export as Thickness Mesh** dialog, shown below. The number of iterations is also selectable.

Export as Thickness Mesh dialog
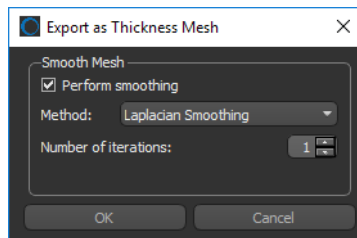
Close Inner Holes

This software release includes an additional morphological operation for regions of interest that lets you close holes smaller than a thresholded distance.

To close inner holes, as shown in the following illustration, right-click the required region of interest and then choose **Close Holes Smaller Than** in the pop-up menu. The threshold distance is selectable in the Threshold dialog.

Original region of interest (left, in red) and results of closing holes (right, in blue)
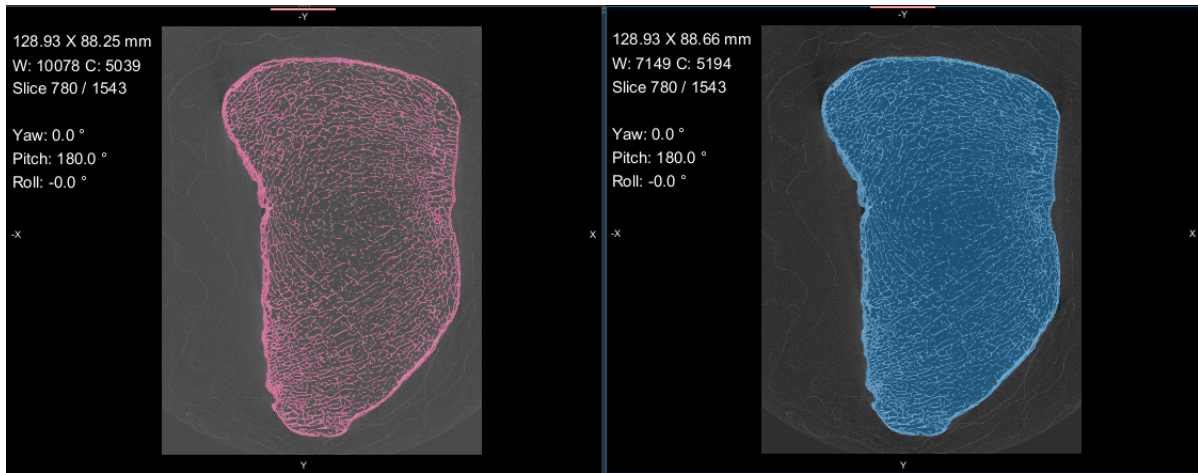
Geodesic Distance Maps

For flow analysis and other applications, this Dragonfly offers the option to create geodesic distance maps that compute the shortest path from a seed point that joins all points inside a region of interest. As shown in the example below, LUTs can be applied to geodesic distance maps, which can be examined in 2D and 3D views and are computed using the Fast Marching method.

Geodesic distance map of a pore network
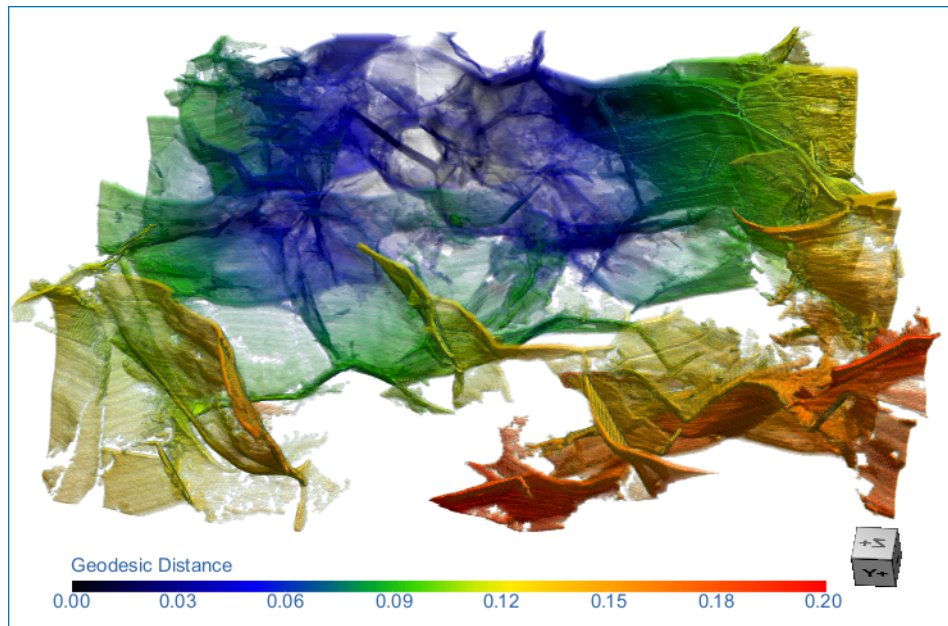
To create a geodesic distance, right-click the region of interest that you need to map and then choose **Create Geodesic Distance Map** in the pop-up menu. You can then select the seed point in the Choose a Seed ROI dialog.

NOTE The *geodesic* distance is the shortest path fully contained within a region that joins two points, while the *Euclidean* distance is the straight line distance.

Export ROI as Binary

Lets you export a region of interest as a binary file, in which labeled voxels are assigned a value of 1 and all other voxels 0.

New Options for Multi-ROIs

A number of new options are available in Dragonfly 4.0 for working with multi-ROIs. These new features are described in the following topics.

Graphing for Multi-ROIs

The graphing option for multi-ROIs provides an opportunity to investigate the inter-relationship between connected components. To create a graph of a multi-ROI, right-click the item in the Data Properties and Settings and then choose **Create Graph from Connectivity** in the pop-up menu. Graphs of multi-ROIs, in which the centroid of adjacent objects are linked, can be examined in 3D views as shown below.

Graph of segments
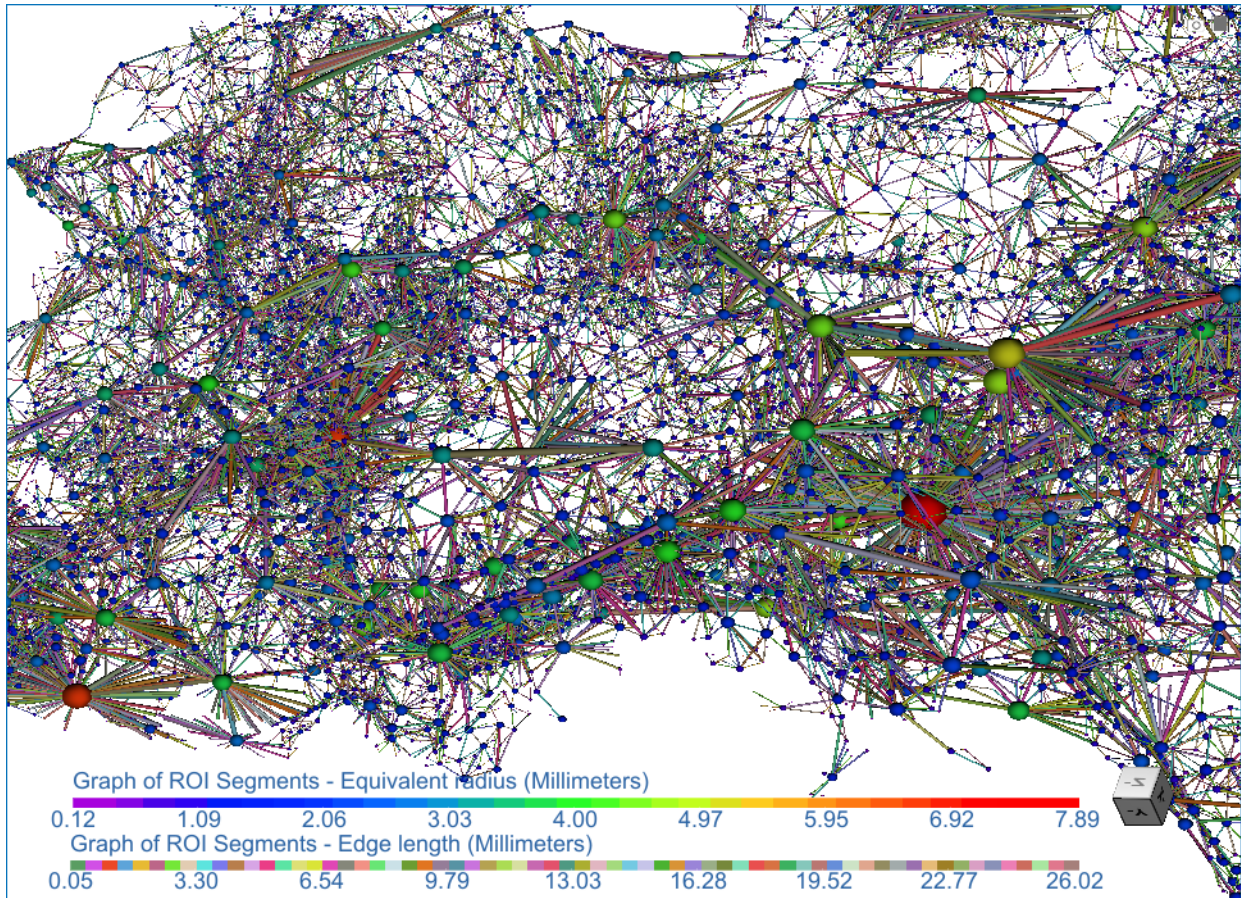
NOTE You can automatically create a multi-ROI of the segments within a region of interest (see Label Edges of Graph of ROI on page 26).

Graph settings, as well as information about the graphed objects, are available on the Data Properties and Settings panel and in the Measurement Inspector, as shown in the following screen captures.

Data Properties and Settings panel and Measurement Inspector
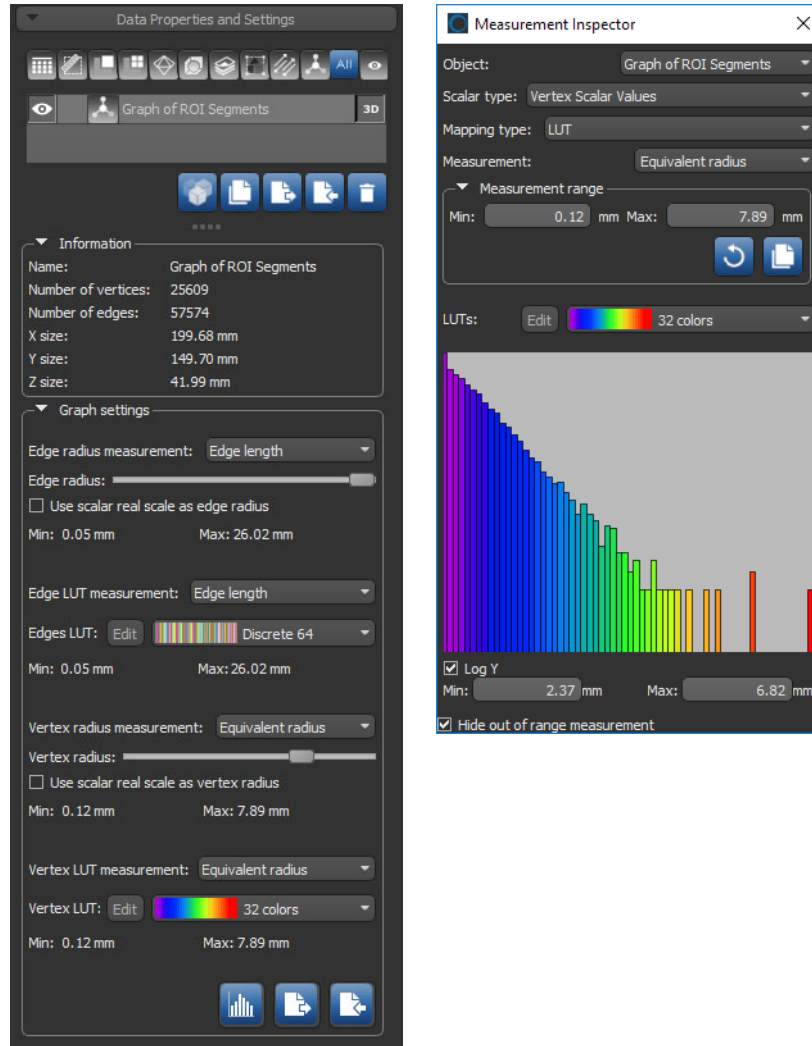
You can do the following in the Data Properties and Settings panel and in the Measurement Inspector:

- Adjust the radius of spheres representing the centroid of each connected component, as well as their connectors.
- Apply different LUTs to ports and adjust measurement ranges by filtering minimum and maximum values in the Measurement Inspector.

TM021-A-05

- Plot histograms of selected measurements, as shown below.
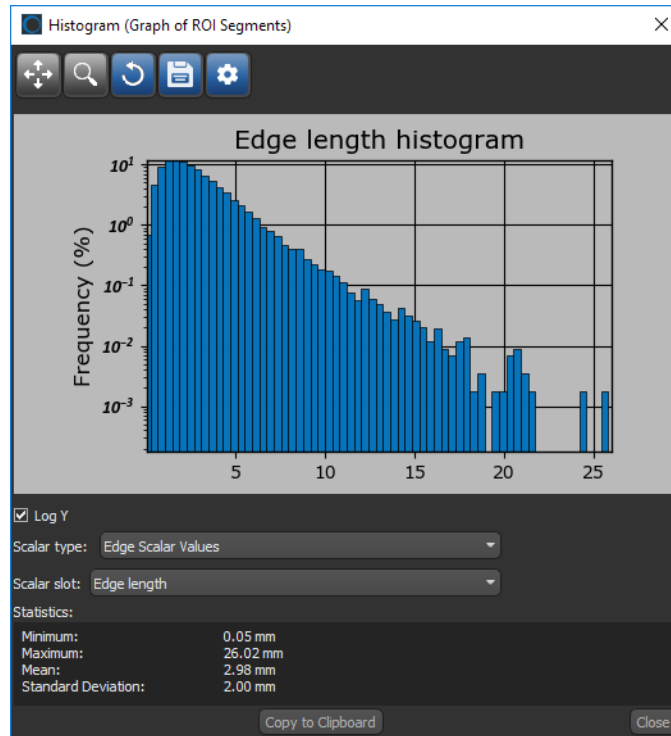
- Export results to a CSV file for additional analysis.

Statistical Properties

This software release includes a number of new statistical properties for analyzing multi-ROIs. These properties are available in the Statistical Properties dialog.

Statistical Properties dialog

New statistical properties for multi-ROIs

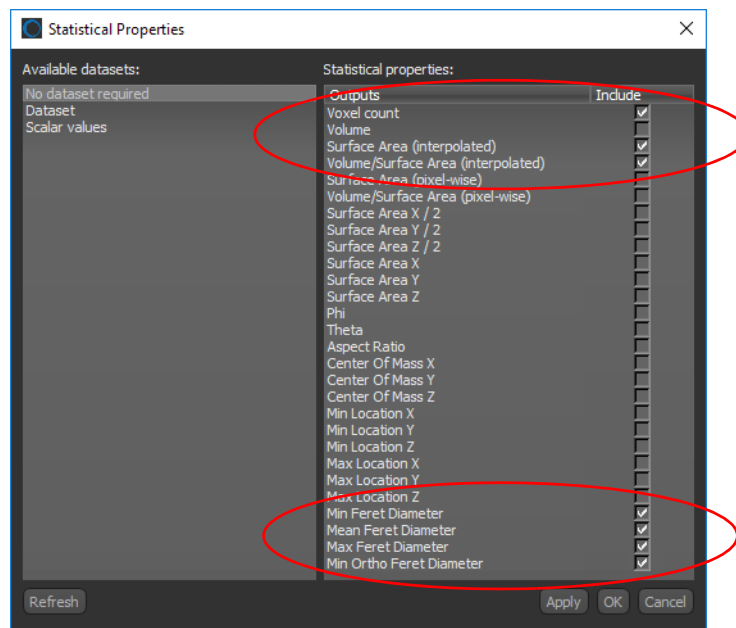|	Description
Voxel Count	Indicates the total number of voxels contained in each connected component.
Surface Area (interpolated)	Provides a more robust method for calculating the surface of the connected components in a multi-ROI than was available previously with the pixel-wise method.
Volume/Surface Area (interpolated)	Provides a more robust method for calculating the ratio of volume to surface area, as described above.
Surface Area (pixel-wise)	Pixel-based method implemented in previous Dragonfly versions for calculating the surface of the connected components in a multi-ROI.
Volume/Surface Area (pixel-wise)	Pixel-based method implemented in previous Dragonfly versions for calculating the ratio of volume to surface area, as described above.
Min Feret diameter	The shortest distance between any two points along the object boundary at an arbitrary angle, also known as the minimum caliper diameter.
Mean Feret diameter	The mean value of the Feret diameters over a sufficient number of orientations.
Max Feret diameter	The longest distance between any two points along the object boundary at an arbitrary angle, also known as the maximum caliper diameter.
Min ortho Feret diameter	The shortest distance between any two points along the object boundary that are orthogonal to the maximum Feret diameter.
Min ortho/Max Feret diameter	The ratio of the minimum orthogonal Feret diameter to the maximum Feret diameter. This measure can provide a good indication for the elongation of a particle.

Previous Analyzes

Whenever you need to re-analyze a multi-ROI, you now have the option to include previously computed properties in your current analysis. These scalar values are available in the Statistical Properties dialog, as shown below. Click **Scalar values** to view and select the properties previously calculated that you want to appear with your current analysis.

Statistical Properties dialog
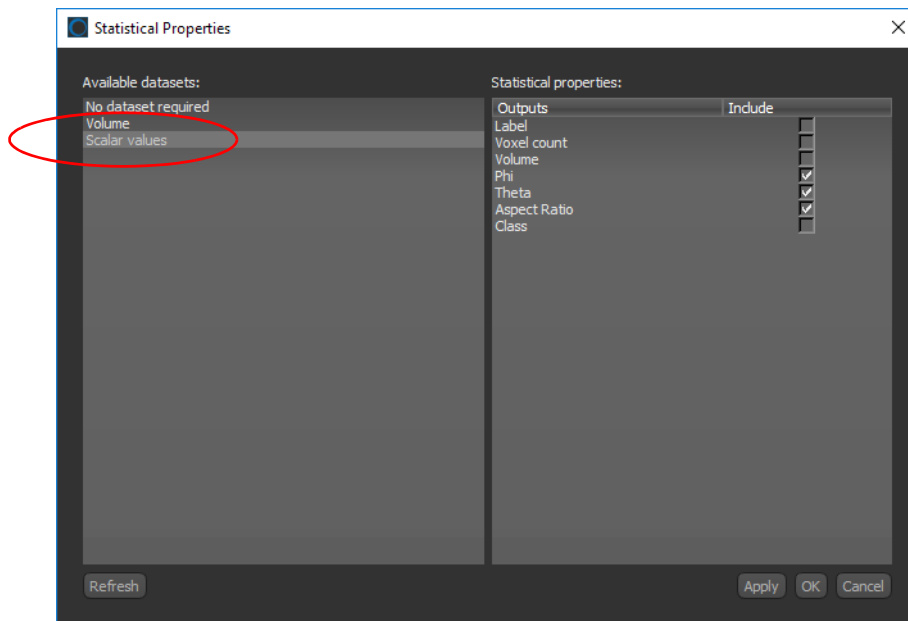
Import Scalar Values

In some cases, you may want to import the scalar values of a multi-ROI or mesh that were exported to a CSV file. As a new feature for Dragonfly 4.0, you can import scalar values from either an ORS-formatted CSV file or from a generic CSV file that contains the required IDs and corresponding values.

Scalar Value Slots Importer dialog
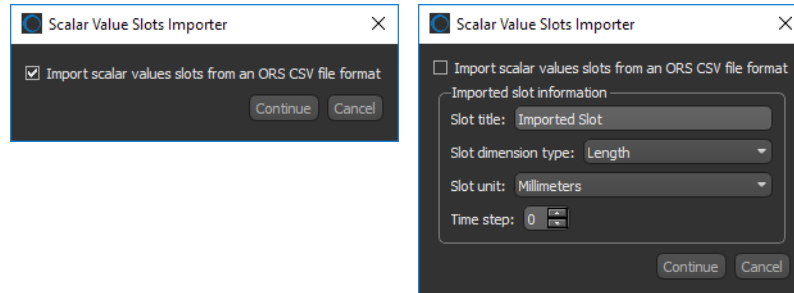
Extract ROIs

This new feature for Dragonfly 4.0 lets you extract a new region of interest from each connected component in the selected multi-ROI. For example, if there are 100 connected components in the selected multi-ROI, then selecting the **Extract ROIs** item in the Data Properties and Settings panel will result in 100 new regions of interest — one for each connected component.

Split Non-Connected Labels

In cases in which you create a multi-ROI and objects with the same label are not connected, you can choose to split those non-connected labels. This can be necessary in cases in which you create a multi-ROI from the greylevel values of a dataset. Right-click the required multi-ROI and then choose **Split Non-Connected Labels** in the pop-up menu to split not connected labels.

In the following example, the original multi-ROI with six labeled objects extracted from the data values of dataset (using the option **New Greylevel Multi-ROI**) is on the left. After splitting the non-connected labels of the greylevel multi-ROI, there are 165 labeled objects, as shown on the right.

Results of splitting non-connected labels
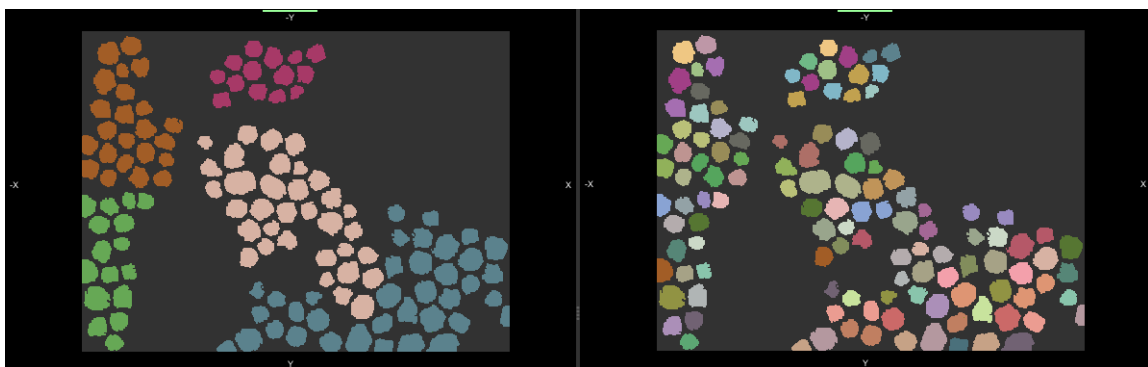
Get Merged Label as Multi-ROI

Lets you create a new multi-ROI with one labeled connected component from a multi-ROI that contains a number of labels that were merged. For example, through a Boolean operation.

New Options for ROIs and Multi-ROIs

The following new options — *Convex Hulls, Remove Touching Objects*, and Boolean operators for removing and keeping intersecting labels — are available in this software release for regions of interest and multi-ROIs.

Convex Hulls

This new option for Dragonfly 4.0 lets you generate convex hulls as filled or outlined regions of interest or multi-ROIs, or as meshes. Convex hulls are calculated from the minimum set of points that define a polygon containing all of the labeled voxels of a region of interest or all of the labeled voxels of each connected component in a multi-ROI. If you imagine the points as pegs on a board, you can find the convex hull by surrounding the pegs by a loop of string and then tightening the string until there is no more slack.

In the illustration below, a convex hull as a mesh (in blue) was generated from a region of interest describing the outline of a mechanical part.

Convex hull as a mesh
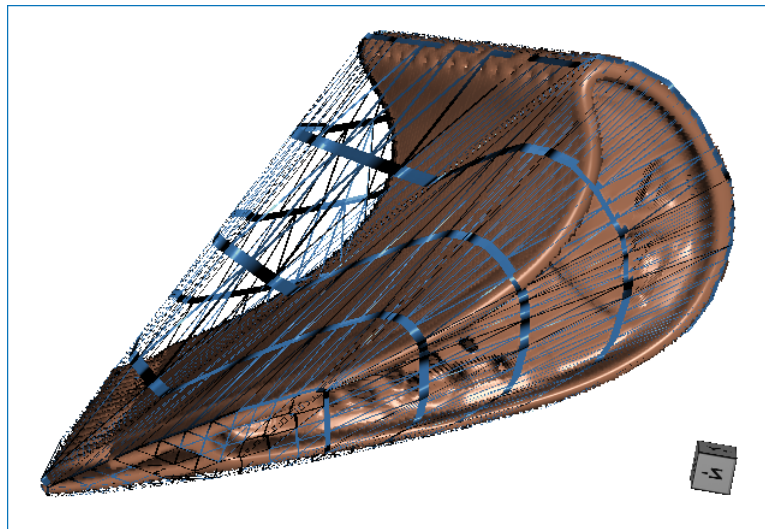
Convex Hull as a Filled ROI or Multi-ROI... Lets you generate a convex hull as a filled region of interest for a selected ROI, or as a series of filled convex hulls for each connected component in a selected multi-ROI.

Convex Hull as an Outer Shell ROI or Multi-ROI)... Lets you generate a convex hull as an outlined region of interest for a selected ROI, or as a series of outlined convex hulls for each connected component in a selected multi-ROI.

Convex Hull as a Mesh... Lets you generate a convex hull as a mesh for a selected ROI, or as a series of convex hulls for each connected component in a selected multi-ROI.

You should note that in this case, each connected component in the multi-ROI will be generated as an unstructured grid.

Remove Touching Objects

You can automatically remove *objects* from a selected region of interest or multi-ROI that touch another region of interest or multi-ROI by selecting the **Remove Objects That Touch Another ROI or Multi-ROI** in the Data Properties and Settings pop-up menu item. You should note that objects can be defined as groups of labeled voxels that are connected.

Boolean Operators

This software release includes two new Boolean operators — **Remove Intersected** and **Keep Intersected** — for modifying and refining regions of interest and multi-ROIs. These options are available in the Boolean operations panel, as shown below.

Boolean operations
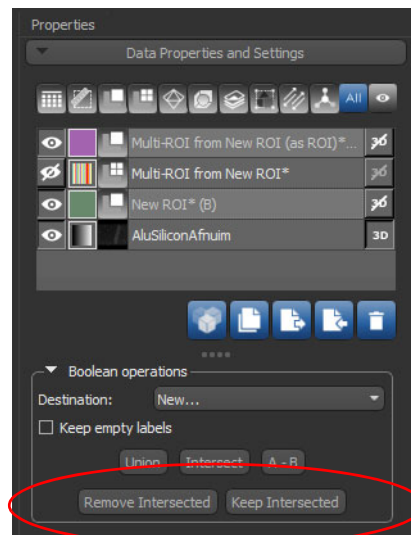
Remove Intersected... Automatically removes all labeled components of the initially selected item that intersect with the other regions of interest or multi-ROIs selected for the operation.

Keep Intersected... Automatically keeps only the labeled components of the initially selected item that do not intersect with the other regions of interest or multi-ROIs selected for the operation.

New Options for Meshes

A number of new options, including new mesh settings, smoothing, and a mesh subdivider, are available in this Dragonfly release for working with meshes.

Mesh Information

This software release provides additional statistical properties, circled below, for selected meshes.

Information for meshes
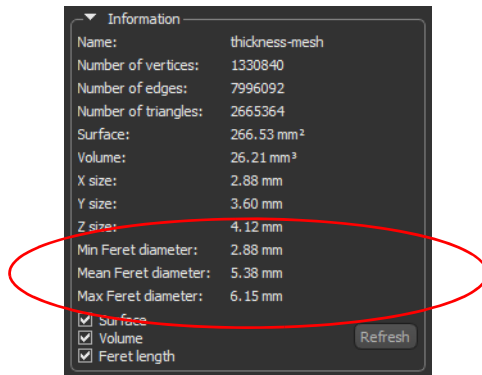
Feret diameters... Provides measurements for the minimum, mean, and maximum Feret diameters contained in the selected mesh (see Feret Diameter Measurements for ROIs and Meshes on page 18). Check the **Feret diameters** option and then click the **Refresh** button to compute the Feret diameters.

Mesh Settings

A new Fill mode — *Outlined* — is available for rendering meshes in 3D views. In this mode, meshes are rendered simultaneously as a solid outline and in wireframe, as shown below.

Outlined mesh
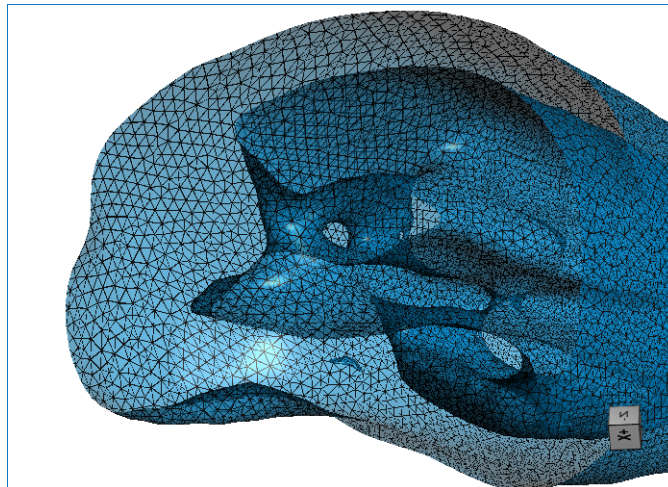
This setting is available on the Data Properties and Settings panel, as shown below.

Mesh settings
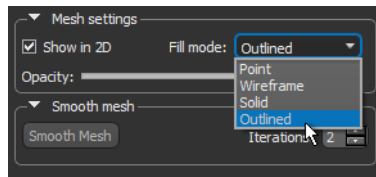
Mesh Smoothing

After generating a mesh, it is sometimes necessary to modify that mesh before further processing or analysis can begin. In particular, meshes extracted from volumetric image data obtained by CT or MRI devices often contain significant amounts of noise. Removing noise while preserving the shape of a mesh, as shown in the example below, is now an option for Dragonfly 4.0.

Original mesh (left) and smoothed mesh (right)
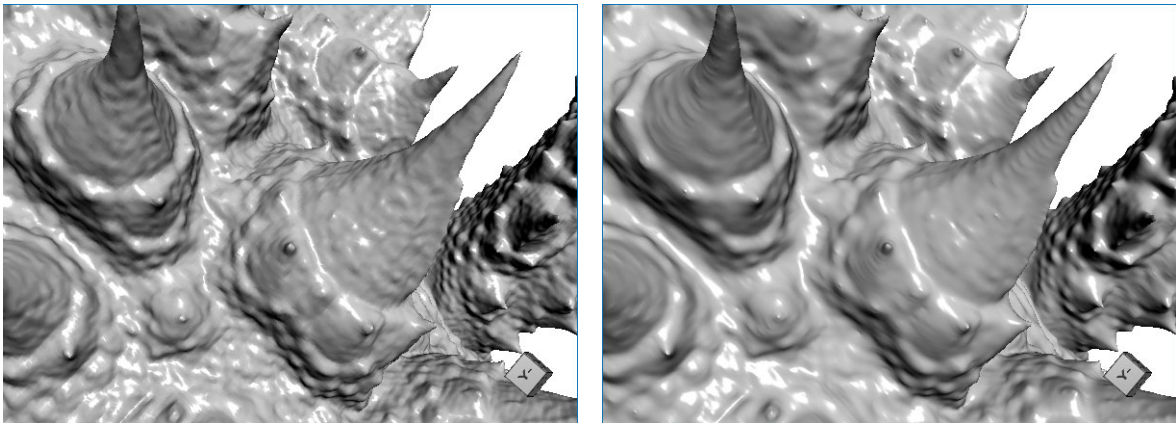
The options for smoothing a selected mesh are available in the Mesh Smoothing dialog, shown below.

Mesh Smoothing panel
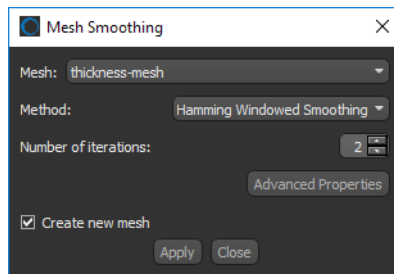
The Mesh Smoothing panel offers two filters for smoothing meshes — *Laplacian Smoothing* and *Hamming Windowed Smoothing*. Outputs of the smoothing operation can be a new mesh, so that the original remains unmodified, or a modified mesh.

TM021-A-05

Mesh Subdivider

Adding subdivisions to a polygon mesh can useful when you need to add detail in a global manner or to create smoother surfaces. Subdividing adds resolution to a mesh by increasing the number of its cells. You should note that for each subdivision level increase, the number of triangles will increase by approximately a factor of 4. For example, if n=2, the number of triangles in the resulting mesh will be 16x the number of triangles in the original mesh.

Original and subdivided mesh
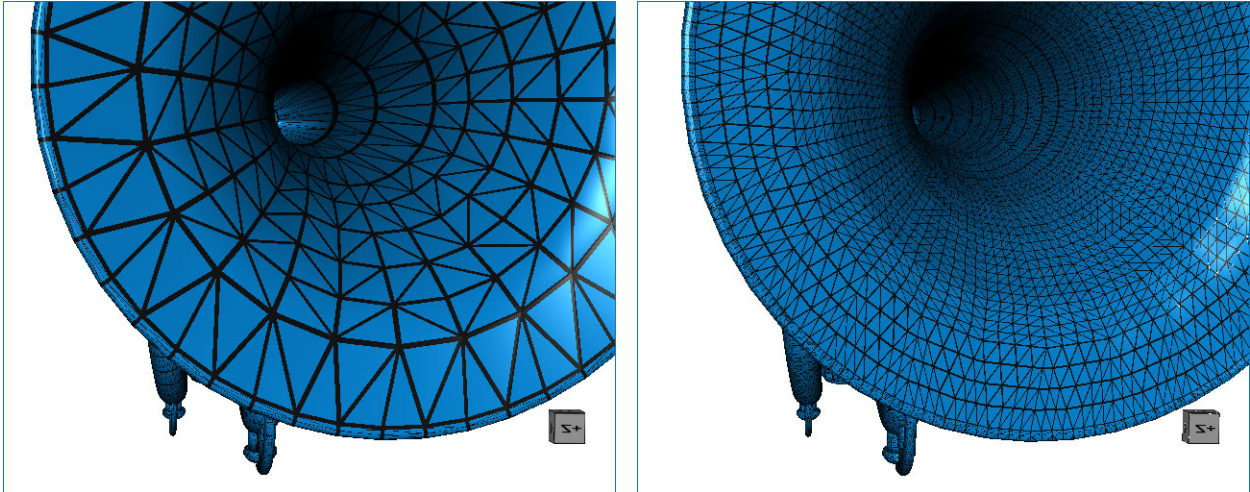
The options for subdividing meshes are available in the Mesh Subdivider dialog, shown below.

Mesh Subdivider panel
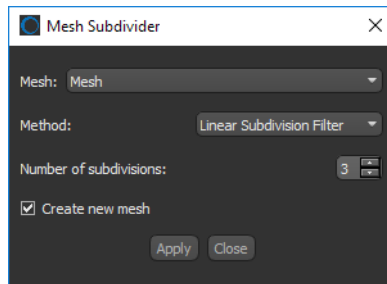
The methods available for subdividing meshes include *Linear Subdivision*, *Loop Subdivision*, and *Butterfly Subdivision* filtering. In addition, the number of subdivisions requested can be selected. Outputs of the subdivision operation can be a new mesh, so that the original remains unmodified, or a modified mesh.

NOTE Refer to https://cmake.org/Wiki/VTK/Examples/CSharp/Meshes/Subdivision for information about the implementation of Dragonfly's Mesh Subdivider.

Get Non-Manifold Edges Count

You can now compute non-manifold edge counts to verify that a mesh does not contain any edges with more than two faces attached to it. You can use this option to evaluate the integrity of a mesh that will be used for 3D printing.

As shown in the example below, non-manifold topology polygons have a configuration that cannot be unfolded into a continuous flat piece. This condition, in which more than two faces share an edge, is known as *multiply connected geometry*.

Non-manifold edge (in red)
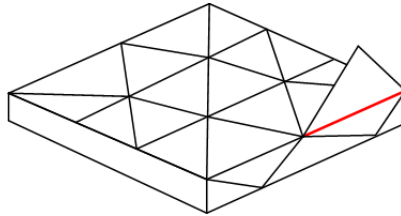
Right-click the mesh you need to analyze and then choose **Get Non Manifold Edges Count** in the pop-up menu. Results are available in the Mesh Information dialog, shown below. You should note that a value of 0 indicates that the mesh does not contain any non-manifold edges.

Mesh Information dialog
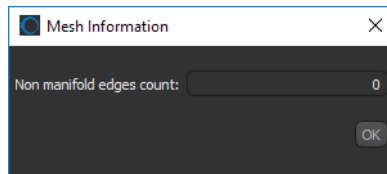
New Options for Scalar Meshes

Histograms, as well as export and import functions, are now available in the Scalar information box on the Data Properties and Setting panel, shown below, for selected scalar meshes.

Scalar information for meshes
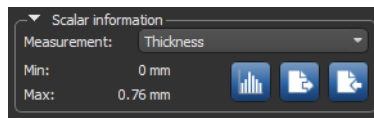
The new options for scalar meshes are described in the following table.

	Function	Description
	Histogram	Lets you plot selected scalar values on a histogram. For information about the new options available for histograms, such as saving figures and customizing captions, see Histograms and Graphs on page 56.
	Export	Lets you export the scalar values contained in the selected mesh to a CSV file.
	Import	Lets you import scalar values from a CSV file. **NOTE** You can also import scalar values from the Data Properties and Settings panel pop-up menu item **Import Scalar Values From a CSV File**.

Shape Properties

The basic properties of a selected shape — such as the height, radius, surface, and volume of a capsule — are now available in the Data Properties and Settings panel. The Basic properties panel is circled below on the following screen capture.

Basic properties for shapes
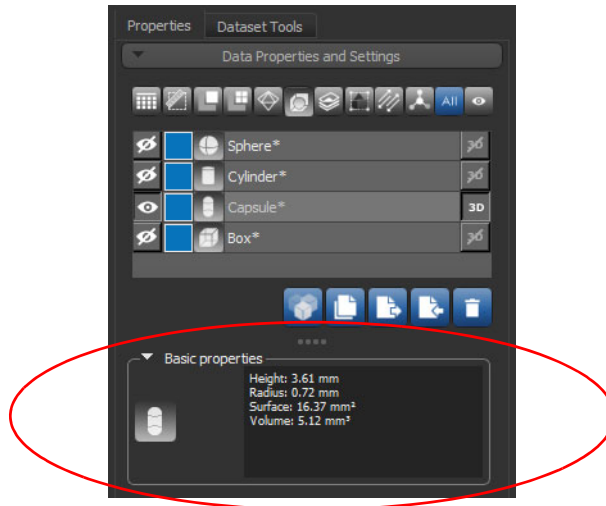
NOTE Some shapes have additional functions, such as masking for dataset registration (see Dataset Registration on page 49).

This software release also provides an **Align Centroid With** option for shapes. This pop-up menu item automatically aligns the centroid of a selected shape with the centroid of another object. Applicable objects include volumetric image data, regions of interest, multi-ROIs, and meshes. Reference objects can be selected in **Choose the Object to Align With** dialog.

New Options for Boxes

In this software release, boxes can be automatically reduced to the smallest encasing rectangle — based on either the maximum Feret diameter of a region of interest or mesh or on the minimal box shape. The results of resizing boxes to segmented ROIs is illustrated below.

Resized boxes

Box shape from Feret of a region of interest

Minimal box shape
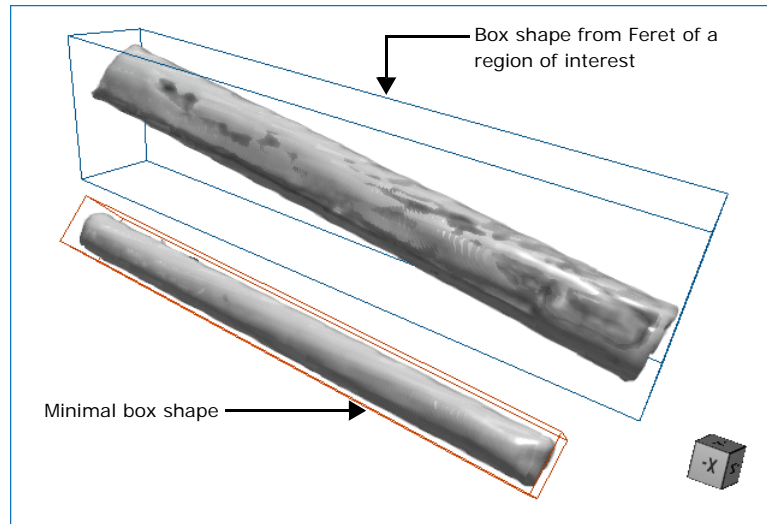
Take Box Shape from Feret Of

Reduces the selected box to the smallest encasing rectangle — based on the maximum Feret diameter and minimum orthogonal Feret diameter of the labeled voxels of a region of interest or of an unstructured grid, such as a mesh. You can select the required object in the **Choose an Object** dialog, as shown below.

Choose an Object dialog
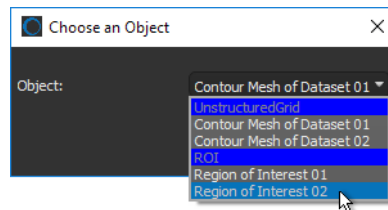
Take Minimal Box Shape Of

Reduces the selected box to the smallest or minimal encasing rectangle of a region of interest or unstructured grid, such as a mesh. You can select the required object in the **Choose an Object** dialog.

TM021-A-05

New Options for Annotations

As a new option for annotations — such as Rulers, Angles, and Regions — you can choose to show or hide associated captions in 2D or 3D views. This option is available in the Properties box and is circled below.

Annotation properties
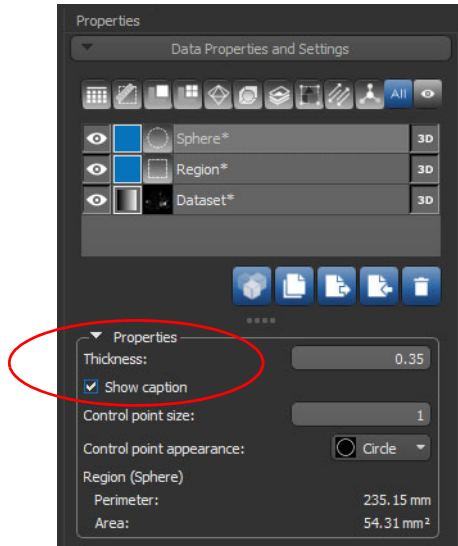
Extract Images from Visual Planes

As a new option for Dragonfly 4.0, you can extract a 2D image that corresponds to the oblique or double-oblique angle of a selected visual plane.

As shown in the screen captures below, a single-slice 2D image (on right) was extracted from the visual plane displaying the data of the corresponding MPR plane (on left).

Visual plane and extracted dataset
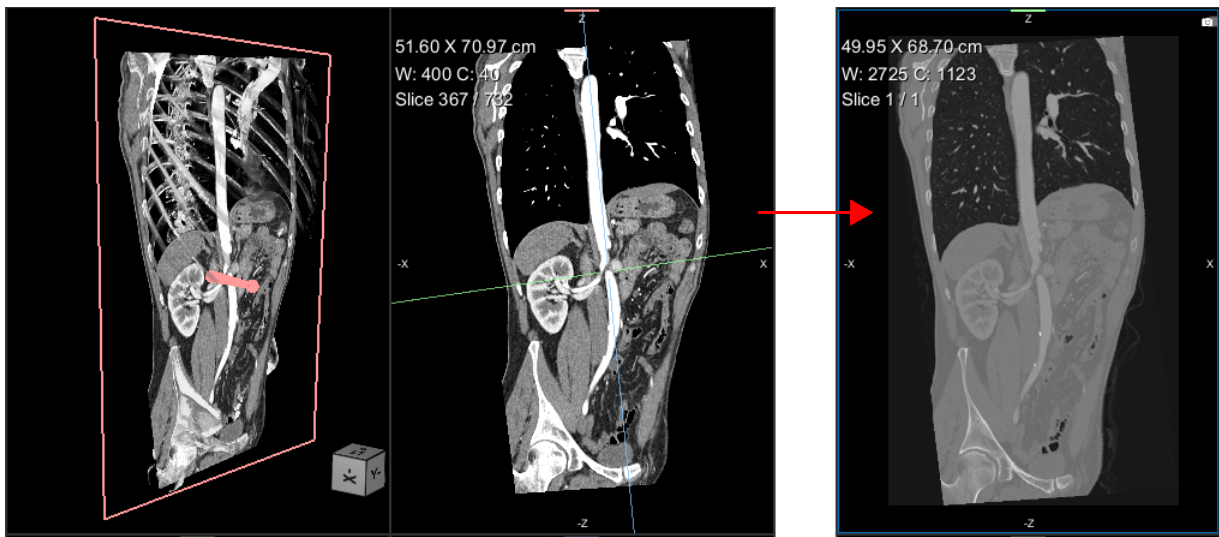
Gamma Ramp for Window Leveling

Gamma correction, or often simply gamma, is a nonlinear operation used to optimize the contrast and brightness in the midtones of an image. The option to control the gamma curve, which is a new feature for Dragonfly 4.0, can help you better visualize the dynamic range of selected window leveling values as shown in the comparative images below.

Original image (left) and the same image with gamma corrected (right)
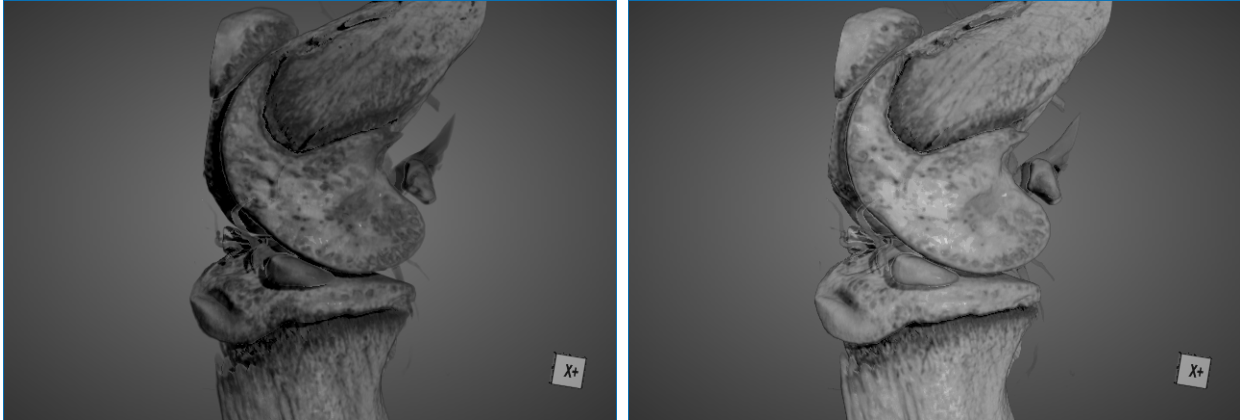
The gamma curve, as well as adjustment controls, are available in the Window Leveling panel, shown below.

Window Leveling panel
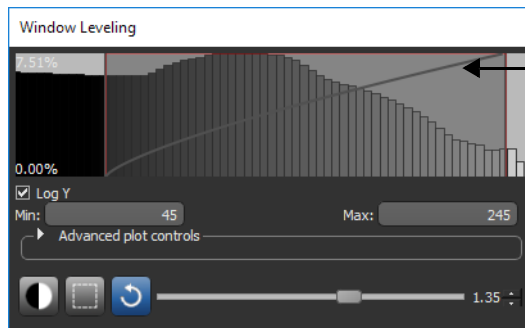
Gamma curve... The gamma curve determines how tones are displayed by defining the relationship between input values and the resulting image luminance. The curve is adjustable with the Gamma slider.

Gamma slider... Lets you adjust the applied gamma curve. You should note that the local gamma typically rises from 1.0 to about 2.0.

Configurable Actions

Additional configurable actions are available for adjusting the window leveling gamma value.

Adjust window leveling gamma in any mode... Lets you adjust the gamma curve in any mode. For example, when zooming.

Synchronize 3D Views

This software release lets you synchronize the 3D views available in multiple scenes in the workspace with the orientation and zoom applied to a reference 3D view. Select the **Position** option in the Scenes Views Synchronizer panel, as shown below, to set the selected 3D view as the reference for all other 3D views in the Dragonfly workspace.

Scenes Views Synchronizer for 3D views
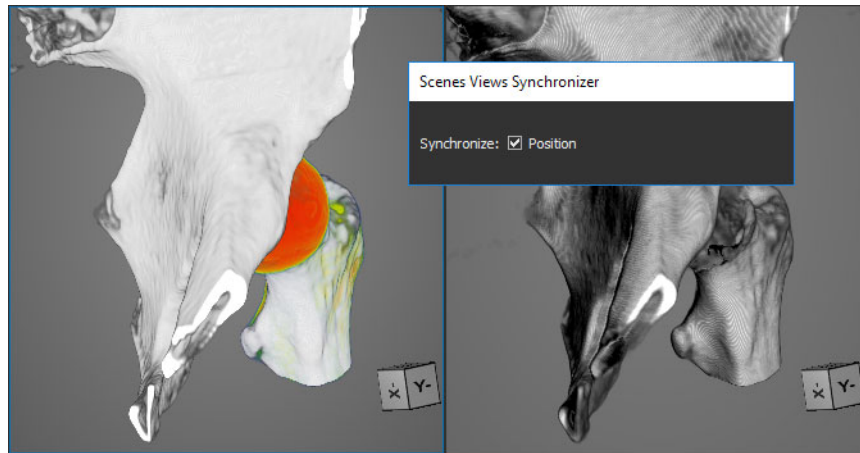
Movie Maker

A number of new options for creating animated sequences in the Movie Maker panel, as well as other improvements, are available in this software release.

New controls for working on the timeline include the following:

• **Set keyframe position...** Lets you manually set an exact keyframe position on the timeline. To open the Keyframe Time dialog, right-click the required keyframe and then choose **Set Keyframe Position** in the pop-up menu. The keyframe position can be selected in the Keyframe Time dialog, shown below.
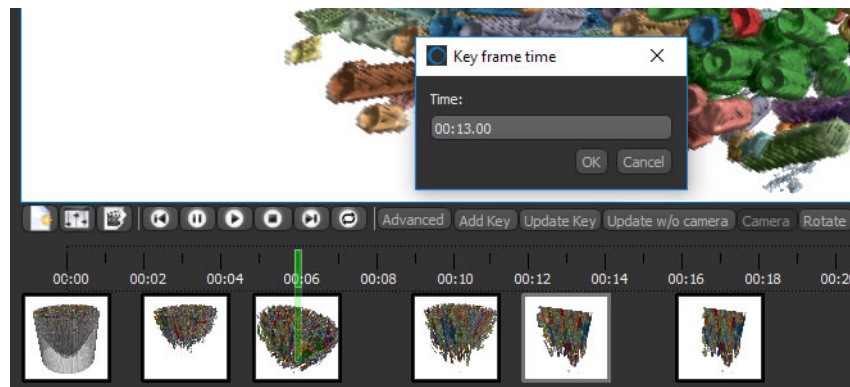
• **Update keyframe without camera...** Lets you update all changes made to a keyframe, except for those related to the camera — such as zooms or rotations. This option lets

you maintain the original position of an object, regardless of any applied camera manipulation. For example, after rotating a view to adjust a clip box.
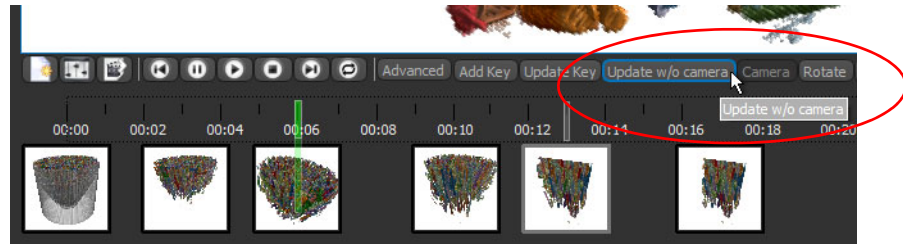
- **Loop playback...** If selected, lets you preview your animated sequence in a continuous loop.
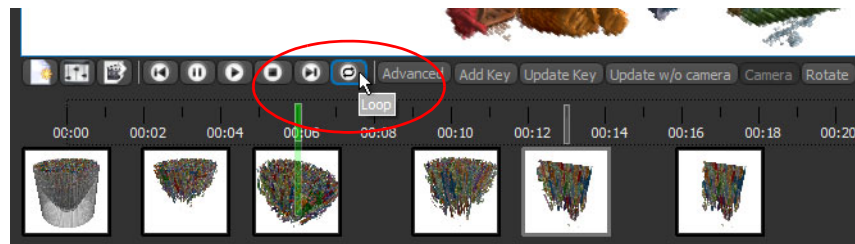
In addition, the following improvements have also been implemented for the Movie Maker:

- Easier manipulation of mesh frames.
- When new objects are added to the timeline, they will appear at the relevant keyframe and onwards only.
- Better interpolation for regions of interest and multi-ROIs, as well as improved performance for animating scalar values.

2D Animations

For 2D animations, this software release provides the option to export 2D animations as images to a number of different file formats. Click the **Export** button on the 2D Animation panel, shown below, to export the selected sequence to a series of BMP, GIF, JPEG, and TIFF image files or in the EPS file format.

2D Animation panel
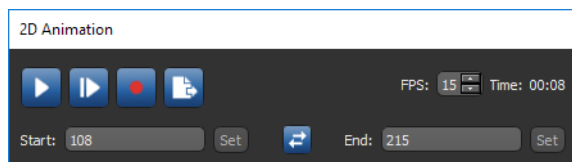
Product Enhancements

This release provides the following product enhancements for Dragonfly 4.0. For information about new features, such as the Organizer, Image Stitcher, and the Bone Analysis modules, as well newly implemented options for image data, regions of interest, and multi-ROIs, see New Features on page 7.

Deep Learning

This software release features a number of enhancements for the initial version of the Deep Learning tool that was first introduced in Dragonfly 3.6. These enhancements include the following:

- The segment dataset with classifier feature can now use deep learning models.
- Multiple channel inputs, such as RBG, are now supported.
- Implementation of options to check and uncheck parameters such as zoom, range, and rotation for data augmentation.
- Elastic deformation on patches with the option to add Gaussian noise.
- Training data statistics are shown for segmentation.
- You can download trained and untrained neural networks from the Infinite Toolbox, as well as publish your own neural networks to the Infinite Toolbox.

Dataset Registration

This software release provides additional options for Dragonfly's feature-based registration workflows, which can automatically register datasets by applying the transformations required to match features between two datasets. These new options, circled below, include using masks and scaling.

Dataset Registration dialog
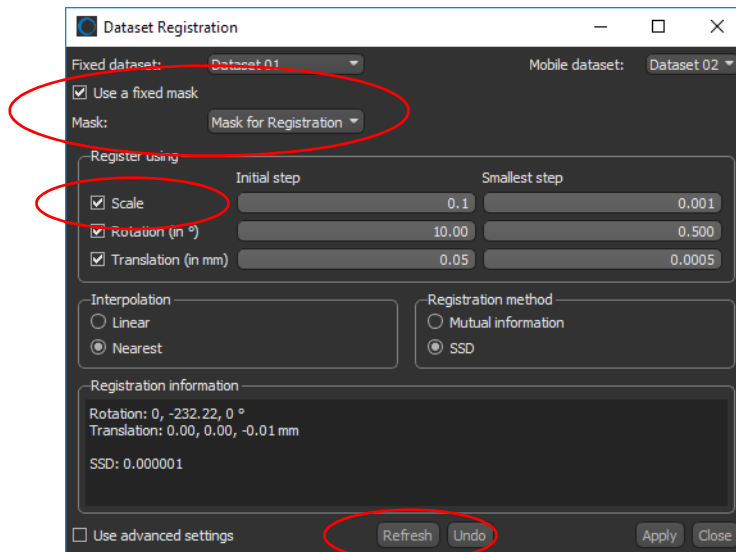
Fixed Mask

If a fixed mask is selected, calculations for the required transformations will be constrained to the 3D region defined by the selected mask. In other words, voxels outside the mask will not be considered when the required transformations are computed. Fixed masks can be a region of interest or any shape, such as a box or sphere, and must overlap with the selected *Fixed* dataset.

Scaling

The registration options now include independent scaling in the X, Y, and Z dimensions in the lattice coordinate system of the selected mobile dataset. The *Initial step* and *Smallest step* for scaling is selectable, and, in Advanced Mode, you can select the initial and smallest steps for each axis.

Refresh

Lets you update the registration score estimate after a change to the registration method, fixed mask, or mobile dataset.

Dataset Sampler

This software release adds the option to upsample or downsample data by a selected factor. These additional options are circled below on a screen capture of the Dataset Sampler panel.

Dataset Sampler panel
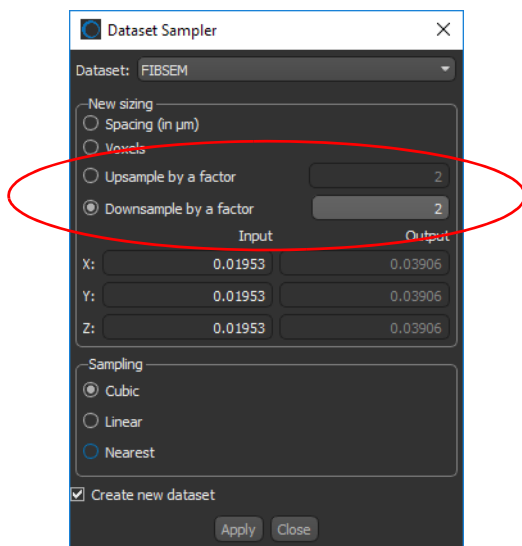
Upsample by a factor... Lets you select an upsampling factor that will be applied uniformly to the spacing values of the input dataset. For an input spacing size of 3.02 nm and an upsample factor of 2, the resulting spacing size will be 1.51 nm. Likewise, for an input matrix size of 512 x 512 x 256 and an upsample factor of 2, the resulting matrix will be 1024 x 1024 x 512.

Downsample by a factor... Lets you select a downsampling factor that will be applied uniformly to the spacing values of the input dataset. For an input spacing size of 3.02

nm and a downsample factor of 2, the resulting spacing size will be 6.04 nm. Likewise, for an input matrix size of 512 x 512 x 256 and a downsample factor of 2, the resulting matrix will be 256 x 256 x 128.

Slice Alignment Outputs

In this software release, you can choose to crop the output of an alignment to the dimensions of the registration selection box or to the dimensions of a user-defined box. This option, circled below, is available in the Output options box at the bottom of the Slice Registration dialog

Slice Registration panel
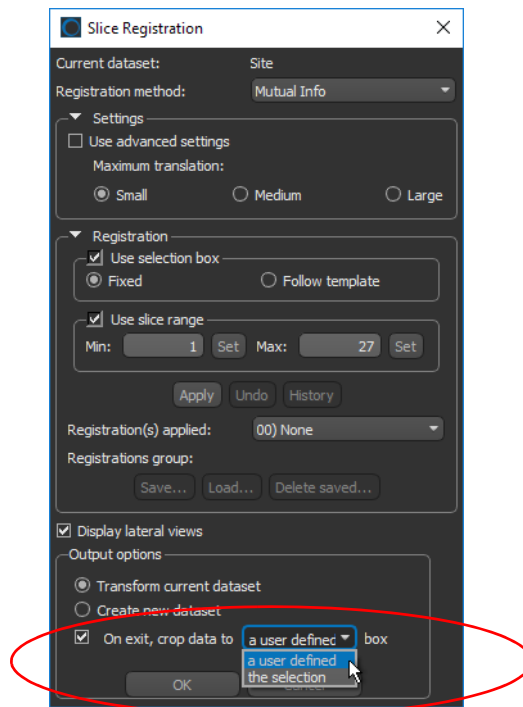
Active Contour

For users who use the Active Contour for segmentation tasks, this software release adds the option to set the direction of the path normals to inward or outward. For example, in cases in which you need to define a tube-like structure with a hollow center.

The **Normals Inward** option is circled on the following capture of the Active Contour panel.

Active Contour panel
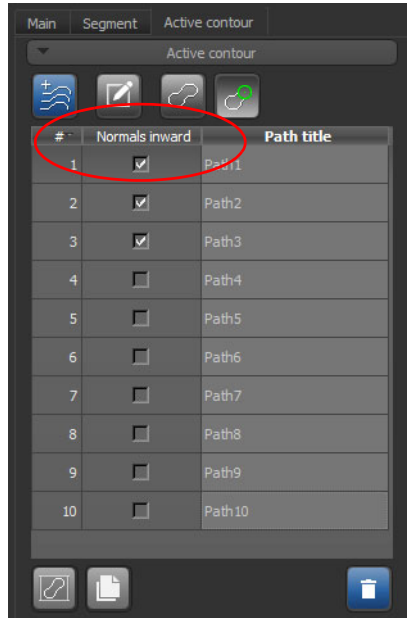
Connectivity Analysis

This software release features an accelerated connected component analysis compared with what was available in previous Dragonfly versions. Connectivity is also selectable (see Selectable Connectivity for Processing on page 28).

Updates for the Dataset Properties

A number of changes and updates are available in this software release for the Dataset Properties and Settings panel and for modifying dataset properties.

List Items

Two new items have been added the Dataset Properties and Settings panel as the result of major new features for Dragonfly 4.0. These are **Graphs** and **Vector Fields**.

Dataset Properties and Settings panel
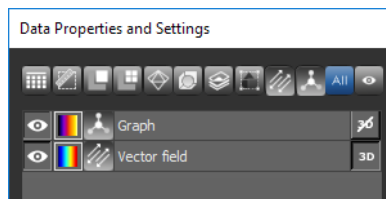
Graphs... Lets you filter the Data Properties and Settings panel list to show only graphs (see Graphing for ROIs on page 24 and Graphing for Multi-ROIs on page 32 for information about graph objects).

Vector Fields... Lets you filter the list to show only vector fields (see Bone Analysis on page 8 for information about vector fields).

TM021-A-05

Undo for Applied Changes

In this software release, changes to the position in space or orientation applied to a dataset in the Advanced Dataset Properties panel can be undone by clicking the **Undo** button in the Move panel, shown below.

Move panel
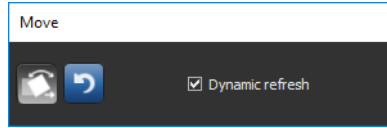
Data Units

The data units selected during file import, circled below, are now displayed in the Dataset Properties panel and can be edited, if required.

Dataset Properties panel
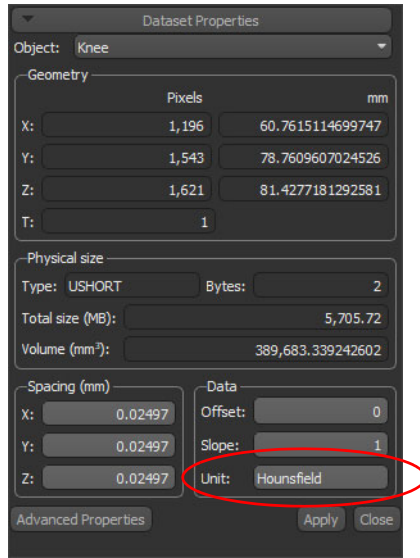
3D Presets

Applying a 3D preset to selected image data lets you quickly apply grouped 3D settings, scene's views properties, and lighting effects to improve the visualization of 3D renderings. In this software release, the default 3D presets available in the new drop-down menu are categorized for specific materials, such as biological samples, concrete, plastics, and metals. In addition, you can also create your own 3D presets for particular materials or data samples. You should note that you can edit and save user-defined 3D presets, but not the default presets.

3D presets
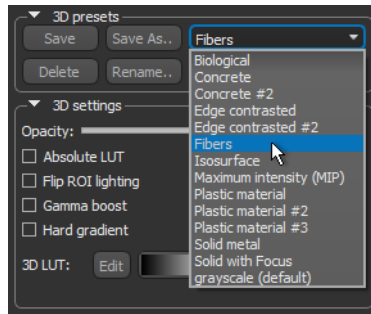
NOTE User-defined 3D presets can be published to the Infinite Toolbox and shared with the Dragonfly user community.

3D Settings

In cases in which a leveled object's boundaries are indistinct, the new **Edge detect** setting can help visualizations by adding a delineated edge computed from voxel depth to a rendering, as shown below.

Edge detect
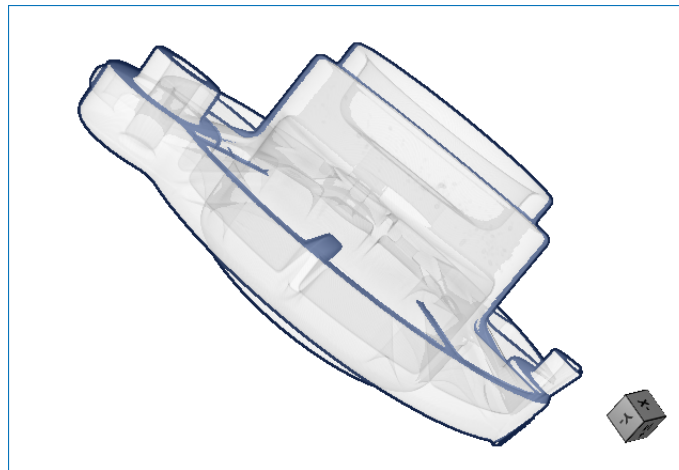
This new option is available in the 3D settings panel, as shown below.

3D settings
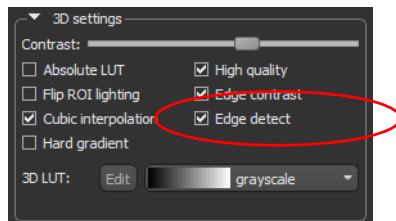
NOTE The **Gamma boost** option has been removed from the 3D settings panel. However, you should note that full gamma adjustments are available in the Window Leveling panel (see Gamma Ramp for Window Leveling on page 46).

Clip and Visual Effects

In Dragonfly 4.0, selected visual effects for clips and shapes now appear in a new *3D live effects* box, circled below. You can select the properties of a visual effect, as well as re-order effects, as previously.

Visual effects
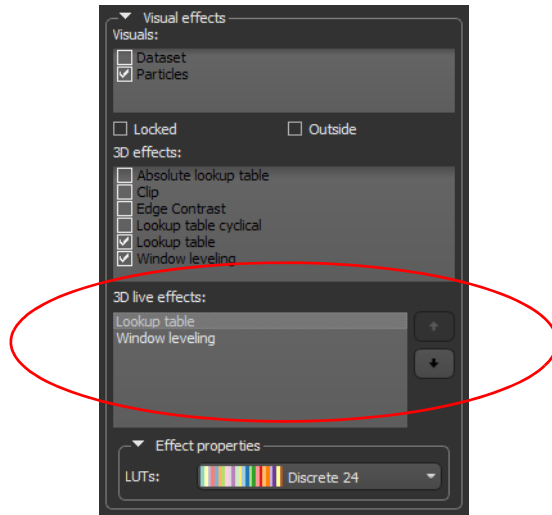
Legends

In this software release, legends can be positioned vertically or horizontally in 2D and 3D views and their height or width can be adjusted.

Legends in 3D view
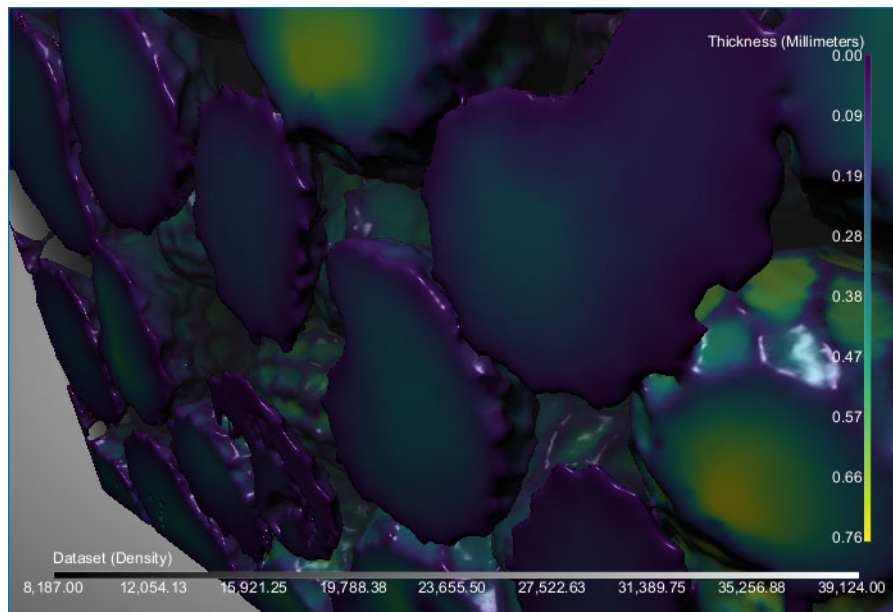
- To change the orientation of a legend, right-click the legend and then choose **Vertical** or **Horizontal** in the pop-up menu. You should note that you can choose a default

orientation for legends in the 2D Settings preferences (see 2D Settings Preferences on page 66).

• To change the width or height, drag from the start or end point of the legend, as shown below.

Histograms and Graphs

A number of additional options are now available for histograms plotted from regions, regions of interest, and meshes with scalar information. You can save an image of the figure, as well as edit captions and the plotted data range. In addition, you should note that these options are also available for intensity profiles and for the results of a slice analysis.

Histogram dialog
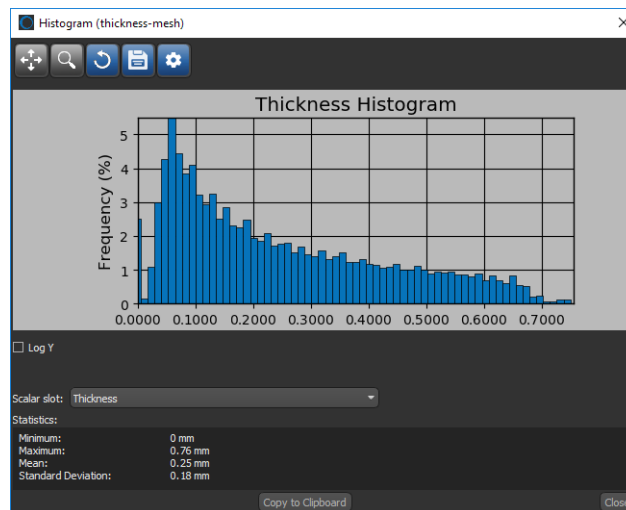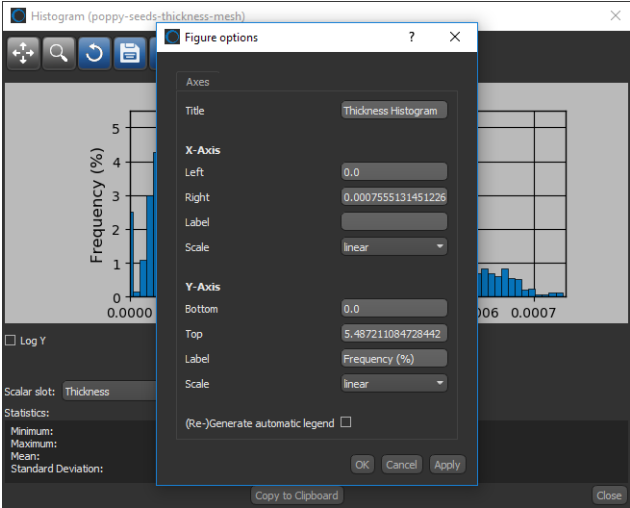
The new options for histograms and graphs are described in the following table.

New options for histograms and graphs

	Description
	Save… Saves the figure as a bitmap image, vector graphic, or in the PDF file format. The figure can also be saved as raw data or PGF code for LaTeX.

	Description
⚙	**Settings…** Lets you edit the captions on the histogram or graph, apply scaling, and set a data range. These options are available in the Figure options dialog, shown below.

Slab Thickness Adjustments for 2D Views

In previous Dragonfly versions, the slab thickness of MIPs, mIP, and average intensity projections could only be adjusted in the corresponding MPR views of the dataset. This software version includes a Slab Thickness dialog, in which a thickness value can be entered directly from the view in Slab mode.

Right-click inside the view in Slab mode and then choose **Set Slab Thickness** in the pop-up menu. You can then enter the required slab thickness in the Enter a New Slab Thickness dialog, as shown below.

New Slice Thickness dialog
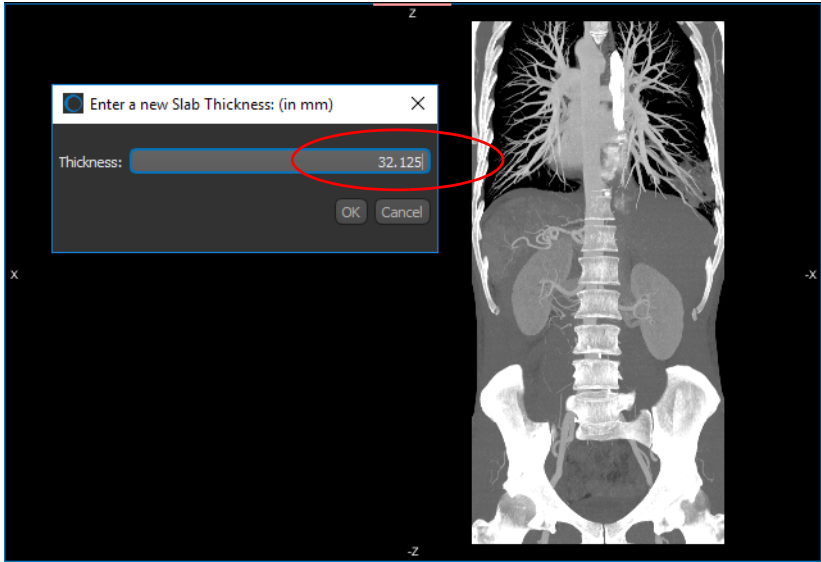
NOTE Selected slab thickness values are also now displayed in the associated MPR views, as shown below.
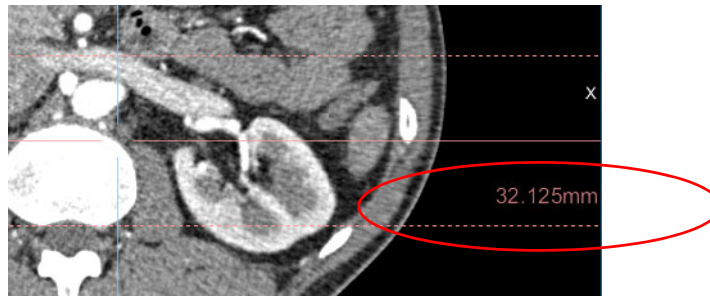
Text Annotations for 3D Views

You should note that a new interactive text annotation — that indicates the size of the 3D view when you are in Orthographic view mode or the distance to the camera pivot point (PD) for perspective views — is available in this software release for 3D views. You can drag up or down from the text annotation to adjust the zoom factor.

Text annotations for 3D views

| Orthographic projection | Perspective view |
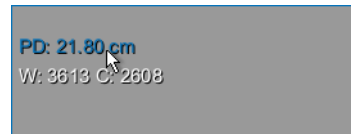
Support for RGB Images

This software release offers additional options for importing RBG images. RGB outputs are available in the File Import dialog, as shown below.

RGB output options
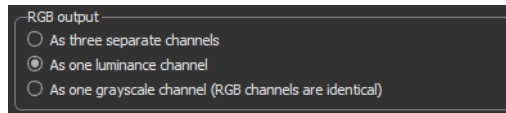
Output options for RGB images

	Description
As three separate channels	If selected, all three channels — Red, Green, and Blue — will be loaded and each separate channel will be identified as to its originating channel in the Data Properties and Settings panel. For example, *Blue Imported Data*.
As one luminance channel	If selected, the RGB image will be converted into a single-channel luminance representation. In Dragonfly, the conversion of an RGB image to a luminance channel is computed as follows: Luminance = 0.2126*R + 0.7152*B + 0.0722*G **NOTE** Refer to https://en.wikipedia.org/wiki/Grayscale for more information about luminance conversions.

	Description
As one grayscale channel (RBG channels are identical)	If selected, one channel will be loaded. You should note that if the Image Loader determines that all three channels are not identical after the loading, a message box will appear.

NOTE The above options are not available for RGBA images. For these images, all four channels — Alpha, Red, Green, and Blue — will be imported and added automatically to the Data Properties and Settings panel.

If required, you can export RGB channels in the BMP, JPEG, PNG, and TIFF file formats. Select the three separate channels on the Data Properties and Settings panel — Red, Green, and Blue — right-click, and then choose the **Export as RGB** item in the pop-up menu. You can drag channels up and down to match them to a specific output in the Export as RGB dialog, as well as replace channels.

Export as RGB dialog
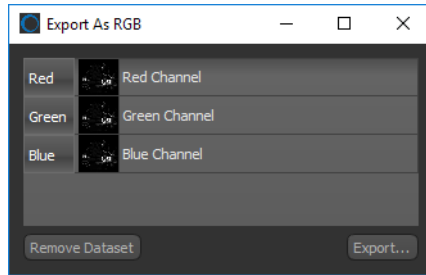
ROI Painter Tools

A number of performance related issues were addressed in this software release. These include the following:

• Acceleration of adding and subtracting with the Circular Brush tool when painting on very large regions of interest — with or without a defined range.

• Acceleration of adding and subtracting with the Square Brush tool when painting on very large regions of interest — with or without a defined range.

Measurement Inspector

A number of issues related to the performance of the Measurement Inspector were addressed in this software release. These include the following:

• Quicker response when making range selections.

• Updates for new graph requirements (see Graphing for ROIs on page 24 and Graphing for Multi-ROIs on page 32).

About Menu Items

Information in the **Help > About** menu item has been categorized by type — Actions, Image Filters, Macros, Menu Items, Object Analysis Statistics, and so on.

About submenu items
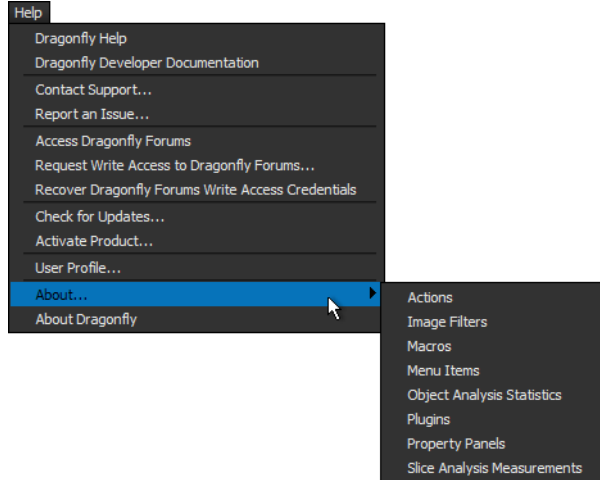
In addition, information about each item is available in a separate dialog. Double-click an item in the About Plugins dialog to view the information available for the selected item, as shown below.

About Plugins dialog
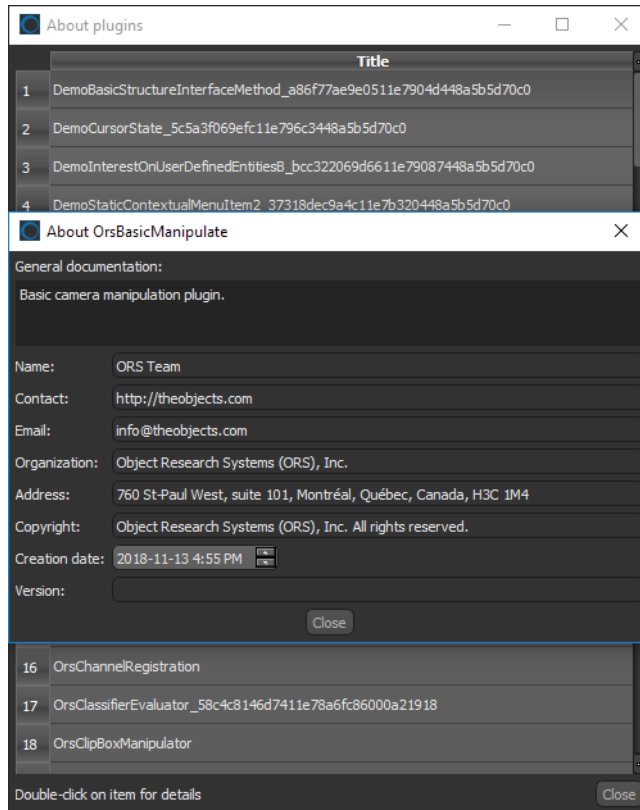
Developer Documentation

The developer documentation for Dragonfly has been updated for version 4.0. Choose **Help > Dragonfly Developer Documentation** on the menu bar to open the documentation system.

IMPORTANT NOTE Some architectural changes were implemented in Dragonfly 4.0. You may need to update development work in progress accordingly. You should also note that citations are now added automatically to user-created plugins and extensions.

Menu Bar Changes

The following changes and new items for the menu bar are implemented for Dragonfly 4.0.

File Menu

New items, listed below, and other changes are available for the File menu.

File menu changes

	Description
Open the Organizer	Opens the Organizer, which provides an easy way to organize, manage, and share your data (see Dragonfly Organizer on page 7).

Tools Menu

A number of new items, listed below, and other changes have been implemented for the Tools menu.

Tools menu changes

	Description
Bone Analysis	Opens the Bone Analysis dialog, which helps you better understand complex metabolic bone diseases (see Bone Analysis on page 8).
HyperChannel Manager	Opens the Hyper Dimensional tab on the left sidebar (see Hyper-Dimensional Imaging on page 16).
Macro Builder	Opens the Macro Builder, which provides an easy way to combine macros for batching (see Macro Builder on page 15).
Open All Users Folder in File Browser	Automatically opens the Dragonfly directory with the Python All Users Extensions folder in your installed file manager. The Python All Users Extensions folder can otherwise be found in ProgramData > ORS > Dragonfly.
Open Current User Folder in File Browser	Automatically opens the Dragonfly directory with the Python Users Extensions folder in your installed file manager. The Python Users Extensions folder can otherwise be found in AppData > Local > ORS > Dragonfly.

Help Menu

A number of new items, listed below, and other changes have been implemented for the Help menu.

Help menu changes

	Description
About	Submenu items — Actions, Image Filters, Macros, Menu Items, Object Analysis Statistics, Plugins, Property Panels, and Slice Analysis Measurements — have been added to the About item to help you find information about Dragonfly plugins easier. In addition, the available information has been augmented with attributions, contact information, and versioning (see About Menu Items on page 60).

Changes to Contextual Menus

The following changes and new items for the contextual menus are implemented for Dragonfly 4.0.

Dataset Pop-Up Menu

A number of new items, listed below, are available for the dataset pop-up menu.

Dataset pop-up menu changes

	Description
Image Stitching	Lets you precisely combine, or *stitch*, overlapping 2D or 3D image tiles to create a single high-resolution image that is beyond the normal aspect ratio and resolution of a microscope's field of view (see Image Stitching on page 12).
Add Gaussian Noise	Lets you artificially add Gaussian noise to an image (see Add Gaussian Noise on page 23).
Extract ROIs	Automatically creates a new region of interest for each intensity value in the selected dataset (see Extract ROIs on page 23).
Overwrite Dataset	Overwrites the intersecting values of a selected dataset with the corresponding values of another dataset (see Overwrite Dataset on page 23).
Create 4D Dataset	Lets you can create a 4D, or *time-enabled*, dataset from multiple volumetric datasets (see Create 4D Datasets on page 14).
Export as RGB*	Lets you export selected red, green, and blue channels as image files (see Support for RGB Images on page 58).
Stitch 3D Datasets	Lets you combine, or *merge*, multiple volumetric datasets into a single 3D dataset (see Stitch 3D Datasets on page 14).

* Available for multiple selections only.

Region of Interest Pop-Up Menu

A number of new items, listed below, and other changes have been implemented for the region of interest pop-up menu in this software release.

Region of interest pop-up menu changes

	Description
Create Graph from ROI	Lets you map pore networks by showing pore throats and porosity connections (see Graphing for ROIs on page 24).
Label Edges of Graph of ROI	Lets you automatically create a multi-ROI in which the segments contained within the selected region of interest are labeled as separate connected components (see Label Edges of Graph of ROI on page 26).
Export ROI as Binary	Lets you export a region of interest as a binary file (see Export ROI as Binary on page 32).
New Multi-ROI (6-connected)	Creates a new multi-ROI in which *connectivity* is determined strictly using the 6 faces adjacent to the current seed (see Selectable Connectivity for Processing on page 28). **NOTE** This item was previously named *New Connectivity Multi-ROI*.
New Multi-ROI (26-connected)	Creates a new multi-ROI in which *connectivity* is determined in all directions, using the 6 faces, 12 edges and 8 corners adjacent to the current seed (see Selectable Connectivity for Processing on page 28).
Multi-ROI Analysis	Replaces the item previously named *New Connectivity Multi-ROI Analysis*, which was based on 6-connected propagation.
Process Islands	Lets you remove unwanted objects or isolate objects in a region of interest (see Remove Unwanted Objects (Process Islands) on page 28).
Close Holes Smaller Than	Lets you close holes smaller than a thresholded distance (see Close Inner Holes on page 30).

	Description
Create Volume Thickness Map	Lets you measure the thickness volume of a region of interest (see Volume Thickness on page 27).
Create Geodesic Distance Map	Lets you generate a geodesic distance map that shows the shortest curve between two points along the surface of a region of interest (see Geodesic Distance Maps on page 31).
Convex Hull (as a Filled ROI)	Lets you generate convex hulls as filled regions of interest (see Convex Hulls on page 37).
Convex Hull (as an Outer Shell ROI)	Lets you generate convex hulls as outlined regions of interest (see Convex Hulls on page 37).
Convex Hull (as a Mesh)	Lets you generate convex hulls as meshes (see Convex Hulls on page 37).
Remove Objects That Touch Another ROI or Multi-ROI	Automatically removes *objects* from the selected region of interest that touch another ROI or multi-ROI (see Remove Touching Objects on page 38). You should note that objects can be defined as groups of labeled voxels that are connected.
Create ROI Using Neighbor Count	Creates a new region of interest that only contains voxels with an original neighbor count greater than or equal to a selected threshold. See Create ROIs Using Neighbor Counts on page 30
Compute Interfacial Surface	Available for multiple ROI selections, automatically computes the interfacial surface between two regions of interest (see Interfacial Surface Computations on page 27).

Multi-ROI Pop-Up Menu

A number of new items, listed below, and other changes have been implemented for the multi-ROI pop-up menu.

Multi-ROI pop-up menu changes

	Description
Import Scalar Values from a CSV File	Lets you import scalar values contained in a selected CSV file (see Import Scalar Values on page 36).
New Multi-ROI (6-connected)	Creates a new multi-ROI in which *connectivity* is determined strictly using the 6 faces adjacent to the current seed (see Selectable Connectivity for Processing on page 28). **NOTE** This item was previously named *New Connectivity Multi-ROI*.
New Multi-ROI (26-connected)	Creates a new multi-ROI in which *connectivity* is determined in all directions, using the 6 faces, 12 edges and 8 corners adjacent to the current seed (see Selectable Connectivity for Processing on page 28).
Create Graph from Connectivity	Lets you graph the inter-relationship between connected components (see Graphing for Multi-ROIs on page 32).
Convex Hull (as a Multi-ROI, Each Label Being Filled)	Lets you generate filled convex hulls for each connected component in a multi-ROI, as a multi-ROI (see Convex Hulls ON PAGE 37).
Convex Hull (as a Multi-ROI, Each Label as an Outer Shell	Lets you generate outlined convex hulls for each connected component in a multi-ROI, as a multi-ROI (see Convex Hulls on page 37).
Convex Hull (Each Multi-ROI Label as a Mesh	Lets you generate convex hulls as meshes for each connected component in a multi-ROI, as a mesh (see Convex Hulls on page 37).
Extract ROIs	Lets you extract a region of interest from each connected component in the selected multi-ROI (see Extract ROIs on page 36).
Get Merged Label as Multi-ROI	Lets you create a new multi-ROI with one labeled connected component from a multi-ROI that contains a number of labels that were previously merged (see Get Merged Label as Multi-ROI on page 37).
Remove Objects That Touch Another ROI or Multi-ROI	Automatically removes *objects* from the selected multi-ROI that touch another region of interest or multi-ROI (see Remove Touching Objects on page 38). You should note that objects can be defined as groups of labeled voxels that are connected.
Split Non-Connected Labels	Lets you a create a multi-ROI in which objects with the same label that are not connected are split (see Split Non-Connected Labels on page 36).

Mesh Pop-Up Menu

A number of new items, listed below, and other changes have been implemented for the pop-up menu for meshes.

Mesh pop-up menu changes

	Description
Mesh Smoothing	Opens the Mesh Smoothing panel, in which you can smooth meshes with a selected method and number of iterations (see Mesh Smoothing on page 40).
Mesh Subdivider	Opens the Mesh Subdivider panel, in which you can increase the resolution of the selected mesh by dividing its cells into smaller units (see Mesh Subdivider on page 41).
Get Non Manifold Edges Count	Lets you compute the number of non-manifold edges in a selected mesh (see Get Non-Manifold Edges Count on page 42).
Import Scalar Values from a CSV File	Lets you import scalar values contained in a selected CSV file (see New Options for Scalar Meshes on page 42).

Shapes Pop-Up Menu

A number of new items, listed below, are available for the Shapes pop-up menu.

Shapes pop-up menu changes

	Description
Extract a One Slice Dataset from Visual Plane*	Extracts a 2D image that corresponds to the oblique or double-oblique angle of a selected visual plane (see Extract Images from Visual Planes on page 45).
Align with Centroid	Lets you automatically align the centroid of a selected shape with the centroid of another object.
Mask ROI	Removes all labeled voxels from the selected region of interest that are outside of the shape.
Take Box Shape from Feret Of**	Reduces a box to the smallest encasing rectangle based on the maximum Feret diameter of the labeled voxels of a selected region of interest or mesh (see Take Box Shape from Feret Of on page 44).
Take Minimal Box Shape Of**	Reduces a box to the minimal encasing rectangle based on the labeled voxels of a selected region of interest or on the bounding box of a mesh (see Take Minimal Box Shape Of on page 44).

 * Available for Plane shapes only.

 ** Available for Box shapes only.

Preferences Changes

A number of new items, listed below, and other changes have been implemented for the setting the application preferences.

Views Preferences

Changes for the Views preferences are indicated in the following table.

Views preferences changes

	Description
Axis indicator size	Lets you choose the size of the Axis indicator that appears onscreen.

2D Settings Preferences

Changes for the 2D Settings preferences are indicated in the following table.

2D Settings preferences changes

	Description
Legend initial orientation	Lets you choose a default orientation for the legend(s) that appear in the scene views. **Horizontal…** If selected, legends will appear horizontally by default. **Vertical…** If selected, legends will appear vertically by default.

3D Settings Preferences

Changes for the 3D Settings preferences are indicated in the following table.

3D Settings preferences changes

	Description
Cubic interpolation	If selected, cubic interpolation will be applied by default to the objects rendered in 3D views.

Autosave Preferences

Changes for the Autosave preferences are indicated in the following table.
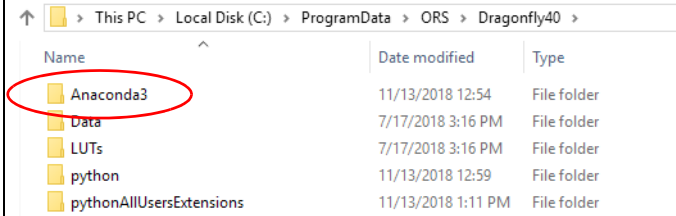
Autosave preferences changes

	Description
Objects to include in autosave file	New objects introduced in this Dragonfly release — *Vector fields* and *Graphs* — have been added to the objects list.

System Requirements Changes

This release supports the base system requirements. Any differences in those requirements are noted below.

System requirements changes

Version	Changes to system requirements
3.0.0	None.
3.1.0	None. **NOTE** Dragonfly 3.1 includes a new Anaconda distribution for Python. You should note that the current version of Python accessed by Dragonfly will be updated automatically to version 3.6 when you install this new release.
3.5.0	None.
3.6.0	None.
4.0.0	None. **NOTE** The Anaconda distribution was changed to version 5.2.0 for this software release. You should also note that the current version of Python accessed by Dragonfly will be updated automatically to version 3.6.5 when you install this new release. In addition, the Anaconda distribution will be installed in the ProgramData folder, as shown below, instead of the Program Files directory. This change was implemented to allow users to update Dragonfly without running in Administrator mode. If you are updating a previous installation, the current Anaconda distribution will be deleted from the Program Files folder.

Extending Dragonfly

Dragonfly's Infinite Toolbox, an open exchange platform for the Dragonfly user community, lets you submit, browse, and download extensions that implement new features and workflows for all of your image processing or analysis needs.

Choose **Tools > Infinite Toolbox** on the menu bar to open Dragonfly's Infinite Toolbox.

Requesting New Features

Let us know if you have a suggestion for a new feature, or an idea for an improvement to an existing workflow.

Getting Help

Learning Dragonfly

Just by taking a quick look around www.theobjects.com/dragonfly, you'll find some great free resources, such as our latest instructional videos, recorded webinars, and user forums.

Reporting Issues

Dragonfly includes an integrated reporting module that lets you include comments and other information along with generated DMP and log files whenever you encounter an issue that results in a crash or application freeze.

Send Report to ORS dialog
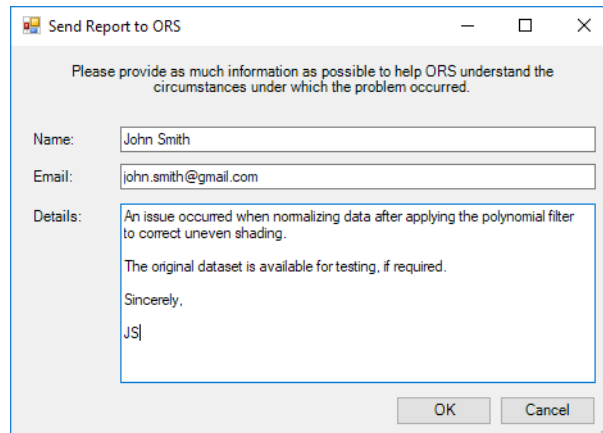
You should note that you can also report an issue at any time by choosing **Help > Report an Issue** on the menu bar.

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