

Simpleware Base

Release Version V-2024.06

June 10, 2024

Import Formats

- DICOM (version 3.0 and 2D stacks) including:
 - 4D (time-resolved) DICOM with time step selection
 - Option to store DICOM tags with imported data
- DICOM encapsulated STL surface models
- ACR-NEMA (versions 1 and 2)
- DICONDE
- Interfile
- Analyze
- Meta-image
- Raw image data
- 2D image stacks:
 - BMP
 - GIF
 - JPEG
 - PCX
 - PNG
 - TIFF
 - XPM
- Natively supported pixel types:
 - 8-bit Unsigned Integer
 - 16-bit Unsigned Integer
 - 16-bit Signed Integer
 - 32-bit Floating Point
- STL
- PLY
- IGES/IGS
- STEP/STP
- Stack of images (BMP, JPG, PNG, TIF)
- DICOM
- Background 4D image:
 - RAW image (all frames/active frame)
 - MetaImage (all frames/active frame)
 - Stack of images (active frame only)
 - DICOM (active frame only)
- Segmented 3D image:
 - RAW image
 - MetaImage
- Segmented 4D image:
 - Mask RAW (all frames/active frame)
 - Mask MetaImage (all frames/active frame)
- Surface model (triangles):
 - STL
 - IGES
 - 3MF
 - OBJ
 - PLY
 - ACIS (SAT)
 - ANSYS surface
 - ABAQUS surface
 - Open Inventor
 - Point cloud
 - MATLAB file surface
 - DICOM encapsulated STL
- Animations:
 - AVI
 - Ogg Theora
 - H.264/MPEG-4 AVC
 - Windows Media Video (WMV)
 - PNG sequence

Export Formats

- Background 3D image:
 - RAW image
 - MetaImage

- Transparent PNG sequence
- 2D and 3D screenshot:
 - JPEG
 - PNG
 - Postscript (*.eps)
 - BMP
 - PNM
 - PDF
 - Generate virtual X-Ray, with object burn
- Export scene – export the current 3D view:
 - 3D PDF
 - 3MF
 - OBJ
 - PLY
 - VRML
- Slice views: display orientation labels, choose whether to use a dark background, specify model contour and mask voxel outline colors
- PACS: two-way PACS communication, configure access (servers, ports, keys etc.)
- Segmentation: options to adjust behavior of some segmentation tools and set Hounsfield presets for the Threshold tool
- 3D view: save last camera position before exiting the document, stereo rendering settings, options to further divide higher-order mesh elements (for FE meshes and NURBS patches)
- Volume rendering: GPU rendering supported, Background volume rendering visibility on startup
- Folders: options to change locations of temporary files
- Statistics: default template for Mask, Model and Centerline statistics
- Number formatting: customize how numbers are formatted within Simpleware software
- Annotations: set default styles for annotations
- Scripting: enable/disable supported scripting languages
- Licensing: change license location
- Miscellaneous: reset suppressible dialogs, clear the undo/redo stack, mask name/color creation options

General User Interface

- Modern ribbon interface
- Custom ribbon with user-selected tools (My tools)
- Quick find search feature for tools
- User-defined customization: dockable toolboxes, range of 2D/3D view options
- Undo/redo operation support
- Independent part visibility control in 2D and 3D
- Keyboard shortcuts: set user-defined shortcuts to commands or tools to customize and speed up repeated workflows
- Ability to import multiple image sets into the workspace to aid segmentation
- Histogram and profile line utilities assist in finding optimal threshold values
- Automatic logging and timestamp of filters and tools applied since the creation of a project
- Workspace tabs: toggle between the active document, mask statistics, model statistics, centerline statistics, the document log, and the scripting interface
- Integrated dynamic help tool
- Interactive tutorials
- Links to external support resources
- Visualize surface and mask objects together
- Preferences – a number of different options available for default settings:
 - General: number of undos to save, default startup layout, max permissible CPUs for parallelized operations

2D User Interface

- 3x 2D views
- Orientation labels
- Scale bars
- DICOM information overlay
- Interactive cropping using 2D view
- Window/Level values and control options
- Ability to work on single slice, selection of slices or whole volume
- Slice cursors to identify the position of 2D slices
- Mask visualization options: solid, translucent, voxel outline
- View 3D model contours from model/3D view, surface objects and volume meshes on 2D slices
- Multi-planar reconstruction through translation and rotation of reslicing axes

3D User Interface

- Background volume rendering: using standard presets or greyscale mapping
- Single mask volume rendering
- Interactive cropping using 3D view

- Clipping box: unconstrained, interactive sectioning of 3D rendering
- Fast 3D preview mode for rapid visualization of segmentation: ability to change preview quality to speed up rendering and reduce memory consumption
- Live 3D: automatic 3D volume rendering refresh of masks
- Mask transparency
- Wireframe mode
- Vertex lines superimposed over surfaces mode
- Lighting and 3D rendering adjustments
- Background adjustments:
 - Single color
 - Two color gradient
 - Skybox
- View surface entities: CFD boundary conditions, node sets, contacts, shells
- View contours of greyscale-based material properties
- Model shading options: none, flat, Gouraud, hardware shader
- Fullscreen mode
- Camera control tool
- Load and save 3D view camera positions
- View slice planes
- Slice intersection position widget
- Show image dimensions on scale axes
- 3D stereoscopic visualization with selected hardware modes available:
 - Crystal eyes
 - Red/blue
 - Interlaced
 - Left
 - Right
 - Dresden
 - Anaglyph
 - Checkerboard
- Shear
- Align
- Register datasets: align background images to other background images or any other dataset type based on sets of landmark points and/or automatic greyscale-based registration
- Basic filters (most commonly used):
 - Smoothing: recursive Gaussian, smart mask smoothing, de-stepping
 - Noise filtering: mean filter, median filter
 - Cavity fill
 - Island removal filter
 - Fill gaps tool (using largest contact surface or mask priority)
 - Bone filling
- Advanced filters (more specialist applications):
 - Binarization
 - Combine backgrounds
 - Connected component
 - Gradient magnitude
 - Lattice factory
 - Local maxima
 - MRI bias field correction (N4)
 - Masking filter
 - Morphological by reconstruction
 - Sigmoid
 - Simplify partial volume
 - Slice propagate
 - Distance maps:
 - Danielsson
 - Signed Maurer
 - CT correction:
 - CT image stabilizer
 - Histogram cylindrical equalization
 - Histogram slice equalization
 - Metal artefact reduction
 - Smoothing and noise removal:
 - Bilateral
 - Curvature anisotropic diffusion
 - Curvature flow
 - Discrete Gaussian
 - Gradient anisotropic diffusion
 - Min/max curvature flow

Image Processing Tools

- Data processing:
 - Crop
 - Pad
 - Rescale
 - Shrink wrap
 - Resample using various interpolation techniques: nearest neighbor, linear, majority wins and partial volume effects
 - Flip

- Patch-based denoising
- Level sets:
 - Canny segmentation
 - Fast marching
 - Geodesic active contours
 - Laplacian level set
 - Shape detection
 - Threshold level set
- Skeletonization:
 - Pruning
 - Thinning
- Morphological filters:
 - Erode
 - Dilate
 - Open
 - Close
 - 3D Wrap
- Segmentation tools:
 - Paint/unpaint
 - Paint with threshold
 - Smart paint
 - Interpolation toolbox – contains the following options:
 - Slice interpolation: smooth or linear
 - Slice propagation: adapts to image or uses direct copy
 - Confidence connect region growing
 - Background flood fill
 - Mask flood fill
 - Threshold
 - 3D editing tools for application of filters to local regions: option to apply in multiple regions and on camera facing surface only in advanced tool version
 - Mask ungroup tool
 - Automated generation of masks for pre-segmented images
 - Magnetic lasso
 - Multilevel Otsu segmentation
 - Split regions tool, with the ability to mark regions in the 3D view
 - Merge regions tool
 - Direct copy: background to mask or mask to background
 - Watershed segmentation tool
- Boolean operations – applied to/between masks. General and Venn diagram UI options:
 - Union
 - Intersect
 - Subtract
 - Invert
- Local surface correction: local, greyscale-informed correction of mask surface, including the ability to apply on a region of interest only
- Multi-label tools – use mask labels to label different regions within a mask. Use for statistics and visualization:
 - Label disconnected regions
 - Split mask into pores
 - Combine masks to multi-label mask
 - Mask label editor
 - Reports (automatically generate pre-formatted reports of common metrics using a multi-label mask or full model's mesh):
 - Particles report
 - Pores and throats report
- Window/level tool
- Overlap check: display/generate mask to check overlap volume in active masks

Statistical Analysis

- Quick statistics: quickly compute commonly required quantities (volume, surface area, average greyscale, etc.)
- Mask statistics (based on voxel information):
 - Built-in templates: general statistics, contact statistics, material statistics, orientation, pore sizes, surface statistics
 - Ability to generate user-defined templates
 - Variety of statistical information pertaining to:
 - Voxels: count, volume, surface area, etc.
 - Greyscales: mean, standard deviation, minimum, maximum, etc.
 - Surface estimation: area, area fraction, volume, volume fraction, etc.
 - Material properties: mass, mass density, Young's modulus, Poisson's ratio, moment of inertia, etc.
 - Axis-aligned bounding boxes
 - Axis-aligned bounding ellipsoids
 - Object-oriented bounding boxes
 - Object-oriented bounding ellipsoids
 - Create a user-defined statistic
- Model statistics (based on polygon information):
 - Ability to generate user-defined templates

- Built-in templates: general statistics (perimeters, surfaces, volumes and NURBS surfaces), mesh quality (CFD, FE-linear elements and FE-quadratic elements), orientation (perimeters, surfaces, volumes), pore sizes, surface quality (linear, quadratic), volume mesh statistics
- Variety of statistical information pertaining to:
 - Surface parameters: element count, node count, edge count, etc.
 - Perimeters: length, mean edge length, mean dihedral angle, etc.
 - Surface triangle and quadrilateral primitives: edge- length, in-out ratio, distortion, etc.
 - Tetrahedral, hexahedral, pyramid and prismatic volume element primitives: angular skew, volume skew, shape factor, Jacobian, etc.
 - Axis-aligned bounding boxes
 - Axis-aligned bounding ellipsoids
 - Object-oriented bounding boxes
 - Object-oriented bounding ellipsoids
 - Create a user-defined statistic
- Centerline statistics:
 - Built-in templates: line orientation, lines by network, lines by node, constriction, shape, twist, nodes by network
 - Ability to generate user-defined templates
 - Variety of statistical information pertaining to:
 - Lines: count, network, length, Euclidean length, curvature, torsion, closed, looped, positions, orientation, connection count, cross-sectional area and perimeter, incircle radius, twist, control points, object-oriented bounding boxes, mean orientation vector, best fit circle, inscribed radius, circumscribed radius, bounding ellipse radius
 - Nodes: name, mask, network, position, line count, connection count.
 - Create a user-defined statistic
 - Probe centerlines to get measurements at specific locations
- Save and import user-defined templates and statistics
- Compute statistics within user-defined regions of interest (ROIs)
- Copy the centerlines generated during the analysis to the centerlines editor for further editing or analysis
- Statistics for analyzed region or region of interest:
 - Analyzed volume, fiber volume, fiber density, principal orientation
 - Eigen analysis (major, medial, minor vectors and value)
 - Orientation tensor
 - Fiber length and cross-section information
- Plot statistics, export as *.png or *.csv:
 - Angle to principal orientation histogram
 - Angle to image axis histogram
 - Orientation tensor components vs image axis
 - Fiber density vs image axis (requires segmentation)
 - Principal orientation hedgehog diagram
 - Length of whole fibers histogram
 - Diameter of all segments histogram (incircle/best fit circle) (requires segmentation)
- Visualize vectors:
 - Orientation vectors, Eigen vectors, Eigen ellipsoids in 3D view
 - Orientation vectors in 2D slices
 - Change color scheme, and glyph density/scale/width
 - Export as *.csv or *.txt files
- Map to mesh:
 - Export (or assign using Simpleware Elite or Apex) fiber orientation information per mesh cell
 - Average orientation tensor, eigenvector and eigenvalue data calculated for each mesh cell
 - Export volume fraction information per mesh cell (requires segmentation)

Fiber Orientation Analysis

- Allows fiber orientation to be analyzed directly from the image data (without the need for segmentation)
- Option to include a mask representing the fiber region for fiber volume and diameter information
- Specify the fiber diameter and the sampling size to be analyzed for the whole image or a region of interest

Particle Analysis

- Allows particles (either isolated or touching) to be analyzed from a mask or multi-label mask
- Two types of pore analysis available:
 - Touching: for particles that are in contact with each other
 - Isolated: for particles that are separated from each other
- Statistics for analyzed region or region of interest:
 - Particle volume (Total, Mean, SD, Min, Max)
 - Particle area (Mean, SD, Min, Max)
 - Particle volume fraction
 - Particle equivalent volume sphere diameter (Mean, SD, Min, Max)
 - Particle bounding box extent (Mean, SD, Min, Max)

- Particle ellipsoid diameter (Mean, SD, Min, Max)
- Particle flatness
- Particle elongation
- Particle shape factor
- Particle sphericity
- Plot statistics, export as *.png or *.csv:
 - Volume histogram
 - Area histogram
 - Flatness histogram
 - Elongation histogram
 - Shape factor histogram
 - Sphericity histogram
- Particle visualization:
 - Contact count
 - Voxel count
 - Surface area
 - Boundary contact area
 - Label contact area
 - Volume
 - Max greyscale
 - Mean greyscale
 - Major length
 - Flatness
 - Elongation
 - Shape factor
 - Sphericity
 - Orientation angle to x/y/z axis
 - Orientation to mean
 - Export as *.csv or *.txt files
- Map to mesh:
 - Export (or assign using Simpleware Elite or Apex) particle volume fraction information per mesh cell
- Internal pore volume (Mean, SD, Min, Max)
- Internal pore surface area (Mean, SD, Min, Max)
- Pore equivalent volume sphere diameter (Mean, SD, Min, Max)
- Pore flatness (Mean, SD, Min, Max)
- Pore elongation (Mean, SD, Min, Max)
- Pore shape factor (Mean, SD, Min, Max)
- Pore sphericity (Mean, SD, Min, Max)
- Pore coordination number (Mean, SD, Min, Max)
- Throat contact count
- Throat contact area
- Throat radius (Mean, SD, Min, Max)
- Throat flatness (Mean, SD, Min, Max)
- Throat elongation (Mean, SD, Min, Max)
- Throat eccentricity (Mean, SD, Min, Max)
- Throat shape factor (Mean, SD, Min, Max)
- Plot statistics, export as *.png or *.csv:
 - Volume histogram
 - Area histogram
 - Flatness histogram
 - Elongation histogram
 - Shape factor histogram
 - Sphericity histogram
- Particle visualization:
 - Contact count
 - Voxel count
 - Surface area
 - Boundary contact area
 - Label contact area
 - Volume
 - Max greyscale
 - Mean greyscale
 - Major length
 - Flatness
 - Elongation
 - Shape factor
 - Sphericity
 - Orientation angle to x/y/z axis
 - Orientation to mean
 - Export as *.csv or *.txt files
- Map to mesh:
 - Export (or assign using Simpleware Elite or Apex) pore volume fraction information per mesh cell

Pore Analysis

- Allows pores (either open or closed) to be analyzed from a mask or multi-label mask
- Two types of pore analysis available:
 - Open: for connected pore networks
 - Closed: for pores that are separated from each other
- Statistics for analyzed region or region of interest:
 - Total pores count
 - Total throat count volume
 - Volume fraction

Surface Mesh Generation

- Topology and volume preserving smoothing
- Triangle smoothing
- Decimation
- Multipart surface creation
- Surface element quality control (for volume meshing in third party software)
- So-called 'sub-pixel accuracy' through the use of partial volume effects data

Surface Mesh Quality Inspection Tool

- Inspect surface triangles or clusters of triangles
- Option to show mesh errors (e.g. surface holes, surface intersections) and warnings
- Show distorted elements above a user-defined threshold
- Display quality metric histograms
- Zoom into the pathological element to inspect it more closely

Measurement Tools

- Create and save points, distances and angles in 2D/3D
- Visualization options to display all at once or selected
- Snap to 3D surface option
- Profile line
- Histogram
- Export as comma-separated values
- Centerline creation toolkit:
 - Centerline creation (general)
 - Centerline creation for fibers
 - Junction editing
- 2D contour measurements:
 - Creation mode
 - Area
 - Total perimeter
 - In-circle diameter
 - Out-circle diameter
 - Trigone-Trigone (TT) distance
 - Septal to Lateral (SL) distance
 - Intercommissural (IC) distance
 - Posterior perimeter
- Mask similarity calculator:
 - Dice score
- Wall thickness analysis tool for masks or surface objects, using a raycasting or sphere fitting algorithm

- Shape-based measurement tools:
 - Shape editor: create, edit, visualize, export and measure shapes
 - Shape fitting: fit shapes to geometry
 - Shape-to-shape measurements: obtain measurements between shape objects
- X-ray image import, with alignment and object registration

3D Printing Toolkit

- Set of tools for editing, analyzing and visualizing surfaces before sending them to a 3D printer which includes:
 - Preparation tools:
 - Model preview
 - Mask to surface
 - Emboss text
 - Hollow
 - Cut
 - Create connectors (inc. manual and automatic options)
 - Pins and sockets connectors
 - Design tools:
 - Create cutting guide
 - Analysis tools:
 - Greyscale visualization
 - Inspection tools:
 - Color proofing
 - Check printability
 - Export a variety of file formats including:
 - 3MF
 - STL
 - OBJ
 - PLY
 - 3D PDF
 - VRML

Animations

- Create and export animations in the 3D view
- Built-in-quick animations:
 - Rotations
 - Slice reveals
 - Volume rendering
- User-defined animations cues:
 - Background colors
 - Camera (orbits, follow path and key frame-based)

- Clipping
- Opacity
- 2D slice planes
- Volume rendering
- Export formats:
 - AVI
 - Ogg Theora
 - H.264/MPEG-4 AVC
 - Windows Media Video (WMV)
 - PNG sequence
- Variety of export sizes: from 480p to 2160p (4K)

4D Frame Toolbox

- Active frame slider to manually control frame displayed in the 2D slice views and 3D view
- Cine mode for active slice view and 3D view
- Compare frames: compare two 2D slice views to examine differences
- Options to set the time between frames and delete unwanted frames

Working with Surface Data

- Surface to mask tool – conversion of surface objects to image masks by voxelization. Three available methods:
 - Accurate for manifold objects: when converting watertight surface object
 - Accurate for non-manifold objects: when converting non-watertight surface object
 - Robust: Less accurate but failsafe option for poor quality surface objects
- Mask to surface tool: use the current 3D visualization of a mask to create a surface object
- Create shape – generate surface object primitives:
 - Cuboid
 - Cylinder
 - Sphere
 - Cone
 - Tube
- Sweep centerlines: create surface objects from centerlines or centerline networks
- Manipulate surface objects both interactively and by absolute position and orientation:
 - Transform
 - Rotate
 - Scale: aspect ratio preserving or along specified axis

- Zero position: move surface object to the image space origin
- Use global, local or user-defined axis for object manipulation
- 2D nudge tool to fine tune position of surface object in 2D views
- Snap registration tool: automatic registration of two surfaces with no additional inputs
- Register datasets tool – register surfaces to other surfaces or any other dataset types:
 - Register to datasets in the current project or a foreign project (a separate Simpleware project file)
 - Best fit algorithm to align surface objects together with 3 methods: landmark, automatic, landmark and automatic
 - Landmark: uses picked landmark points on the moving and fixed surface objects
 - Automatic: uses all points on the moving and fixed surface objects
 - Landmark and automatic: uses landmark registration initially, then automatic registration for fine tuning
 - Root mean square error (RMSE) reported
- Check and fix tool: check for surface errors and attempt to fix them
- Group surfaces: group surface objects into one single object
- Ungroup surfaces: create new surfaces by separating a surface object into its connected components
- Surface to surface Boolean operations – general and Venn diagram interface options:
 - Union
 - Intersect
 - Subtract
- Smooth – surface triangle smoothing:
 - Option to preserve volume
 - Option to preserve edges above a user-defined angle threshold
- Subdivide – increase triangle count, e.g. to better capture surface curvature, with the following methods:
 - Adaptive linear
 - Linear
 - Butterfly
 - Loop
- Flatten: project triangles to a plane
- Decimate: reduce triangle count by percentage reduction or maximum number of triangles
- Remesh: regenerate surface triangulation based on target edge length
- Remove triangles: delete unwanted triangles

- Fill holes – in a surface’s triangulation:
 - Displays number of holes and smallest/largest hole diameter
 - Fill all holes or fill holes up to a user-defined maximum hole size
- Resurface: use voxelization and iso-surface extraction to re-triangulate surface objects
- Clip: cut a surface object using finite plane
- Extrude: extrude selected triangles in a specified direction
- Hollow: hollow a surface object, creating an inner and outer surface
- Sweep: dilate the triangles of a surface object inwards and outwards to create a tube (Specialist option only)
- Auto-pad: auto pad the image boundary to contain surface object
- Feature edge editor: visualization and selection of feature edges that the meshing algorithms should try to preserve
- Interactive clipping box for section views of surface objects in 3D
- Surface deviation analysis tool – comparison of a test surface:
 - Tool allows re-meshing of surfaces (user can set edge lengths required)
 - Options to set distance limits for deviation analysis
 - Surface deviation on regions of interest or the whole part can be calculated
 - 3D color map with customizable scale, and option to set out of range color
 - 3D color map also allows the user to set nominal and critical thresholds for positive and negative values
 - Annotate visualization with minimum and maximum surface deviation
 - Probe the visualized surface deviation to show point deviation values
 - Statistical values calculated for:
 - Upper and lower deviation
 - Mean (overall), mean positive and mean negative
 - Root Mean Square Error (RMSE)
 - Percentage area above critical and nominal positive deviation
 - Percentage area below critical and nominal negative deviation
 - Export statistics as text file

Internal Structures Wizard

- Allows shelling and adding a range of internal structures flexibly to any surface object
- Applications include reducing material usage and weight of 3D printed models
- Unit cell types available are:
 - Schwartz primitive
 - Schwartz primitive (pinched)
 - Schwartz diamond
 - Schwartz 'W'
 - Schoen gyroid
 - Neovius' surface
 - Cylinder grid
 - Schwartz primitive (2.5D)
 - Schwartz primitive (pinched) (2.5D)
 - Schwartz 'W' (2.5D)

Scripting

- The Simpleware Application Programming Interface (API) is an object-oriented programming library that allows access to most of the features of Simpleware
- Support for a variety of scripting languages:
 - Python 3
 - C#
- Macro recording: record, save and play macro
- Convert log entry to script
- Script editor with autocomplete functionality
- Console: a GUI-less version of Simpleware which can be run with scripted workflows