Simpleware Medical Base
Release Version W-2024.12

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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

Export Formats

- Background 3D image:
  - RAW image
  - MetaImage

- 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
  - Transparent PNG sequence

- 2D and 3D screenshot:
  - JPEG
  - PNG
  - Postscript (EPS)
  - BMP
  - PNM
  - PDF
  - Encrypted PDF
  - Generate virtual X-Ray, with object burn
- Export scene – export the current 3D view:
  - 3D PDF
  - 3MF
  - OBJ
  - PLY
  - VRML

General User Interface

- Modern ribbon interface
- Custom ribbon with user-selected tools (My tools)
- Customizable GUI profiles (create, edit, save and import)
- 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

- 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

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

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

- Shear
- Align
- Morph datasets: morph masks, surfaces, volume meshes and point measurements between project files (requires registration) and 4D time frames
- 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:
  - 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
- 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)

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
- 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 files:
  - 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 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)

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 files:
  - 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 particle 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

- 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 files:
  - 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 pore volume fraction information per mesh cell

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
- Wall thickness analysis tool for masks or surface objects, using a raycasting or sphere fitting algorithm
- Mask similarity calculator:
  - Dice score

- 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
- 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

*Information About Tools Not Cleared as a Medical Device

Please note: tools with an asterisk (*) are intended for non-clinical research use only, and have not been cleared for use as a medical device in accordance with U.S. Food & Drug Administration (FDA) 510(k) or European Union CE marking standards.