Simpleware:
Converting 3D Images into Numerical Models
Company Overview
Simpleware

Developers of world-leading image processing environment for the conversion of 3D images into numerical models.

- Image-based meshing software and services for your research in:
  - Biomechanics
  - Materials
  - Natural Sciences
- Headquartered in Exeter, UK
- US sales office and world-wide reseller network
- Global customer base
Simpleware Software

Automatic conversion of 3D images into high quality CAD models and meshes, which can be directly used for:

- Computer Aided Design (CAD)
- Rapid Prototyping (RP)
- Finite Element Analysis (FEA)
- Computational Fluid Dynamics (CFD)
Target Markets & Applications

Medical & Dental
- Biomechanics & Orthopaedics
- Implant Design
- Physiological Flows
- Consumer Products
- Cell Mechanics

Materials & Geology
- Oil & Gas
- Non-destructive Evaluation
- Composite Analysis
- Material Characterisation
- Pore Scale Fluid Flow

Natural Sciences
- Palaeontology
- Archaeology
- Functional Morphology
- Food Sciences
- Pollination
Software Solutions
Image-Based Meshing

Robust, high quality surface and volume meshing of multipart objects with conforming interfaces

Stack of 2D Images

Identify Voxels of Region of Interest - Segmentation

Volume & topology preserving smoothing to generate 3D object
Direct approach - from scan to model

Scanning
Volume image data
e.g. MRI, CT, µCT etc

simpleware

ScanIP
Image processing
Volume mesh generation

CAD & FE/CFD
Model

+CAD
CAD import & positioning
ScanIP software
Image Processing/Segmentation
ScanIP – Base Module

Complete image processing environment for importing, filtering, segmentation and visualisation of volume images.

- Import wide range of data formats
  - Dicom, stacks of images, Raw images, volume images etc.
- Filters: can be applied both on image and segmented mask data
  - Noise reduction, smoothing, morphological, metal artefact reduction...
- Manual and automated segmentation tools
  - Paint, paint with threshold, threshold, region growing, floodfill
- 3D editing tools for interactive segmentation in 3D view
  - Apply filters (smooth/dilate/delete) on local regions in 3D view
ScanIP – Base Module

Complete image processing environment for importing, filtering, segmentation and visualisation of volume images.

- Robust and high quality multipart surface mesh generation
  One click required to generate STL for RP/CAD or surface meshes for FE packages

- 2D and 3D measurement and statistics
  Volume fractions, porosity, surface areas, centre of mass, moments of inertia, av/sd greyscale values, point-to-point distances (2D/3D), mask connectivity

- Wide range of visualisation options
  Full screen view, backgrounds, lighting, 3D stereo, vertex lines, clipping

- Full 64bit support and automatically parallelises

- Intuitive and user friendly interface
  Quick to learn, tooltips, fully documented, log history
+CAD – Bolt on Module

- Direct import of most common CAD formats
  STL, IGES, STEP, 3DS

- Interactive 3D positioning widget or constrained motion
  Rotate and translate using mouse or type in values

- Superimpose image data for improved positioning
  Volume rendering and clipping to help position implants

- CAD primitives for surgical template generation
  Create cylinders, tubes, spheres, cuboids within application

- Internal micro-architecture generation
  Import STL file to shell out and replace with internal structure,
  Reduce material usage and weight for RP applications

- Import and repair dirty CAD data
  Import poor quality STL and use image processing techniques to fix -> mesh
+FE – Plugin Module
FE/CFD mesh generation
Unique Features
Unique features of Simpleware

*Simpleware’s technology has several key advantages:*

- **Image Filters**: wide range and flexible
- **Multi-part meshing**: robust automated mesh generation for topologies of arbitrary complexity and with any number of constituent materials/phases
- **Image-based accuracy**: the geometric accuracy of mesh domains is only dependent on image accuracy
- **Surface/Volume mesh quality**: automatic high qualities and user definable
Wide range of image filters

Extensive list of basic and advanced filters to help reduce noise in the image or clean up the segmentation

- Noise
- Metal artefact
- Closing
- Cavity Fill
3D Editing Tools for Interactive Segmentation
Unique features of Simpleware

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- **CAD/Surface mesh quality**: high quality triangulation of the surfaces
- **Volume mesh quality**: high quality tet or hex/tet volume discretization of the domains
Automatic handling of multiparts

- Smoothing and meshing multiple segmented regions, important to maintain interfaces from segmentation to model
Automatic handling of multipart

- Smoothing and meshing multiple segmented regions...
  Traditional part-by-part approaches risk poor meshing, gaps/overlaps, non conforming interfaces.

Traditional approach
Build parts one by one

Simpleware algorithms
Unique features of Simpleware

Simpleware’s technology has several key advantages:

• **Multi-part meshing**: robust automated mesh generation for topologies of arbitrary complexity (such as foams) and with any number of constituent materials/phases

• **Image-based accuracy**: the geometric accuracy of mesh domains is only dependent on image accuracy

• **CAD/Surface mesh quality**: high quality triangulation of the surfaces

• **Volume mesh quality**: high quality tet or hex/tet volume discretisation of the domains
Smoothing – Topology Preservation

- Accuracy of 3D model from segmentation to smooth 3D surface/volume mesh

Unsmoothed voxel model

Traditional non-topology preserving smoothing

Simpleware topology preserving smoothing
Smoothing – Volume Preservation

- Accuracy of 3D model from segmentation to smooth 3D surface/volume mesh

Unsmoothed voxel model 204 mm³

Traditional smoothing 193.9 mm³
~5% loss

Simpleware smoothing 203.5 mm³
~<0.5% loss
Image-based accuracy: Partial Volume

No loss of accuracy during smoothing

a. Binary interpolation
b. Greyscale based interpolation
Image-based accuracy: Partial volume

Binary interpolation  Greyscale interpolation
Unique features of Simpleware

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+FE-Grid mesh

Extracts +FE-Grid surface mesh

+FE-Free remeshes surface according to features

+FE-Free fills remeshed volumes with tet elements
Meshing Options

- Surface meshes – single and multipart
- Volume meshes – single and multipart
- Additional mesh features –
  node sets, surfaces, shells and CFD boundary conditions
Choose **+FE-Free Algorithm**

Set Your Coarseness Level

Edit Advanced Parameters – Optional
+FE Free mesh controls
Multipart Mesh Decimation (+FE Free)

Interactive mesh refinement zones

- Draw and position a refinement volume on 3D rendering
- Define degree of refinement and mesh
- Control surface and internal mesh densities
- Can work on multiple parts....
Multipart Mesh Decimation (+FE Free)

Interactive mesh refinement zones

Volume

Surface Only
Initial scripting implementation

- Scripting user interface in ScanIP
Initial scripting implementation

- Simpleware API
Case Studies
- Biomechanics/Biomedical -
Head Model for Realistic Simulation

- **In vivo MRI scan of 26 year old male**

- **Segmentation**
  - Threshold, floodfill and filters
  - Segmentation of 12 structures

- **Multi-part mesh generation**
  - 12 structures meshed simultaneously
  - Multipart smoothing with conforming interfaces

- **FE analysis Abaqus and LS-Dyna**
  - Boundary conditions and loads
  - Response to blast wave and to dynamic loading conditions

*In collaboration with: Naval Research Laboratory and ARUP*

Head Model for Realistic Simulation
Dental Model

- **In vivo CT scan**
- **Segmentation**
  - Threshold, floodfill and filters
  - Teeth and mandible
- **+CAD**
  - Introduce template
  - Use template to position implant
- **Multi-part mesh generation**
  - Teeth, mandible and implants
  - Multipart smoothing with conforming interfaces
- **FE analysis in COMSOL**
  - All boundaries and domains available for selection in COMSOL

*In collaboration with: COMSOL Italy*
Investigating Vascular Complications using Computational Fluid Dynamics

- **Abdominal Aortic Aneurysms**
  - Balloon like distensions which are prone to rupture causing life threatening complications
  - Endovascular repair (EVAR) – treatment

- **Patient specific models**
  - Segmented in ScanIP
  - Adaptive surface mesh - ScanFE

- **Boundary conditions**
  - Inlets and superior/inferior outlets

- **Outcome**
  - Analyses may prove useful in determining dangerous hemodynamic factors, allowing for improved risk assessment, assisting the choice between treatments/surgeries

*Thanks to: Dr. Samuel Thrysøe  
MR-Center, Aarhus University Hospital Skejby*
Designing and Manufacturing Patient-Specific Implants

Workflow
- Using ScanIP to process the patient CT data to provide an accurate STL to the bone geometry
- Then use the Delcam software tools to design and manufacture an implant

ScanIP
- Segmented in ScanIP
- Volume and topology preserving

Delcam
- CopyCAD – design – tribrid modelling
- Partmaker – production CAM
- Powermill – tool paths for CNC machine

Outcome
- From image to implant in 1 week

Thanks to:
Chris Lawire, Delcam
Chirs Whittington, Camplex
New features include:

- Boundary layer meshing for FE models
- New ABAQUS CFD export option
- Orientation overlays for medical applications
- ROI-defined boundary straightening
- Mesh snapshots
- Improved transparency visualization
- Improved slice planes
- ROI creation from a mask’s shape
Simpleware Version 7.0 – what’s new?

Introduction of the new Physics Modules

- Extend ScanIP’s capabilities with fully integrated modules
- Calculate wide range of effective material properties
- Run full simulations with built-in FE solver or use quick semi-analytical estimates
- Visualise and create animations from your data

Scripting:

- Automate repeatable tasks and operations
- Use macro recording interface to translate actions into programming code
Simpleware Version 7.0 - Physics Modules

Features of the Physics Modules

<table>
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<th>Feature</th>
<th>+SOLID Module</th>
<th>+FLOW Module</th>
<th>+LAPLACE Module</th>
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<td>Generate High Quality Volume Meshes (Hex/Tet or All Tet)</td>
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<td>Automated Greyscale based Material Property Assignment</td>
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<td>Calculate Effective Thermal and Electric Properties</td>
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<tr>
<td>Visualise FE Simulation Results</td>
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Overview of the Physics Modules - +SOLID Module

Calculates the effective stiffness tensor and individual elastic moduli of material samples. Perform numerical homogenisation with a built-in FE solver or derive quick semi-analytical estimates from segmented images.

- Calculate effective stiffness tensor/elastic moduli
- Full simulations with built-in FE solver
- Model multiphase materials
- Quick semi-analytical estimates
- Visualise deformations, stress and strain
- Assess isotropy/orthotropy levels.
Overview of the Physics Modules - +FLOW Module

Calculates the absolute permeability tensor of samples of porous materials. Numerical homogenisation is performed using a built-in Stokes solver.

- Calculate absolute permeability;
- Full simulations with built-in solver;
- Visualise velocities and pressures;
- Assess isotropy levels.
Overview of the Physics Modules - +LAPLACE Module

Calculates the effective properties of materials whose behaviour is governed by the Laplace equation, including electrical conductivity/permittivity, thermal conductivity and molecular diffusivity. Perform numerical homogenisation with a built-in FE solver or derive quick semi-analytical estimates from segmented images.

- Calculate effective electrical conductivity and permittivity
- Calculate thermal conductivity
- Calculate molecular diffusivity
- Full simulations with built-in FE solver
- Quick semi-analytical estimates
- Visualise fields
- Assess isotropy levels.
Conclusions
Summary

- Using Simpleware you can ...
- ...generate **accurate models** easily and **rapidly** simulation/analysis - allows image processing to move beyond descriptive/statistical analysis of data
- ...mesh **any number of structures** simultaneously (handles multi-part junctions) and **define contact surfaces** between them - interfaces are without gaps or overlaps.
- ...generate coupled finite element and finite volume meshes for **multi-physics** applications
- ...**incorporate designs** in the image data – predict and compare the performance of different designs

=> Development based on customer needs
Simpleware Forum

www.simpleware.com/forum

- Post questions, suggestions or share knowledge with other users
- Download archived webinars and training videos
- Access download links for the latest software version
Simpleware Reseller

Computational Mechanics Laboratory, LLC (CompMechLab® Ltd.) – official Simpleware reseller in Russia, CIS, Baltic States, Poland and Finland

CompMechLab® Ltd. supplies enterprises, R&D centres and universities with licenses, provides technical support and maintenance, as well as tutorial courses.

Address: 195220, Gzhatskaya str., 21, build. 2, of. 217, St. Petersburg, Russia
Phone/Fax: +7 (812) 309-18-88
Mobile: +7 (921) 881-41-30

Contact person: Anton Aleksashkin, CAE Software Distribution Department Director
E-mail: Aleksashkin@CompMechLab.com, Baltsii@CompMechLab.com