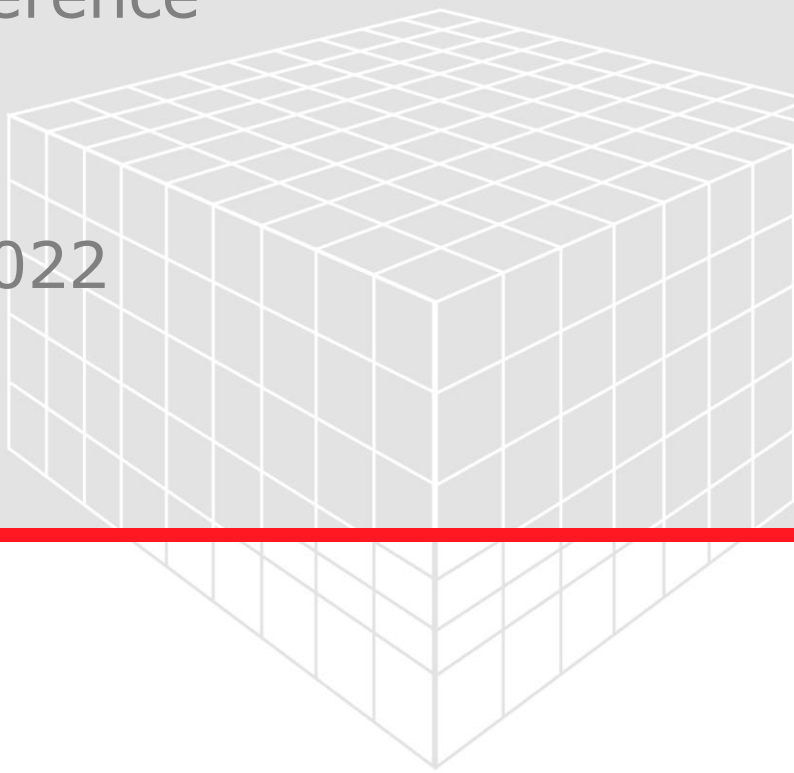
GeoDict®

GUI and Base Reference



User Guide

GeoDict release 2022

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GeoDict

https://doi.org/10.30423/userguide.geodict2022-basereference

INTRODUCTION TO GEODICT

GeoDict® is the innovative, integrated, and user-friendly material simulator and predictor developed by Math2Market®. GeoDict is the software for multi-scale 3D image processing, material characterization and analysis, material modeling, visualization, and property analysis.

GeoDict is the tool needed for non-destructive material characterization, for the reduction of high-cost and time-consuming laboratory analysis, and for innovative, fast, and competitive material engineering.

GeoDict allows you to:

- **Import** and **segment** 3D- image data from micro-CT scans, nano-CT scans, or FIB/SEM-scans and
- **Convert** this imported 3D-image data into 3D material models.
- **Characterize** and **analyze** 3D morphological and physical material properties of these structure models by simulation. The **Dict** modules provide computational results of characteristics of pore space and solid materials, and physical properties such as flow velocity, permeability, effective elastic coefficients, and more. Effective flow properties and effective mechanic properties can be simulated for any 3D digital object. Advanced computations, for combined complex physical properties such as saturation-dependent material properties, or pore size distribution analysis are also available.
- **Output and export** data for input into CAE tools and other software packages. Export to Fluent™ and Abaqus™ are available without further need for mesh generation beyond the previous export to standard 3D image formats, surface triangulations, and ASCII formats.
- **Design** novel materials on the computer. The **Geo** modules, or structure generation modules, include nonwoven fibrous structures, paper and foams, woven structures, granular and sintered structures, pleats, and various regular structures with arrays of objects. Characteristic to all random structures is that they are defined through some average properties. This means that any time you generate one, a different structure appears.

  Structure manipulation includes virtual compression, morphological operations, simple image filtering, and construction of overlapping and layered structures, and many more.
- **Visualize** 3D material models and property characterization results
- **Analyze** and **plot** property characterization results
- **Script** command sequences in Python to automate time-consuming, routine parameter studies or use editable pre-defined scripts (GeoApps) to quickly obtain results fitting a common process.

GeoDict application in industry sectors

GeoDict is used worldwide for simulation-driven material development, property characterization, and process optimization in many industrial sectors. Among others:

- Filtration - Design of filter media and filter components, and optimization of filtration and separation processes for the automotive industry (catalytic converters), and design of membranes for industrial and environmental ultrafiltration (water, air).
- Oil & Gas (Upstream) - Digital Rock Physics, Digital Sand Control, and Digital Hydraulic Fracturing for Enhanced Oil Recovery (EOR) in the upstream oil and gas industry sector.
- Electrochemical storage and alternative power sources - Simulation of processes and design of components of fuel cells and batteries for the automotive industry.
- Composites, ceramics, metals and foams – Design of materials and non-destructive testing of properties (mechanical, thermal, electrical, flow) and simulation of processes for the automotive, aerospace, and alternative energy (wind) industries.
- Hygiene – Design of woven and non-woven media for personal care and health industries.
- Weaves & Paper - Simulation of processes and design of paper dewatering felts and forming fabrics for the paper industry.
- Biomedicine, Biotechnology, Bioengineering – Studies of structural properties of porosity and diffusivity in scaffolds for regenerative implants, study of assemblies of supramolecular synthons, study of diffusivity in fungal pellets for production and extraction of proteins, organic acids and natural products, etc.
- Thermal and electrical insulation - Design of thermal and electrical insulation media and simulation of thermal and electrical processes for construction and textile industries.
- Acoustic insulation – Design of acoustic insulation media and simulation of processes for sound insulation.
- Simulations for colloid transport and bio-geochemical interfaces for water remediation.
- Simulations of flow for the delivery of pain alleviation medication through pump infusion systems.
- Simulations of micro particle filtration and clogging phenomena in microfluidic devices.

GeoDict modules

The GeoDict software suite is organized into modules which can be combined to suit the needs of specific applications in numerous industrial sectors.

GeoDict Base (with Pre- and Post-processors)

- Structured, clear, and user-friendly Graphical User Interface, ray caster-render-engine for fast and advanced 2D / 3D visualization, electron microscope view (SEM), and result viewer. Image and video capturing and processing tools for professional editing of images and the creation of sophisticated videos from material models and simulation results.
- ImportGeo-Base imports GeoDict formats (GeoDict analytic data (.gad), GeoDict binary data (.gdt), GeoDict ASCII (.leS) and GeoDict 32 bit data (.g32).
- ExportGeo-Base exports GeoDict material models and 3D-image data as volume image (.raw, .vol) and GeoDict analytic data (.gad), as well as Avizo binary files (.am) and 2D image stacks (as .png files).
- GadGeo is the module to manually construct and manipulate analytic object material models for easy and interactive fine-tuning by object for adjustment of material models in 3D.
- ProcessGeo modifies and transforms 3D structure models: cleanse, rescale, dilate, add binder, compress, reassign, etc.
- LayerGeo layers and combines 3D structure models.
- GeoLab is the GeoDict interface to Matlab® to automate processes and for seamless integration into current user workflows.
- GeoPython is the automation interface integrated in GeoDict and based on Python 3.6. With GeoPython, commands and functions can be recorded, edited, and executed as scripts prescribing sequences of operations without intermediate user interaction (macro) and with automatic parameter variation.
- GeoDexcel for the analysis of GeoDict result data in a customized Microsoft Excel® spreadsheet.

GeoDict modules for digital material design

- FiberGeo generates digital nonwoven and fiber reinforced composite models when given the statistical properties. This can be used to design materials with the same geometric properties as 3D material models from imported image data from µCT, nCT, or FIB/SEM, and study the influence of single parameters during the development and the calibration stages.
- PaperGeo is the generalization of FiberGeo for cellulose natural fibers and generates digital paper models. In addition to the usual parameters specified for fibers in FiberGeo, the fibers may change diameter and have torsion.
- GrainGeo generates digital granular and sintered ceramic material models, randomly close sphere-packed and piled structure models, and dense packs and piles of objects with arbitrary shapes. The generated model reproduces the randomness of the real structure and not its exact geometry. Advantages of using

GrainGeo generated models include the available high-resolution display, their periodicity, and the generation of countless structure variations.

- FoamGeo models regular Kelvin structures (closed-cell foams, open-cell foams) and random foams.
- WeaveGeo generates digital woven models based on thread distances, thread diameter, number of filaments, and weave pattern.
- GridGeo models membrane layers as grids of spheres, cylinders, or foils with conical holes.
- PleatGeo is the module to generate pleated filter models.
- MeshGeo is the module to create triangulated models from GeoDict models and directly from gray values of CT-scans. It offers helpful functions for post-processing the triangulations and making them ready for workflows with CAE software. MeshGeo is delivered within ExportGeo-CAD.

GeoDict modules for digital material analysis and property prediction

In 3D models generated in GeoDict and in 3D material models from imported 3D image data from µCT, nCT, or FIB/SEM,

- FiberFind identifies fibers and binder quantitatively using trained neural networks (FiberFind-AI and BinderFind-AI) and determines the length, the diameter, the orientation, and the curvature of fibers in fibrous media. FiberFind works directly on 3D scans obtained through µCT or FIB/SEM.
- GrainFind identifies grains and pores quantitatively with advanced algorithms and determines grain volume, diameter distribution and sphericity. It identifies binder in structures using trained neural networks (GrainFind-AI). GrainFind works directly on 3D scans obtained through µCT or FIB/SEM.
- PoroDict determines pore structure characteristics such as geometrical pore size distribution, porosimetry and percolation paths, and estimates porous structure's surface area, open and closed porosity, and the chord length distribution for the study of the properties of porous media.
- MatDict is, with PoroDict, the module to characterize porous media. MatDict analyzes the geometry of the material components of porous media. It provides the structure's material information, such as connected components, 1D- and 2D-statistics (for density distribution), and GAD-Objects orientation (for realized anisotropy).
- DiffuDict calculates effective diffusivity and tortuosity factor in porous media.
- ConductoDict computes the effective thermal and electrical conductivity, respectively, in porous media and composite materials.
- FlowDict simulates fluid flow (air, gas, water, oil, etc.), and calculates hydraulic properties such as pressure drop/velocity curves, flow velocity, flow resistivity, and flow permeability.
- ElastoDict computes effective mechanical properties (Young's modulus and full elasticity tensor), compression, and large deformations for porous and composite materials.

- FilterDict simulates filtration processes on various length scales. On filter media structure models, it computes pressure drop, MPPS, filter efficiency and filter lifetime. On 3D models of filter elements or complete filters including the filter housing, it determines flow patterns, pressure drop and filter lifetime. FilterDict visualizes particle motion and deposition, filter media clogging and cake formation.
- BatteryDict is the module to design and analyze battery structures and to simulate the charging, discharging and cycling of Li-ion batteries.
- AddiDict simulates the transport of solid particles in liquid-flow or gas-flow through porous materials. It provides effective diffusivities, breakthrough-curves, time-dependent particle concentrations as well as residence times of the particles in the different materials and the possibility to compute first order chemical reactions.
- SatuDict calculates saturation dependent material parameters such as capillary pressure curves, two-phase flow, relative permeability, relative diffusivity, and relative thermal and electrical conductivity.
- AcoustoDict computes the effective acoustic parameters needed for the Delaney Bazley and the Allard Johnson models, which calculate the acoustic properties of materials.

GeoDict interfaces to other software

- With ImportGeo-Vol and ImportGeo-CAD, GeoDict can import data from µCT- and nanoCT-scans or FIB/SEM image data of different 3D image file formats, and CAD file formats such as STL files.

  ImportGeo converts these formats into 3D-material models for material analysis or property analysis with other modules of GeoDict or external software packages.
- With ExportGeo-Base, ExportGeo-CAD, ExportGeo-Fluent, and ExportGeo-Abaqus, GeoDict can export 3D-material models as voxelized data, analytic data, RAW, VOL, Avizo binary files (AM), or PNG files, and as CAD formats (STL, WRL, OBJ, X_T, IGS, STP, SAT), and enables computations with Fluent™ and Abaqus™ on structures generated with GeoDict.

DOCUMENTATION AND SUPPORT

This GeoDict Base Reference and the handbooks of the modules are aimed to familiarize you with the GeoDict software and to assist in using it efficiently.

The Base Reference:

- gets you started with GeoDict and explains GeoDict's terminology
- provides information on file management, conventions in GeoDict and morphological operations,
- describes GeoDict's GUI layout and briefly depicts GeoDict's basic functionality.

The handbooks for every GeoDict module are designed to clarify the functionality of the module by describing their GUI screen layouts and performing specific simulation tasks on sample applications.

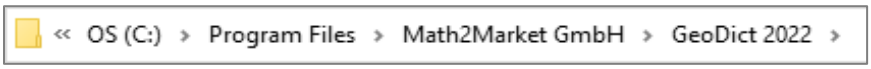
- Complete and up-to-date on-line documentation is available at www.geodict.com/Support/UserGuide.php
- Tutorials with step-by-step instructions to complete a task with GeoDict are available at www.geodict.com/Support/tutorials.php
- Workshop Videos and Video Tutorials for different applications are very useful to get started with simulations in GeoDict. They are available at www.geodict.com/Support/Workshops-TutorialVideos/workshop-tutorialvideos.php or can be found directly in the Math2Market YouTube channel.
- Math2Market GmbH offers specific training courses and online seminars for GeoDict. Information on current online seminars is accessible at www.geodict.com/Events/seminars_and_workshops.php
- Have a look at the GeoDict forum (forum.math2market.de) to find answers to specific questions or to post a question yourself.
- Additional personal assistance is reachable by contacting support(at)math2market.de.

FILE MANAGEMENT

INSTALLATION, SETTINGS, AND PROJECT FOLDER

GeoDict works with three different folders for the management of installation settings, user settings, and user result files:

- The **installation folder** is the folder where GeoDict and the solver executables of the downloaded version are located. Among others, it also contains site-specific default settings.



- The **settings folder** is created during the process of licensing and installation. The settings folder contains user-specific default settings, the license file, log files, etc. It is located at **~/.geodict2022** in Linux and at

in Windows.

- The **project folder** contains the files with user-defined options and parameters for the generated structures and the result files from the solvers' computations after working with GeoDict. It might be created and placed by the user at his/her convenience or, by default, is located at

GeoDict File formats and extensions

The file extensions for the most important GeoDict files are as follows:

GUF	GeoDict universal file	Contains ASCII header followed by binary data. GUF is designed to contain all information on 3D images in a single file. Instances are saved by their own suffix and not found as .guf, e.g., .vap (velocity and pressure file), .das (displacement and stresses file), .gof (GeoDict orientation file, object orientation and position), .grw (GeoDict raw file, for gray-value images), .gpt (GeoDict particle trajectory), or .gpp (GeoDict particle position)
.gad	GeoDict analytic data	File format to store material models with analytic data. Save through **File → Save Structure as...** in the menu bar. See the GadGeo2022 handbook of the User Guide.
.gdr	GeoDict result file	Created during structure generation and the run of the solvers by all property predictors. Contains generation statistics and all solver results.
.gdt	GeoDict compressed file	Preferred file format to store and load structures in GeoDict. Save through **File → Save Structure as...** in the menu bar. Since GeoDict 2019, analytic data can be stored in .gdt files as well and not only voxel data.
.py .gmc	GeoPython file GeoDict macro file (deprecated)	Stores all parameters and settings recorded during GeoDict processes. Record a .py macro through **Macro → Start Macro Recording...** in the menu bar
.gps	GeoDict project settings file	Store the entries set in an option or parameter Edit dialog in the GUI by clicking the saving icon at the bottom of the corresponding dialog.

IMPORTED, EXPORTED, AND SAVED FORMATS IN GEODICT

	Import into GeoDict using
.gdt .leS .gad .g32	ImportGeo-Base
.raw .cur .vol .gif .grw .ico .gdt .jpeg .leS .jpg .g32 .pbm .rek .pgm .am .png .txm .ppm .vox .svg .iass .svgz .tif .xbm .bmp .xpm	ImportGeo-Vol
.stl .obj	ImportGeo-CAD

	Export from GeoDict using
.gad .vol .raw .png .am	ExportGeo-Base
.stl .igs .wrl .stp .x_t .sat .obj	ExportGeo-CAD
.msh .neu	ExportGeo-Fluent
.inp	ExportGeo-Abaqus

	Save formats with GeoDict
.gdt .gad .leS .raw	3D voxelized or analytic objects generated with GeoDict	**File → Save Structure as...**
.png .xbm .bmp .jpg .pgm .pbm .xpm .ppm	Image formats saved by GeoDict	**File → Save Image as...**
.mp4 .mpg .mkv	File formats to save movies of models and results in GeoDict	**File → Save Video as...**
.vap .gvf .das .pas .hht .dst .gof .gpp .leS .cap .g32 .gpt .est .raw	File formats for visualization of structure models and simulation results.	Saved by GeoDict solvers
.pde .cff .log	File formats for parameter input to solvers and generators	Saved by GeoDict solvers

GeoDict sample structures

Sample structures can be downloaded in **.gdt** or **.png** file format.

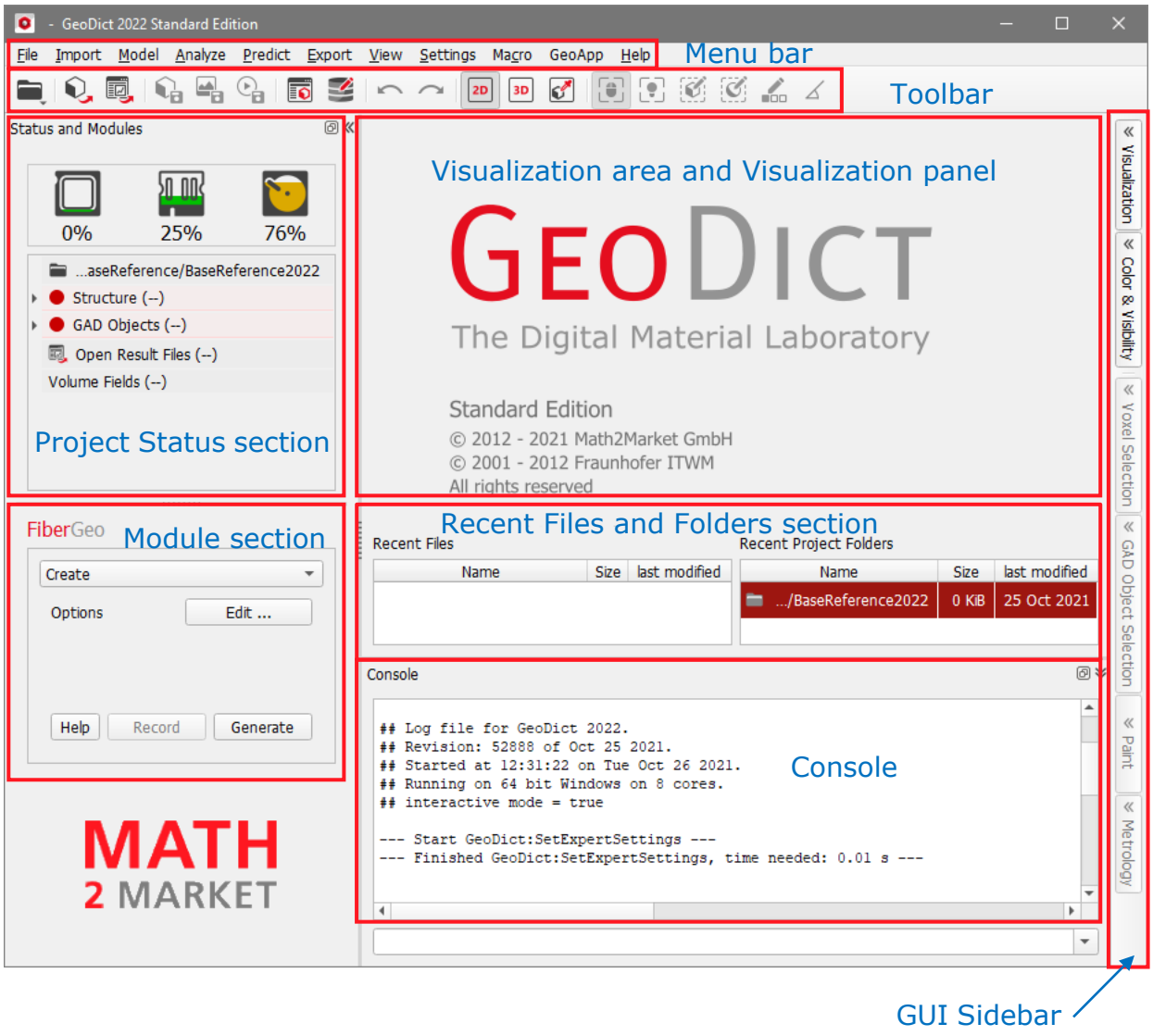
Some of them are too large to perform flow or strength calculations for them on single processor machines. GeoDict on multi core 64-bit computers brings this capability to desktop PCs.

Sample structures may be found in the gallery of GeoDict Structures on the Math2Market website.

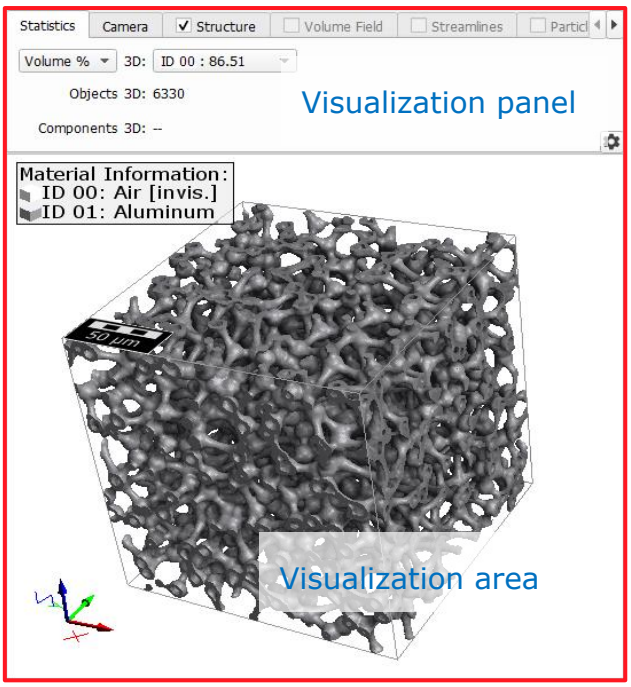
GeoDict Graphical User Interface

The standard GeoDict GUI (Graphical User Interface) is partitioned into **Menu bar**, **Toolbar**, **Project Status** section, **Module** section, **Visualization area** and **Visualization panel**, **GUI Sidebar**, **Recent Files and Folders** section, and **Console**.

At the program start, the heading for the **Module** section is for one of the licensed modules, e.g., the FiberGeo module. The **Visualization area** shows the program's splash screen.

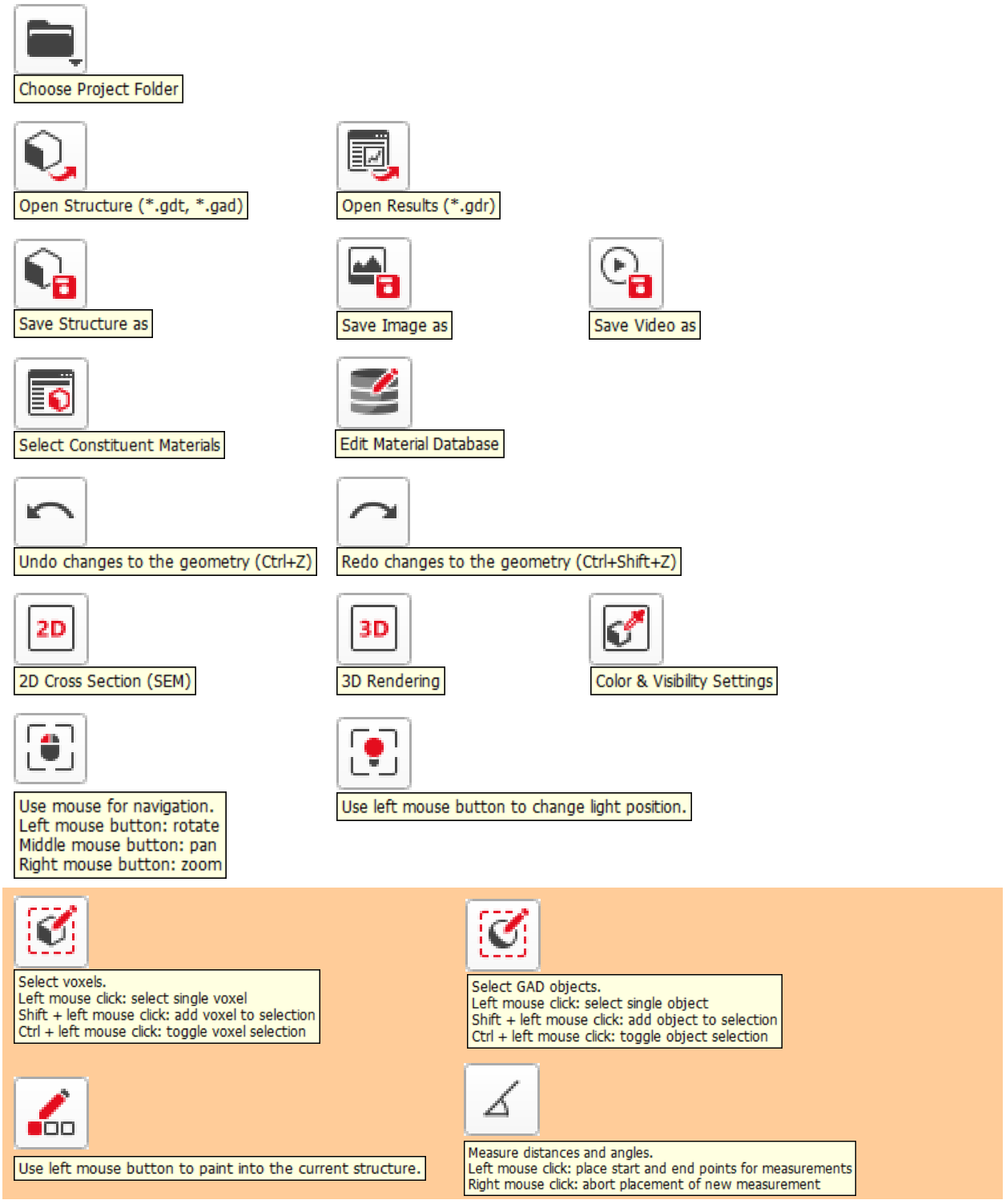


When a structure model is displayed, a **Visualization panel** with several tabs appears above the **Visualization area** to control the visualization of the structure or the results computed for it.



TOOLBAR

The **Toolbar** displays tools for selected functions, mostly included in the **Menu bar**, frequently used in GeoDict. Resting the mouse pointer over a tool for a moment prompts a tool tip explaining the function.



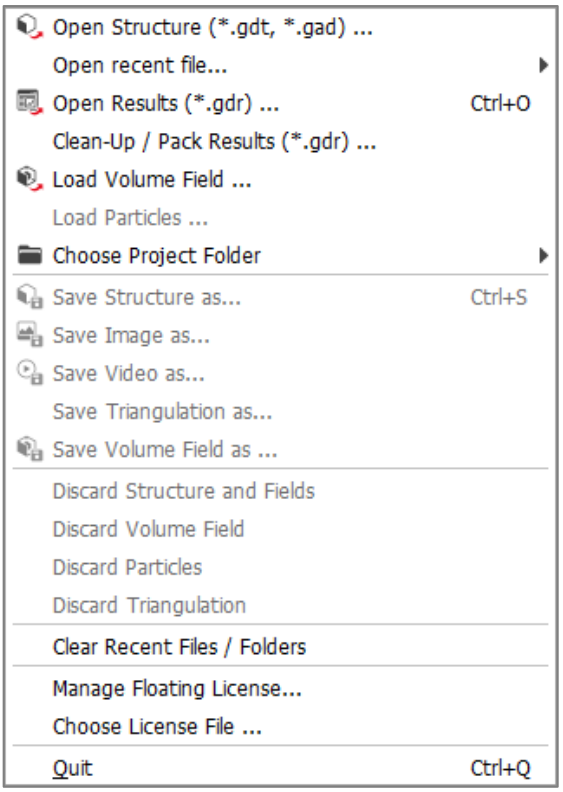
The selecting and editing functionality of Voxel Selection, GAD Object Selection, Paint and Metrology are part of the GUI Sidebar, and thus, are explained below starting on page 61.

Menu bar

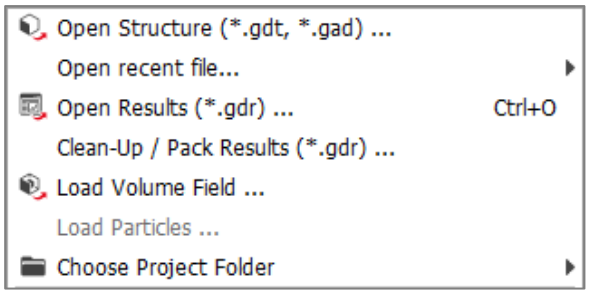
The **Menu bar** contains the menus: **File**, **Import, Model**, **Analyze, Predict, Export, View**, **Settings**, **Macro**, **GeoApp**, and **Help**. Their functions are accessible by scrolling down in the pull-down menus.

File

The **File** menu entries are organized into panels:



Open files, pack and Load results, Project Folder



Select **Open Structure (*.gdt, *.gad) ...** to open a saved generated structure file in **GDT** format (GeoDict compressed format) or in **GAD** format (GeoDict analytic data). Such files are usually saved and, thus, located in a personal project folder created by the user for the current project.

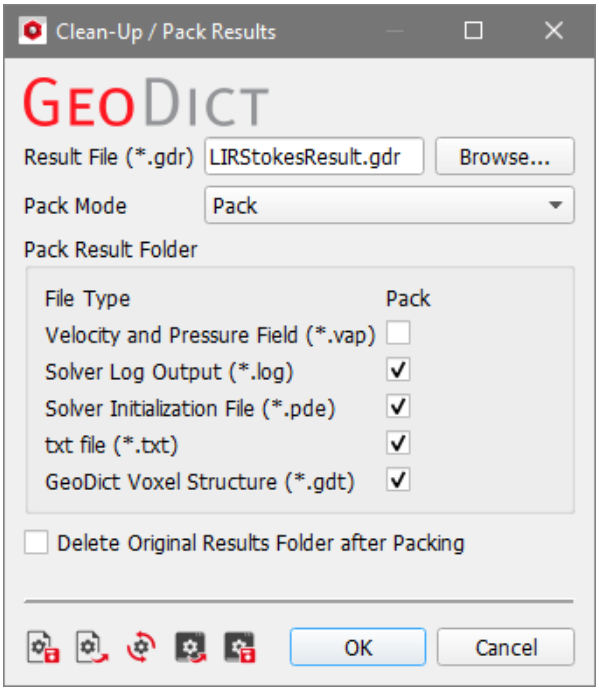
Select **Open recent file...** to choose a file from a list with the files opened or created in the last GeoDict session.

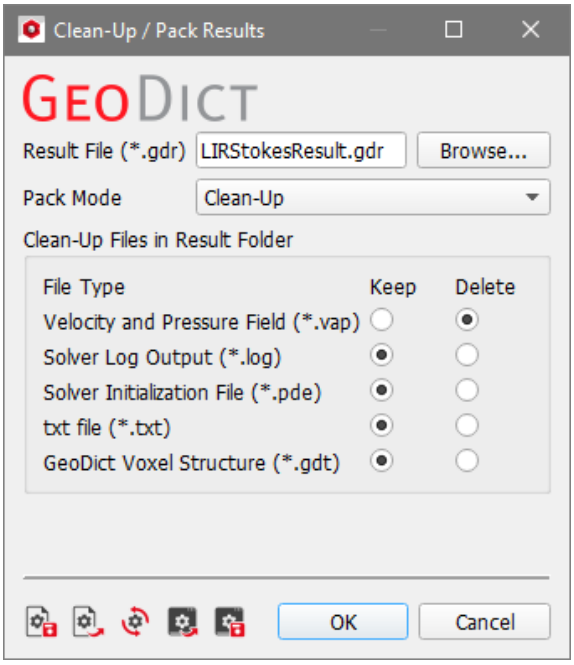
Select **Open Results (*.gdr) ...** to open and load result files in **GDR** format (GeoDict results), obtained from a previous run of a GeoDict solver or structure generator, and saved in the project folder.

The toolbar icons  and  are the shortcuts to open structures and results.

Clean-Up / Pack Results (*.gdr) ... allows to choose a result file and its result folder and to decide how the files that it contains should be handled.

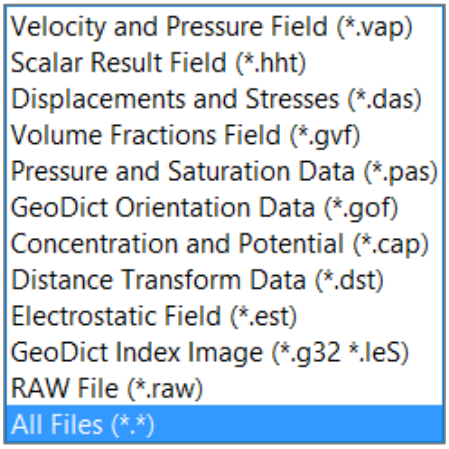
The user can decide if a particular **File Type** in the results folder should be kept or deleted. The results folder with the kept files can be packed. The original files can be kept or deleted after packing (**Delete Original Results Folder after Packing**)





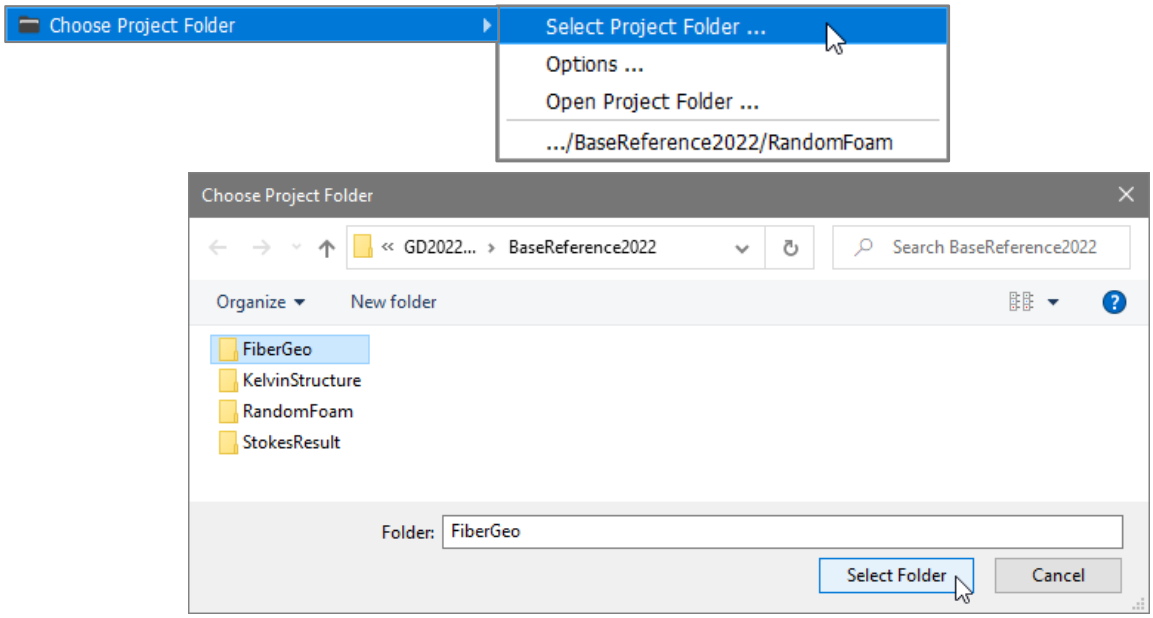
Select **Load Volume Field...** to open and visualize volume fields, e.g., .vap files (velocity and pressure) located in the result folders. The user can open and load result files for visualization in numerous formats.

If a compressed volume field is opened, it is possible to load the field in compressed form or to decompress it during loading. A compressed field is saved when checking **Write Compressed Volume Fields** under the Solver tab of the **LIR Solver Options** dialog. Notice, that some operations and visualization features of volume fields are available only if the field is loaded in uncompressed form.

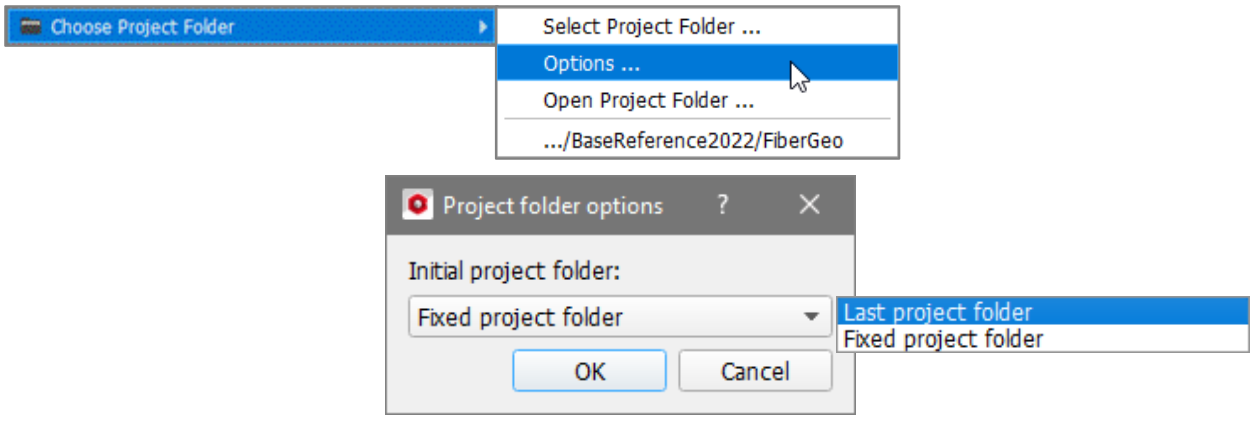


Select **Load Particles...** to open and visualize particle trajectories and particle positions for FilterDict or AddiDict simulations (.gpt and .gpp files).

In **Choose Project Folder...**, click **Select Project Folder...** to open the **Choose Project Folder** dialog. Find the path to a previously created and already listed project folder (see also page 7), or right-click in the dialog to create a new project folder to save the results and settings files produced with GeoDict.



Follow **Choose Project Folder... → Options...** to set up how the project folder is selected at the start of GeoDict. **Last project folder**, or a **Fixed project folder** can be selected.



The **project folder** will contain the files with the generated structures and the result files from the solvers' computations.

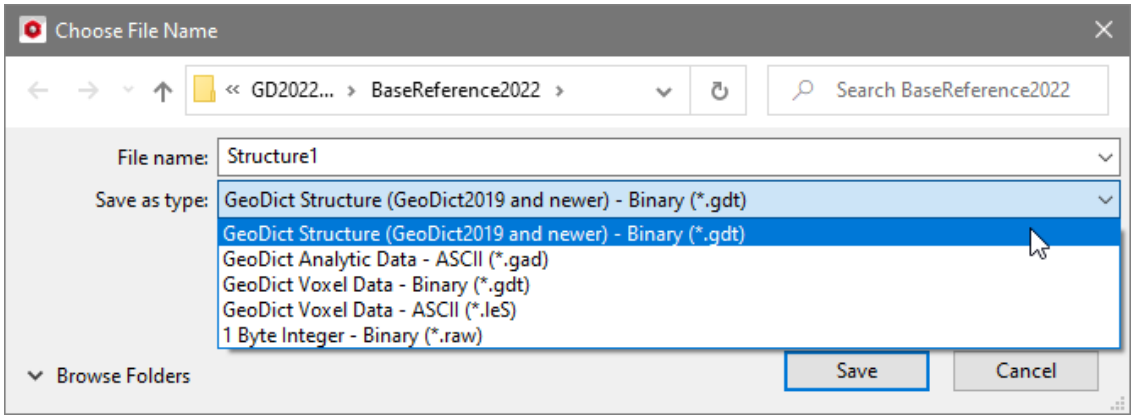
The location of the project folder is defined by the user at his/her convenience. The initial project folder for the first start of GeoDict, is located in Windows, by default at...

SAVE STRUCTURE, IMAGE, VIDEO, TRIANGULATION, OR VOLUME FIELD

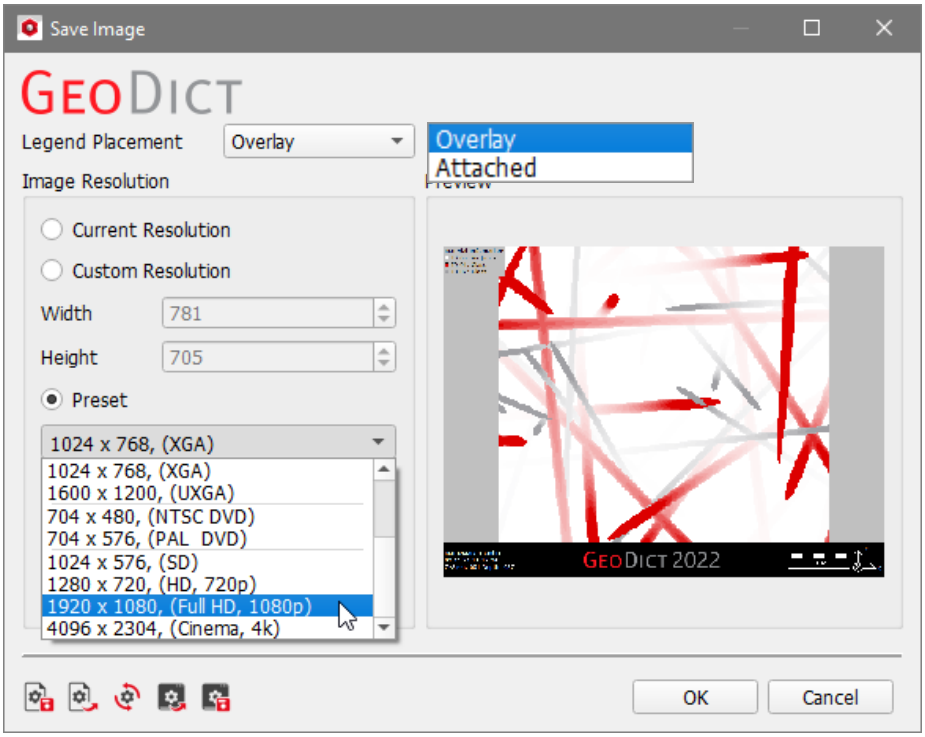
Select **Save Structure as ...** to save the generated structure in the supported file formats (**GDT**, **GAD**, **leS**, and **RAW**).

The file containing the structure data should be saved in the project folder.

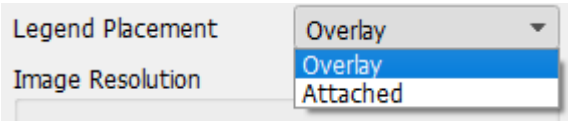
The toolbar icon is the shortcut to this function.



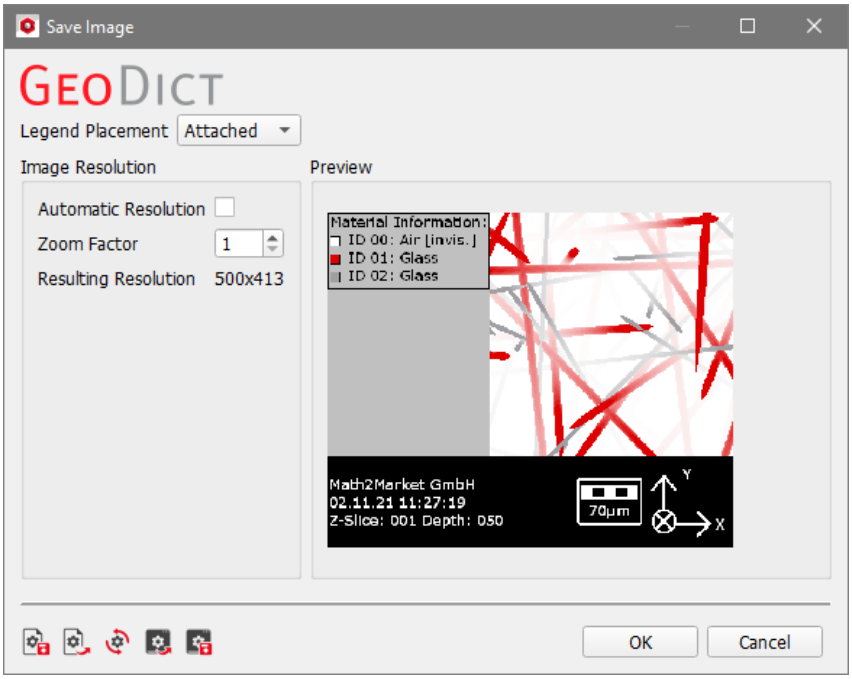
Choosing **Save Image as ...** saves the current image in the supported file formats (***.png**, ***.jpg**, ***.xpm**, ***.xbm**, ***.bmp**, ***.pgm**, ***.ppm**, and ***.pbm**) in the project folder. The toolbar icon is the shortcut to this function.



For 2D images, in the **Save Image** dialog that opens, select first where to place the legend in the image.

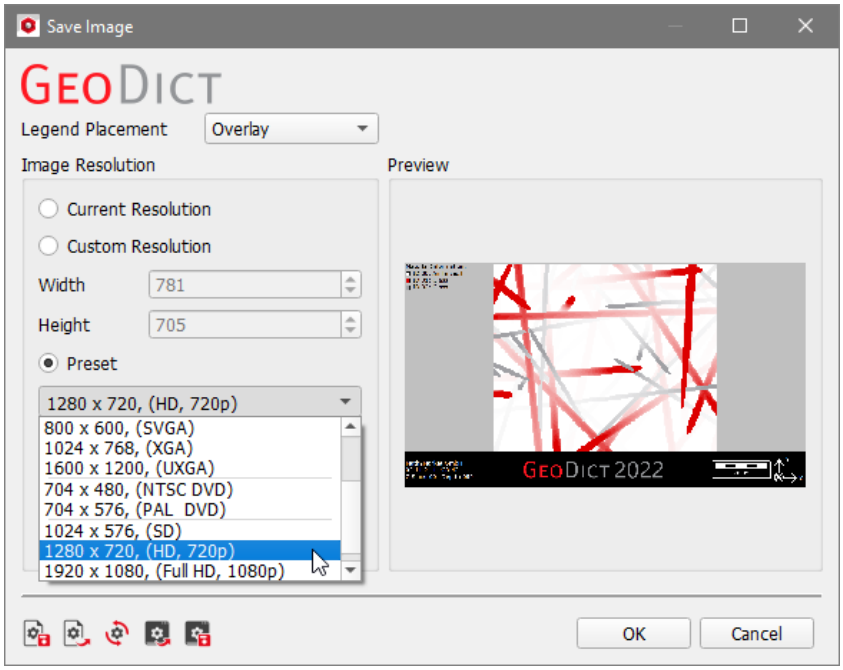


- Choose **Attached** to place the legend outside of the image but attached to it.



If this is selected, the resolution can be selected automatically or manually by defining a zoom factor. Uncheck the **Automatic Resolution** box, to set the zoom factor.

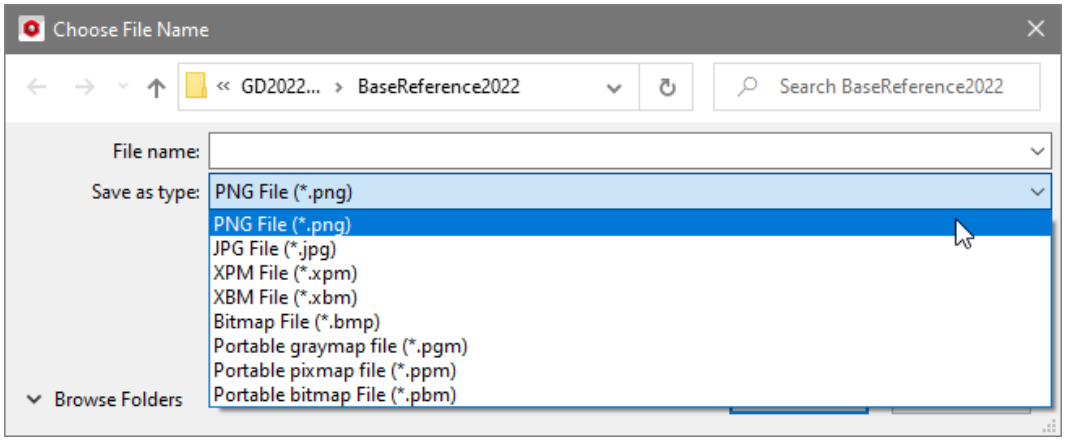
- Choose **Overlay** as the **Legend Placement** to allow that the legend overlaps the image.



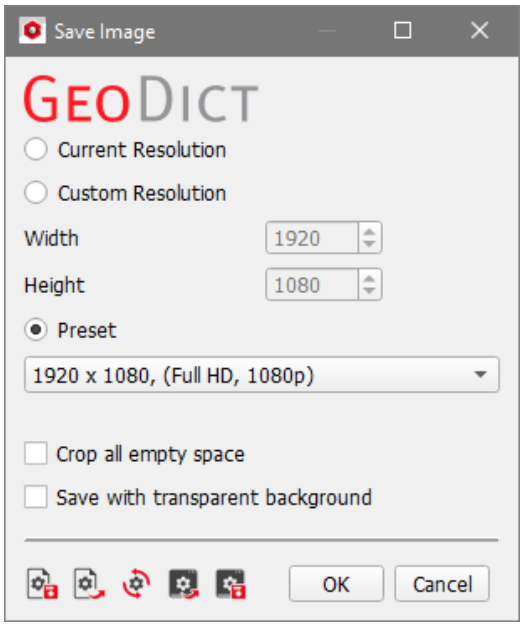
In this case, the user can choose to save the image with the **Current Resolution**, to define a **Custom Resolution** or to use the **Preset** resolution values that fit his/her needs.

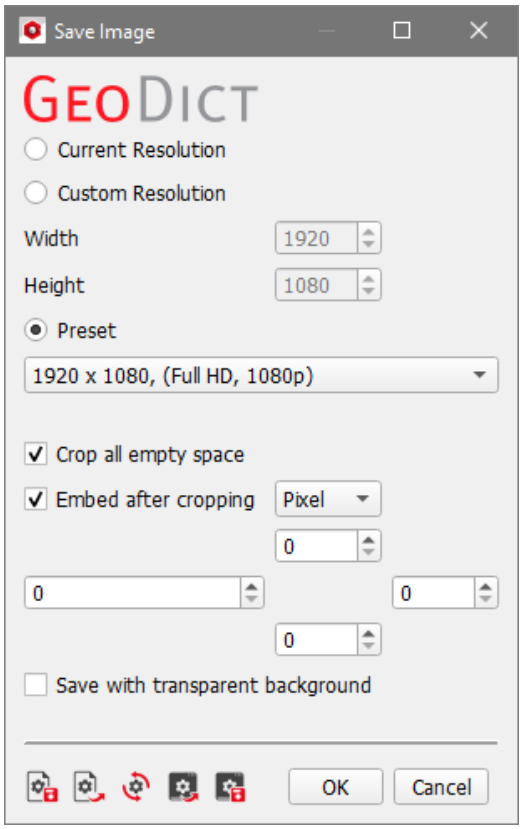
A preview of the image is shown in the right part of the dialog. Click **OK** to select the settings.

Choose a file name and an image format and save the image by clicking **Save**.



For 3D images, choose the resolution to save the image with the **Current Resolution**, to define a **Custom Resolution** or to use a **Preset** resolution.





Select **Crop all empty space** to reduce the image size by removing all borders in background color.

If this is selected, the image can be embedded in borders with the background color **(Embed after cropping)**. The number of pixels for each border can be defined separately in this case.

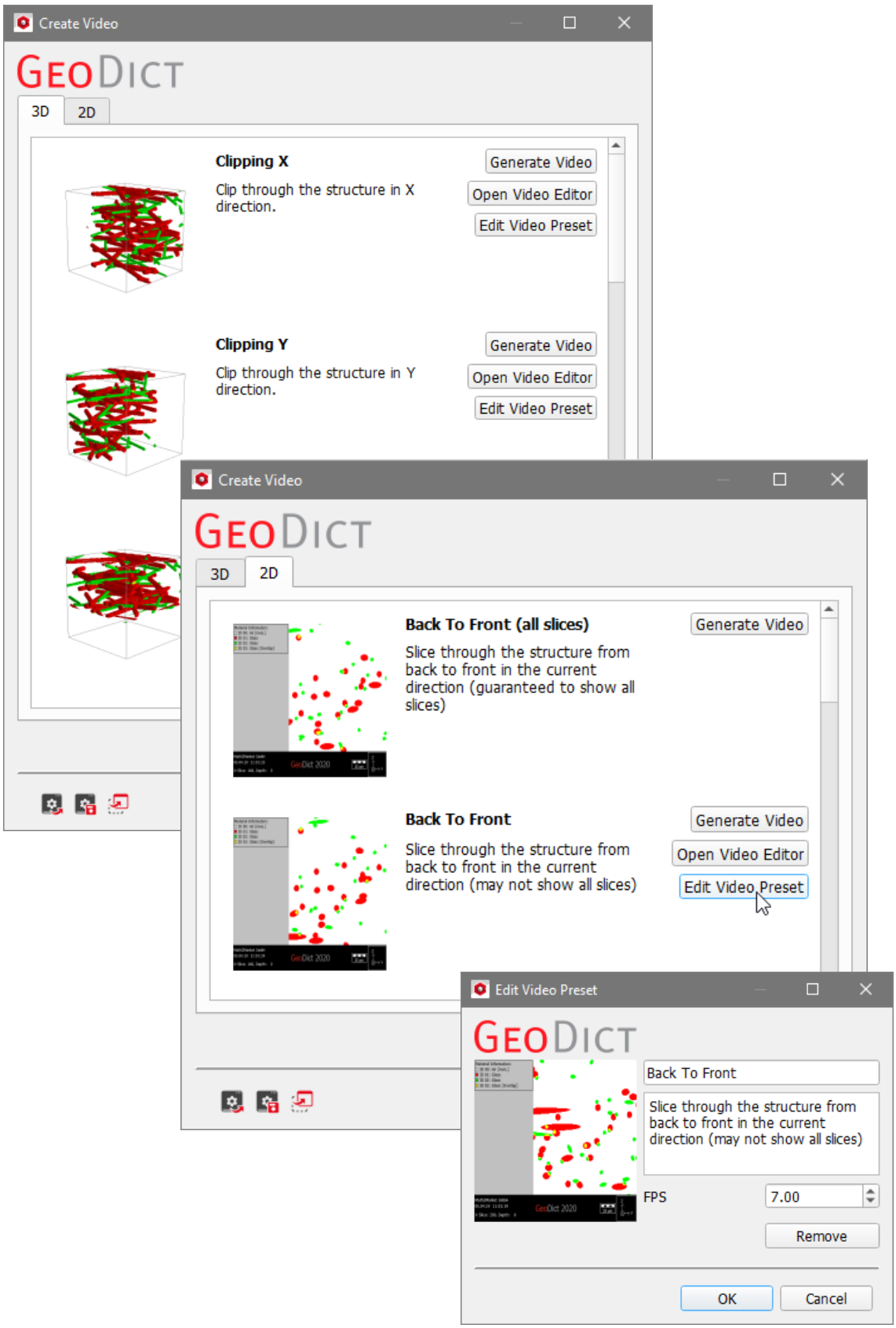
Finally, check **Save with transparent background** to save the image without a background color.

Selecting **Save Video As...** allows choosing preset scripts that execute the making of a video with appropriate standard settings. The preset video scripts can be opened in the 2D or 3D Video Editor (**Open Video Editor**) for modifications. Minor changes, such as the description of the video or the number of frames per second (FPS) can be made through a dialog (**Edit Video Preset**). The following preset movie clips are available:

- In 3D: **Clipping X**, **Clipping Y**, **Clipping Z**, **Fly-by**, **Follow Particle**, **Particle Animation**, **Rotate X**, **Rotate Y**, **Rotate Z**, and **Streamlets**. Also given is the option to import settings from the Video Dialog 3D to be listed in the preset video scripts (**Import as Predefined Video**), to produce a 3D video using 2D images from a stack of scanned images (**Create Video from Image Stack**), and to simply open the Video Dialog 3D editor without loading a specific preset video script (**Open Editor**).
- In 2D: **Back To Front (all slices)**, **Back To Front**, **Front To Back (all slices)**, **Front To Back**, **Import as Predefined Video**, **Create Video from Image Stack**, and **Open Editor**.

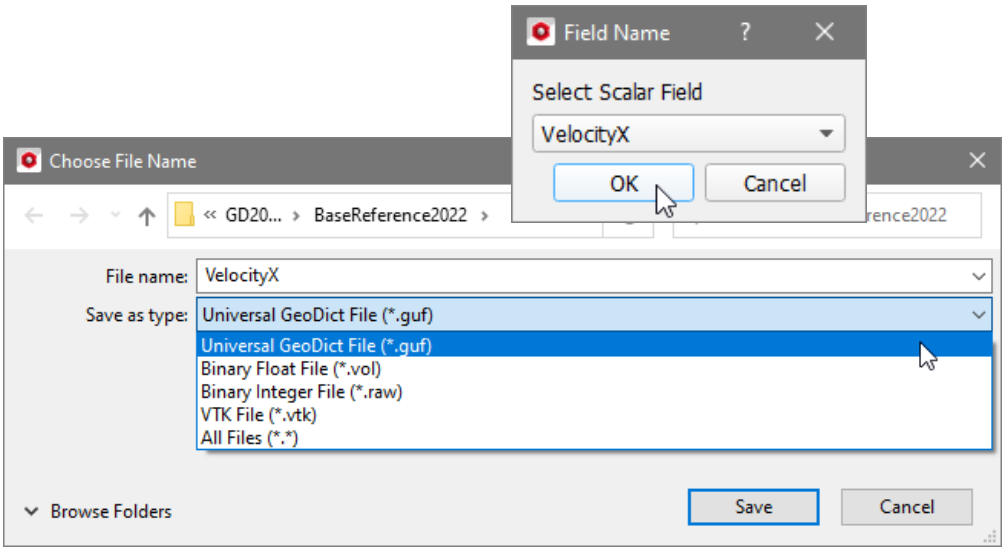
See the Create Videos 2022 handbook for more details about creating videos in GeoDict.

The use of **Save Image as... and Save Video As...** are excellent and easy-to-use choices when the user intends to present to the public structures and visualized results after working with GeoDict.
The high resolution achievable when saving images or videos this way is suitable for press-ready flyers and posters.


Create Video
GEODICT
3D
2D
Clipping X
Clip through the structure in X direction.
Generate Video
Open Video Editor
Edit Video Preset
Clipping Y
Clip through the structure in Y direction.
Generate Video
Open Video Editor
Edit Video Preset
Create Video
GEODICT
3D
2D
Back To Front (all slices)
Slice through the structure from back to front in the current direction (guaranteed to show all slices)
Generate Video
Back To Front
Slice through the structure from back to front in the current direction (may not show all slices)
Generate Video
Open Video Editor
Edit Video Preset
Edit Video Preset
GEODICT
Back To Front
Slice through the structure from back to front in the current direction (may not show all slices)
FPS
7.00
Remove
OK
Cancel

Select **Save Triangulation as...** to save triangulations obtained by creating a mesh through MeshGeo or by importing in ImportGeo-CAD.

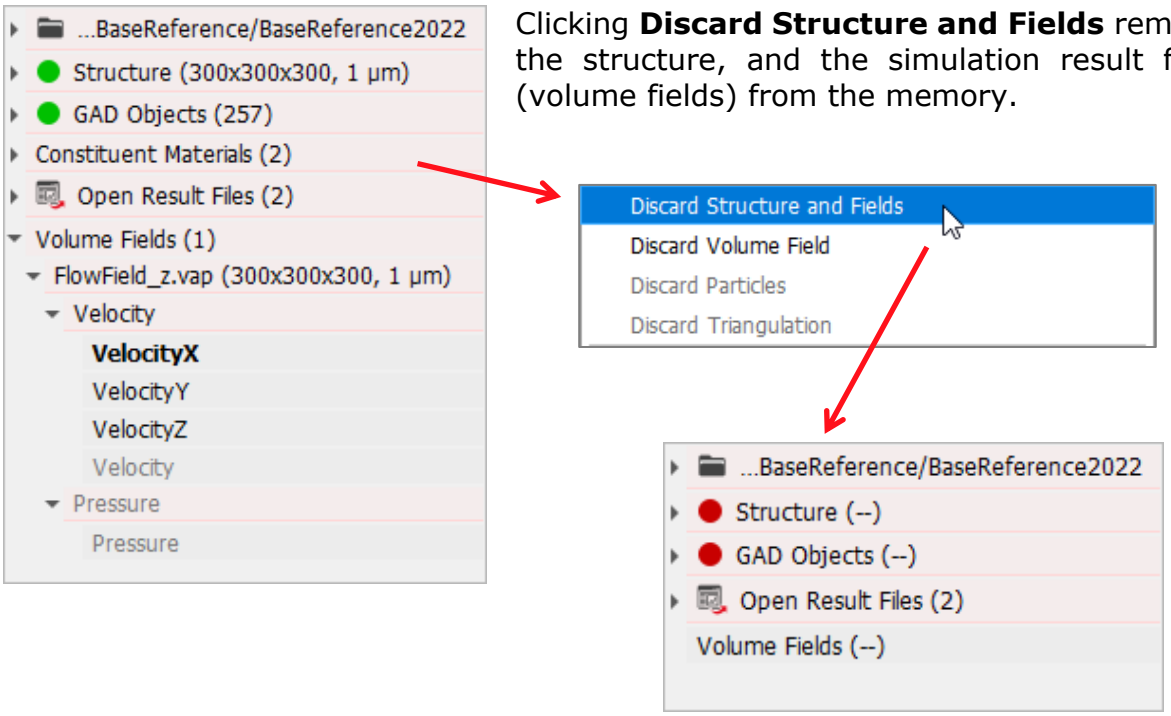
Select **Save Volume Field as...** to save simulation results in several file formats. For example, after running a flow simulation with FlowDict, select a name to save the field of the velocity in X direction as raw float data (*.vol) or GeoDict universal file (*.guf).



DISCARD STRUCTURE OR SIMULATION RESULTS

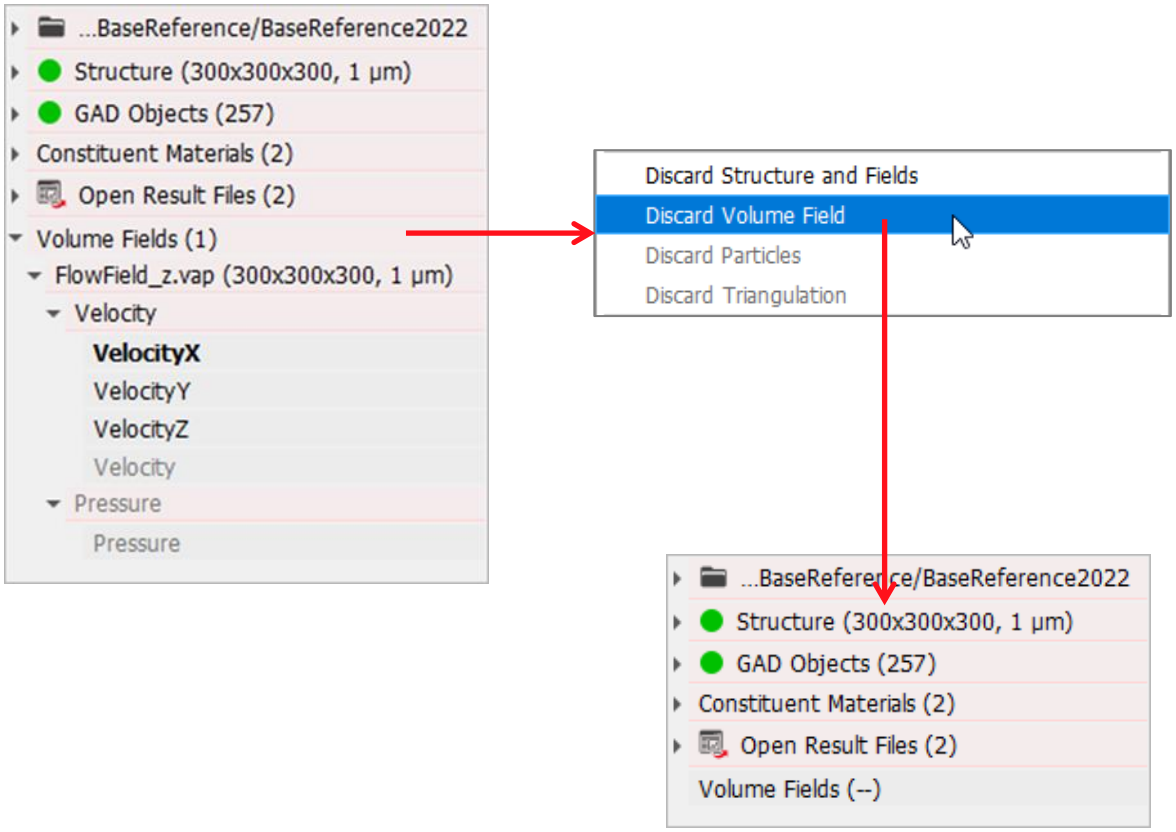
Selecting **Discard Structure and Fields** makes the structure, and all simulation result fields available for this structure, disappear from memory and from the Visualization area. The initial GeoDict splash screen appears in the Visualization area instead.

In the example shown here, a fiber structure is loaded in GeoDict, together with the volume fields of velocities in x-, y- and z-direction, loaded from the .vap file of a flow simulation.



Clicking **Discard Structure and Fields** removes the structure, and the simulation result fields (volume fields) from the memory.

Selecting **Discard Volume Field** eliminates only the simulation result fields (volume fields) of the structure displayed in the Visualization area from memory.



In the same way, for a particle simulation result (created with FilterDict or AddiDict), if particle trajectories or positions are available in GeoDict memory, **Discard Particles** removes the particle information from memory.

A structure in STL format (Stereosurface triangulation language), imported with ImportGeo-CAD, and shown in the Visualization area, is deleted from memory when **Discard Triangulation** is selected.

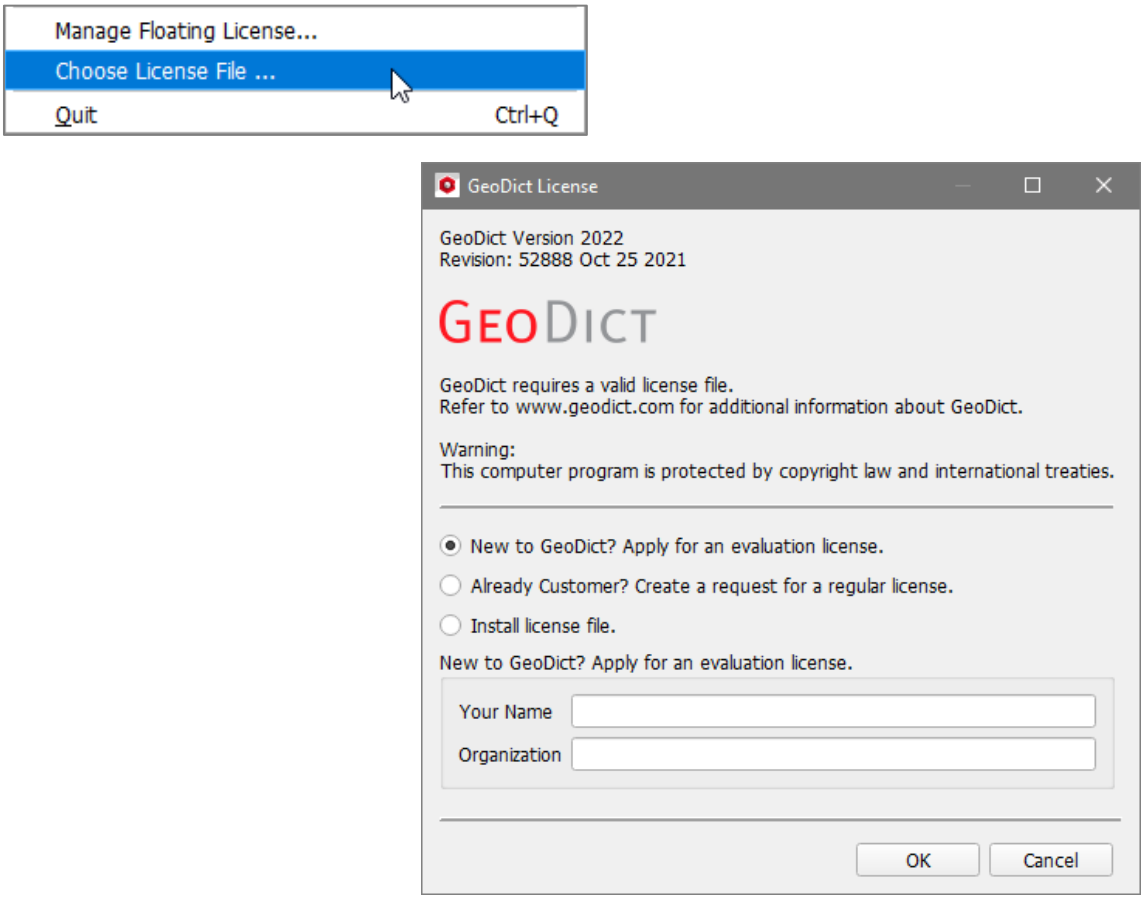
Clear Recent Files / Folders

Clicking **Clear Recent Files / Folders** clears the list of Recent Files and Recent Project Folders shown in the GUI.

Manage Floating License, Choose license file, and Quit

Clicking **Manage Floating License...** allows a floating license user to choose which of the licensed modules he would like to use in this session. Deselected modules will be shown as unlicensed in GeoDict's menu, and their license will then be free for other users to use.

Select **Choose License File ...**. to select a license file, e.g., to change the license from evaluation to purchased or leased license, to upgrade the license for another term, or to request a new license file following the procedure explained in **Licensing** GeoDict in the Download, Installation and Licensing handbook of the User Guide.



Selecting **Quit** ends the current GeoDict session.

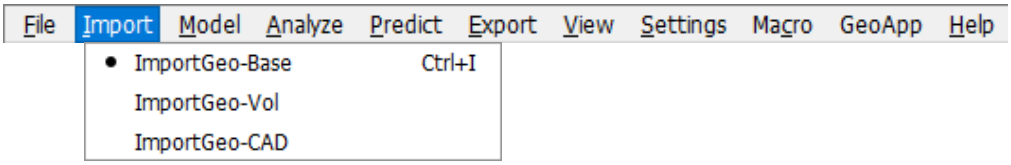
IMPORT

Accessible from the menu bar are interfaces to import image and structure files into GeoDict (ImportGeo). See page 5.

For many image file formats, ImportGeo can perform 3D processing on gray value images and import them to the index image characteristic of GeoDict. The extraction from gray value images is done by segmentation, a procedure to convert them to index values. ImportGeo can also be used to load, import, and visualize a structure in the formats supported by GeoDict.

ImportGeo-Base always appears in the menu because it is included in the GeoDict Base Package, other modules that have not been licensed appear under **unlicensed** in the list.

Start an ImportGeo module by clicking **Import** in the menu bar and selecting one of the sub-modules available to import the file formats listed in page 9. If a module is selected, a dot appears in front of it in the module list and the module section changes to show this module.



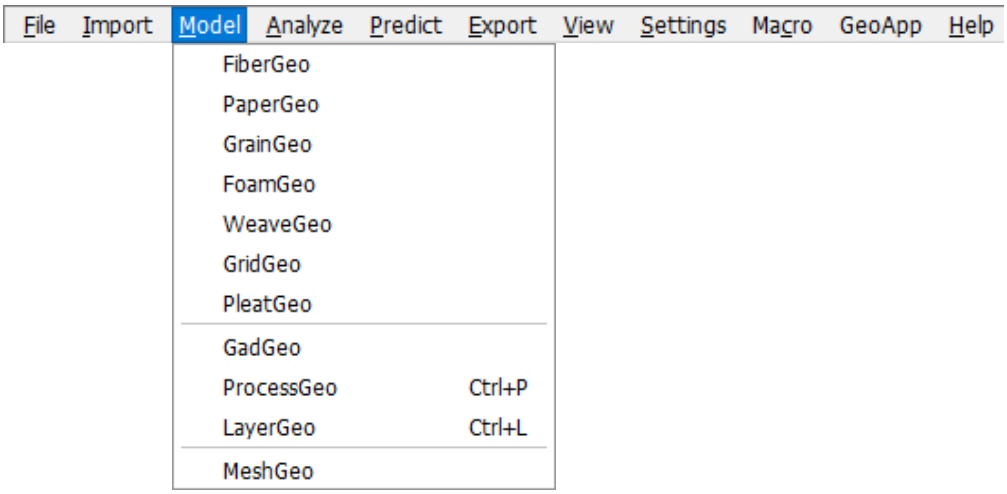
For complete information on interfaces to GeoDict see the ImportGeo-Base 2022 handbook, ImportGeo-CAD 2022 handbook, and the ImportGeo-Vol 2022 handbook of the User Guide.

MODEL

The **Model** menu gives access to the list of modules for digital material modeling that are included in the user's license.

GadGeo, ProcessGeo, and LayerGeo can always be used because they are included in the GeoDict Base Package. Other modules that have not been licensed appear in the list under **unlicensed**.

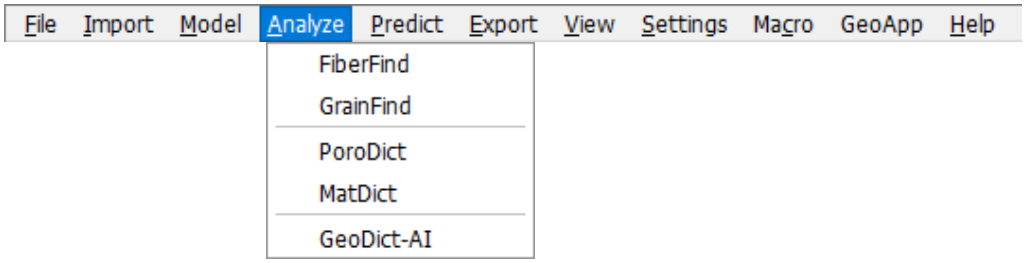
The GeoDict modules for digital material design available for licensing are:



ANALYZE

The **Analyze** menu gives access to the list of modules for digital material analysis that are included in the user's license.

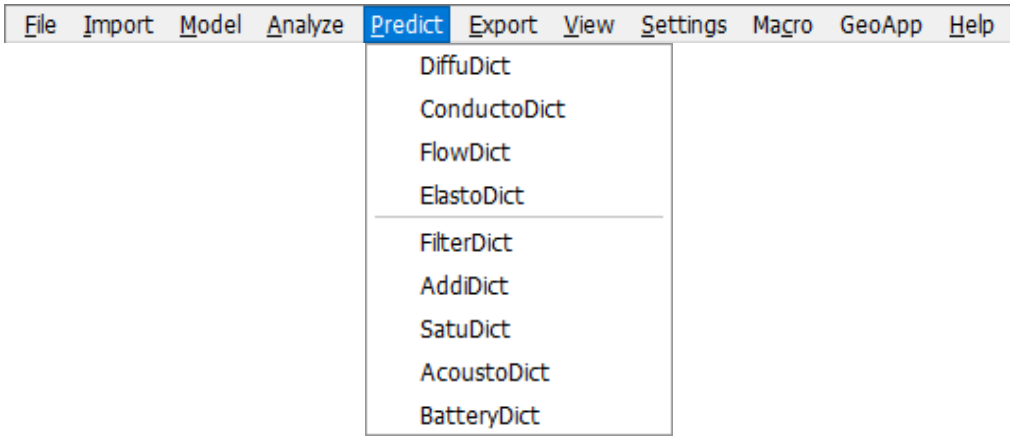
The GeoDict modules for digital material analysis available for licensing are:



PREDICT

The **Predict** menu gives access to the list of modules for the prediction of material properties that are included in the user's license.

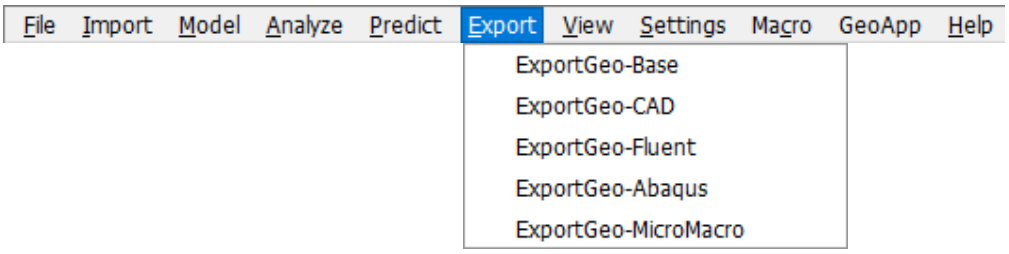
GeoDict modules available for prediction of material properties are:



EXPORT

Accessible from the menu bar are interfaces to export structure files, images, and simulation results from GeoDict (ExportGeo) to many other software packages. See page 5.

To export a GeoDict file to other formats, select **Export** in the menu bar, and choose between ExportGeo-Base, ExportGeo-CAD, ExportGeo-Fluent, ExportGeo-Abaqus and ExportGeo-MicroMacro.



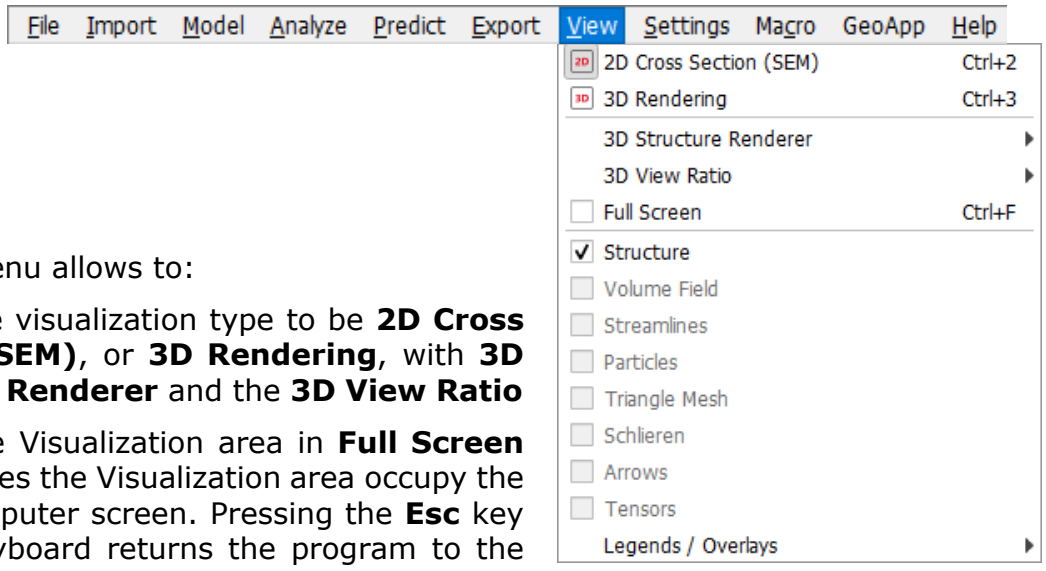
With ExportGeo, structures from GeoDict can be exported to other formats so that files produced by the GeoDict user are compatible with other software and can be used for customized workflows:

- ExportGeo–Base converts voxelized data to RAW, VOL, PNG and Avizo Binary File (.am) formats. Furthermore, it converts analytic data, particles, trajectories and streamlines to GeoDict's GAD format.
- ExportGeo-CAD converts voxelized or analytic structures to commonly used surface triangulation and CAD formats like STL, VRML, or Parasolid.
- ExportGeo-Fluent and ExportGeo-Abaqus convert voxelized data to formats for flow and heat computations with **Fluent™** or elasticity computations with **Abaqus**.

For complete information on interfaces from GeoDict, see the ExportGeo-CAD / MeshGeo 2022 handbook, the ExportGeo-Fluent 2022 handbook, and the ExportGeo-Abaqus 2022 handbook of the User Guide.

VIEW

After modeling a structure, either by generating it in GeoDict or after importing 3D µCT or FIB/SEM images, choosing between the **View** menu entries changes the visualization settings. A shortcut to many of these parameters can also be set through the Visualization Side Bar, as explained shortly below, starting on page 60, and in more detail in the Visualization 2022 handbook.

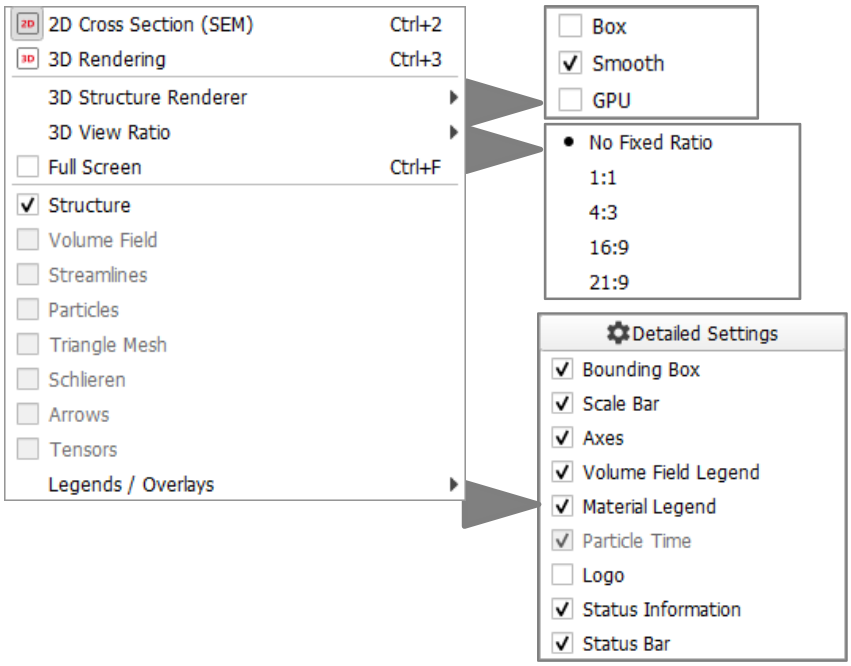


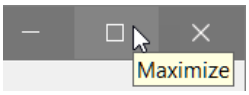
The **View** menu allows to:

- choose the visualization type to be **2D Cross Section (SEM)**, or **3D Rendering**, with **3D Structure Renderer** and the **3D View Ratio**
- display the Visualization area in **Full Screen** which makes the Visualization area occupy the entire computer screen. Pressing the **Esc** key on the keyboard returns the program to the normal display.
- select which components are displayed in the **visualization**, and
- choose the **Legends / Overlays** to be displayed.

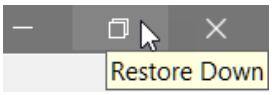
Some of these options are only accessible when choosing to visualize in **3D Rendering** or when visualizing solver results (**Volume Field**, **Streamlines**, **Particles**, **Triangle Mesh**, **Schlieren**, **Arrows**, and **Tensors**).

Choose **Detailed Settings** to access the Visualization Side Bar, see page 60 and the Visualization 2022 handbook.





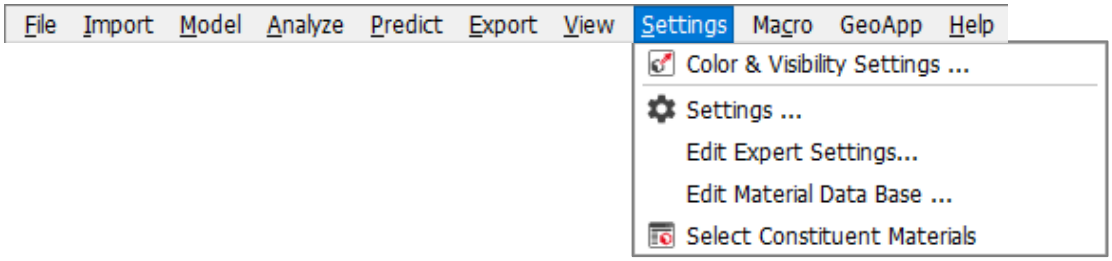
Maximize the main screen to occupy the entire computer screen



Restore Down the main screen to the normal size.

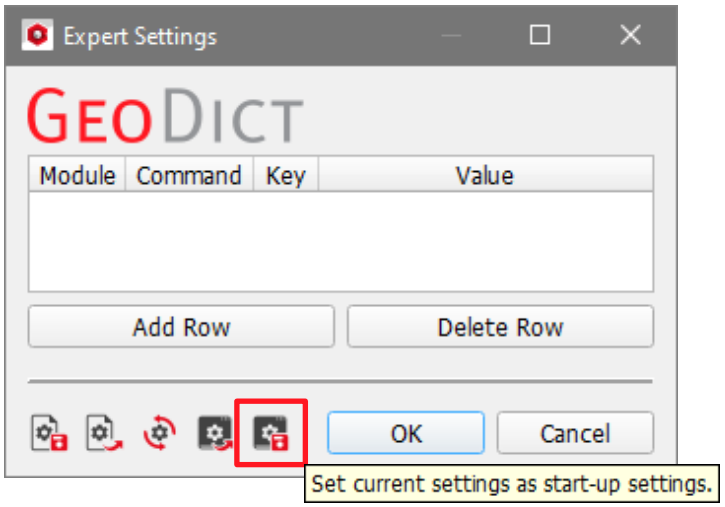
SETTINGS

The **Settings** menu includes **Color & Visibility Settings**, **Settings**, **Edit Expert Settings**, **Edit Material Data Base**, and **Select Constituent Materials**.



The parameters entered in the **Settings** dialogs can be saved into GPS (*.gps, GeoDict Project Settings) files and/or loaded from them. Remember to restore and reset your (or GeoDict's) default values through the icons at the bottom of the dialog when needed and/or before every GeoDict run.

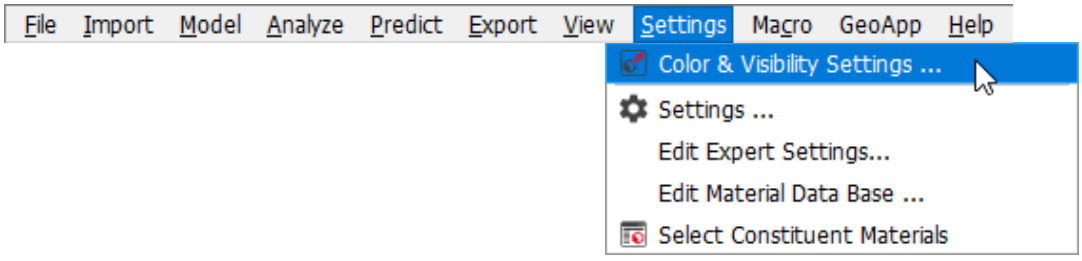
Resting the mouse pointer over the icons in the lower left of settings dialogs prompts a tool tip showing the icon's function to appear. For example, for the Expert Settings:



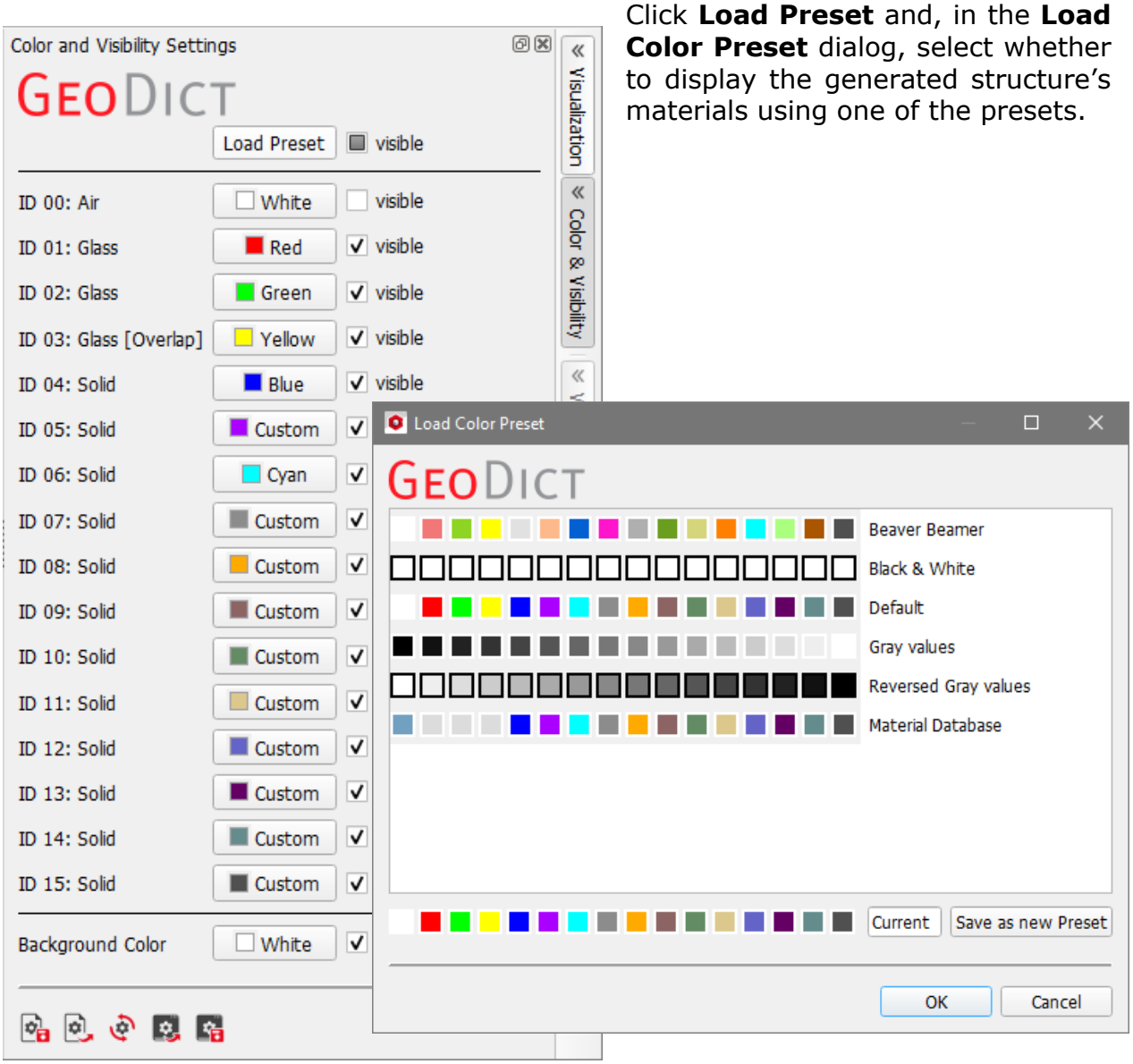
Clicking **OK** at the bottom of these dialogs, results in carrying out the modifications and closing the dialog. Select **Cancel** to discard the modifications entered in the dialog. Keeping a **Color & Visibility Settings** dialog open, instead of closing it by clicking **Close**, is helpful when trying to find the most adequate settings for a particular visualization.

COLOR & VISIBILITY SETTINGS

The default color settings applied to the background and materials during the generation with GeoDict, can be changed through the **Color & Visibility Settings** dialog, that opens on the right of the Visualization Area.

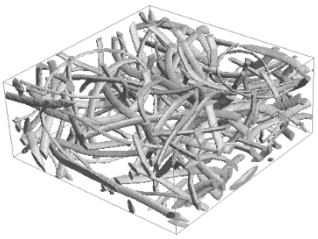


A color preset is a particular group of colors that are applied together.



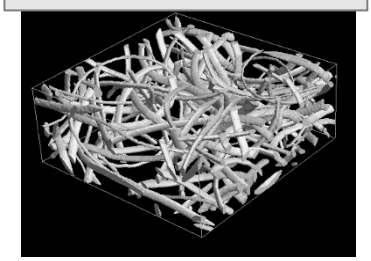
Click **Load Preset** and, in the **Load Color Preset** dialog, select whether to display the generated structure's materials using one of the presets.

Material Database



Gray values

Reversed gray values

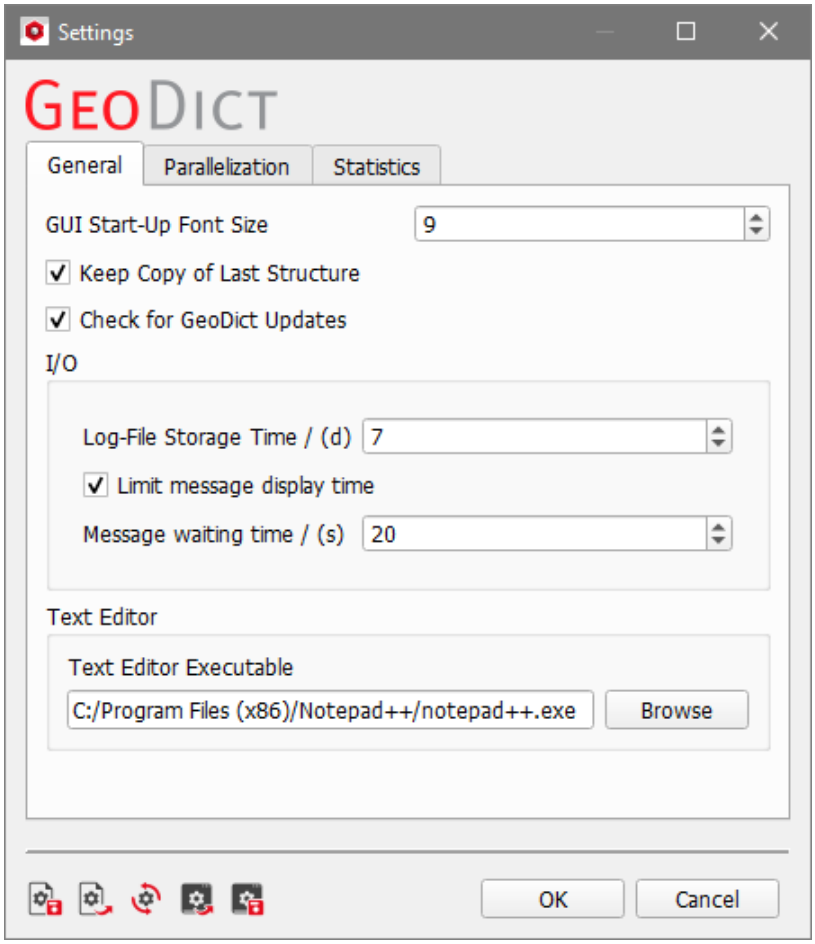


After selecting new colors through the buttons in the **Color & Visibility Settings** dialog, the current group of colors can be saved as a preset (**Save as new Preset**), to have it appear in the list of color presets later.

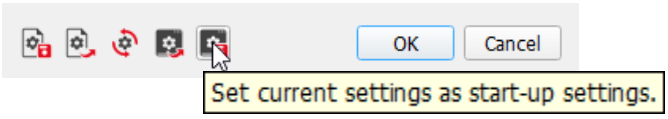
More details about the GeoDict colors and visibility settings can be found in the Visualization 2022 handbook.

SETTINGS...

Selecting **Settings...** from the **Settings** menu opens the **Settings** dialog to modify the general preferences or properties when working with GeoDict. The dialog contains the **General, Parallelization** and **Statistics** tabs.



They contain a collection of settings that a user typically wants to apply to any GeoDict session. If the chosen setting should not apply only to this GeoDict session but should also be chosen at the next GeoDict startup, the user must, after making his choices, first click the icon at the bottom of the dialog:

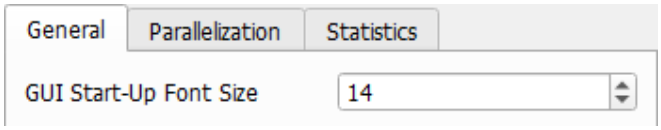


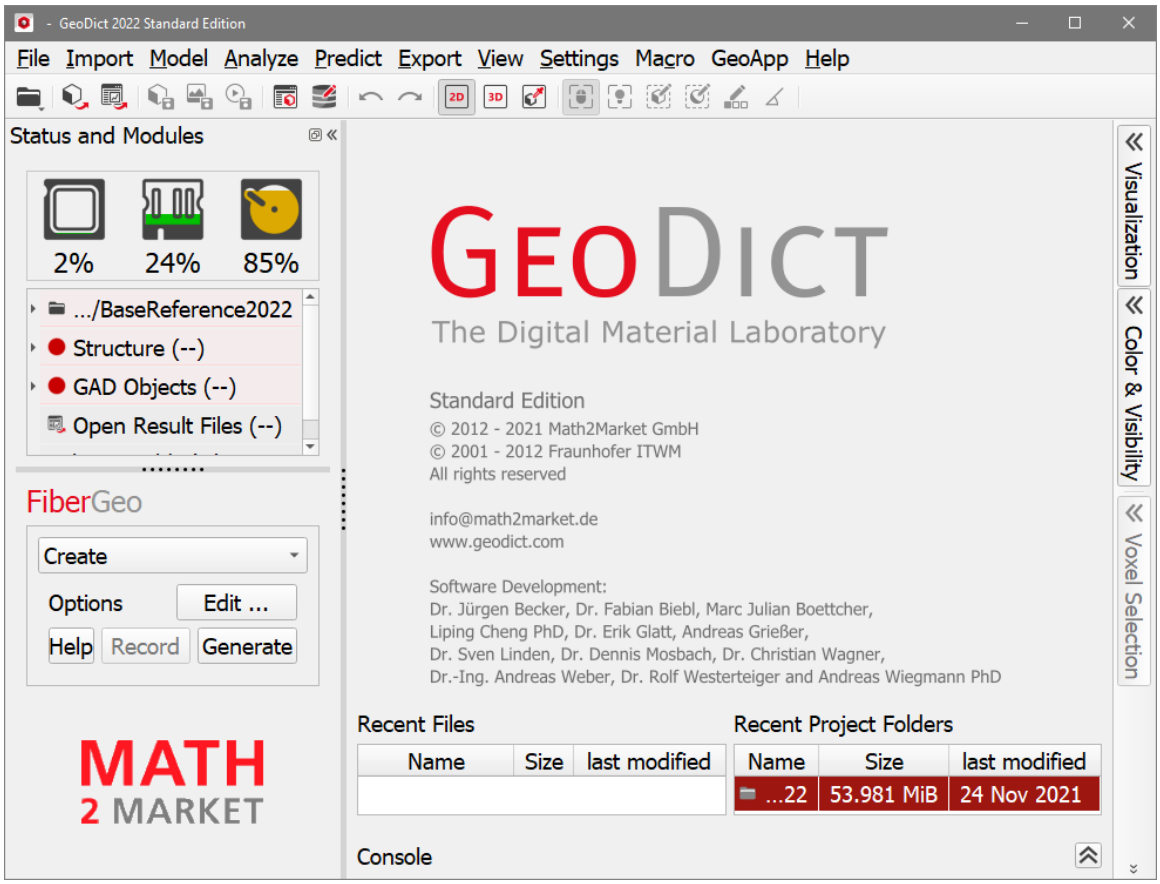
After setting the current settings as start-up setting, click **OK**.

GENERAL

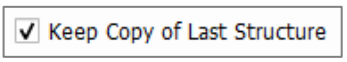
The first option under the General tab controls the size of the fonts used in the GUI at start-up (**GUI Start-Up Font Size**).

For example, increasing the **GUI Start-Up Font Size** to 14 results in the display of a larger font overall in the GUI after restarting GeoDict.





When **Keep Copy of Last Structure** is checked,



GeoDict automatically stores a copy of the previous 3D structure, before applying any changes to it. This allows to quickly undo any changes using the undo function:

Disadvantage of using **Keep Copy of Last Structure** is that some runtime and hard disk space is required for saving the structures.

If **Check for GeoDict Updates** is checked, GeoDict will automatically search (requires internet connection) if updates are available and print a message if an update is found.

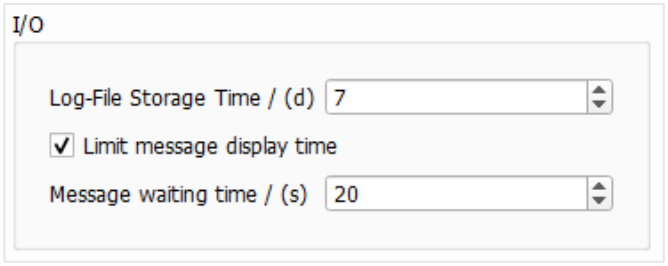
GeoDict will not automatically download or install those updates.

In the corresponding panels underneath are the options for disk usage (**I/O**), and for setting a default **Text Editor**.

I/O

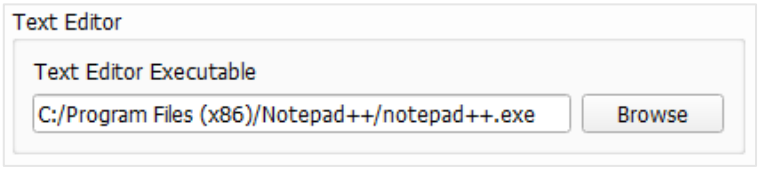
In the **I/O** (input/output) options, define how many days the log files, in which the events happening while running GeoDict are recorded, should be kept.

Also define whether the time a warning message is displayed should be limited, and the time of the limitation in seconds.



Text Editor

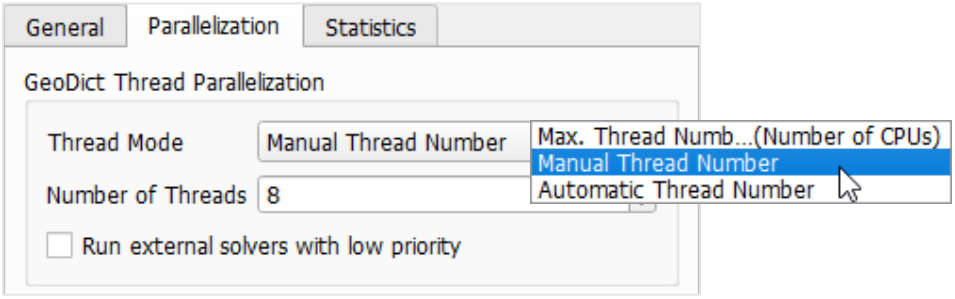
The user can set which text editor is to be opened automatically when editing macros and other editable files. Click **Browse** to search and set the path to the location where the executable for the favorite text editor is located.



PARALLELIZATION

GeoDict Thread Parallelization

The user can set the number of parallel processes (threads) GeoDict should use, e.g., for the visualization, for the image processing, and for the structure generation. When not all available CPUs of the computer should be used, perhaps to allow other users to work simultaneously on the same machine or to improve the running of other programs, the number of used parallel processes can be limited by setting a **Manual Thread Number**.



Choosing **Automatic Thread Number** uses the maximum number, if up to eight cores are available. If more than 8 cores are available, the maximum of 8 and the number of cores divided by two is used.

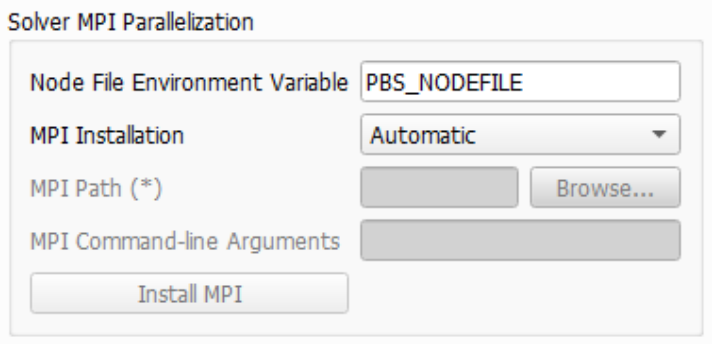
This option has nothing to do with the solver processes, which can be set for all GeoDict solvers in the Dict modules independently. However, if the selected **Number of Threads** for a solver is larger than the number of threads that the license supports, an error message appears.

Check **Run external solvers with low priority** to make the system more responsive when working interactively while a solver is running.

Solver MPI Parallelization

For cluster computations, set the environment variable that holds the location of the node file, i.e., the file that contains the list of assigned compute nodes.

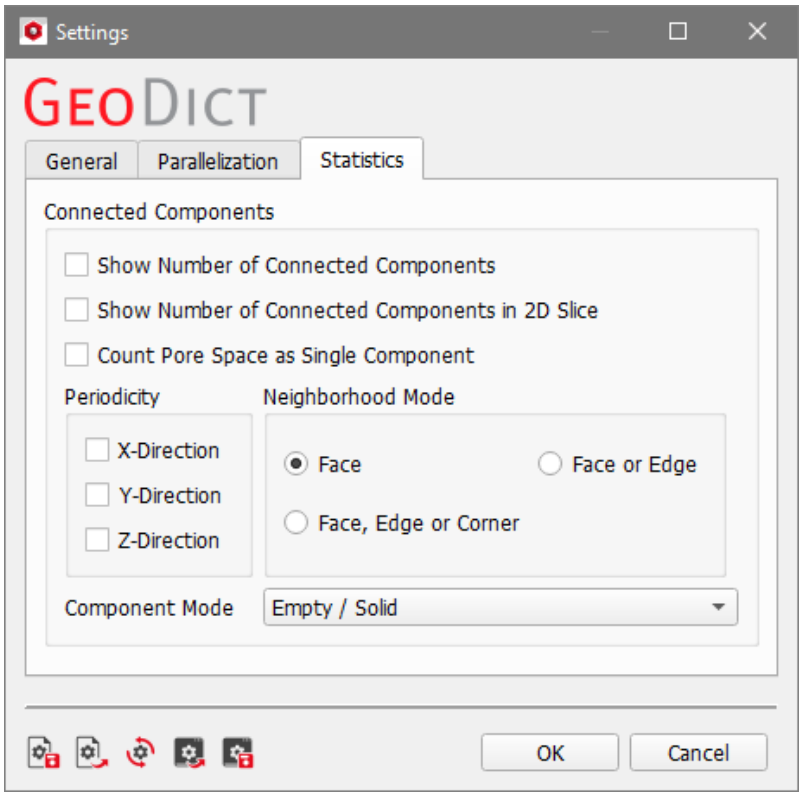
For MPI parallel computations, set the path to the **MPI Installation** that should be used for the parallelization. Select **Automatic** to look automatically for MPI installations.



For more information, refer to the High Performance Computing handbook of the User Guide.

STATISTICS

The **Connected Components** panel is found under the Statistics tab.



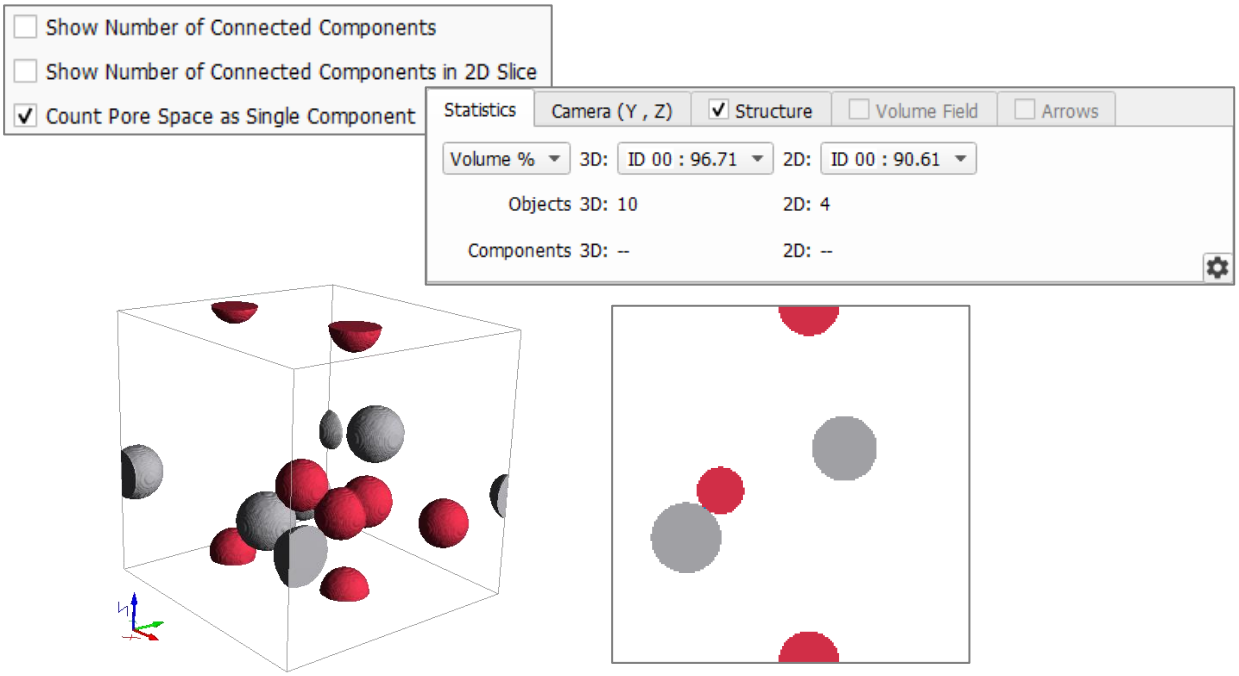
A connected component is defined as a complete set of color voxels.

Checking **Show Number of Connected Components** or **Show Number of Connected Components in 2D Slice**, and clicking **OK**, adds the number of **Components 3D** and **Components 2D** to the **Statistics** tab in the Visualization panel above the Visualization area.

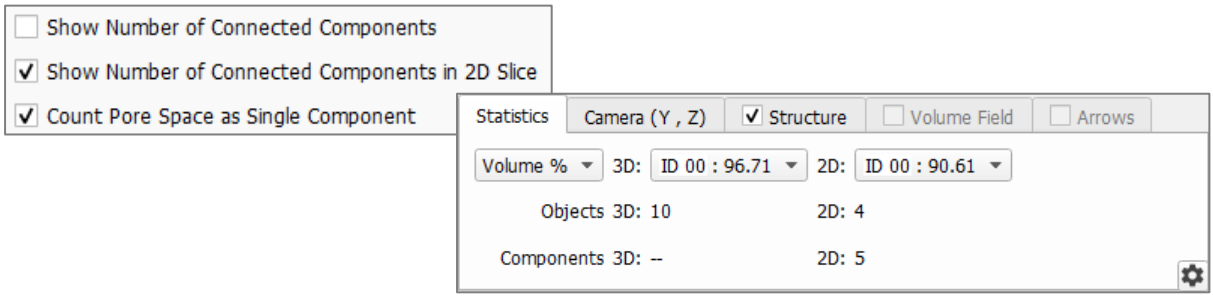
When **Count Pore Space as Single Component** is checked, the complete background is counted as one connected component. The pore space does not count as an object and does not add to the number of **Objects**.

As example, a simple periodic structure model contains 10 spheres. At the corners, it is the same grey sphere that disappears and reappears on the other side. Two red spheres are also cut in half. They disappear and reappear in Z-direction. Three of the red spheres overlap and one of the red spheres touches a grey sphere.

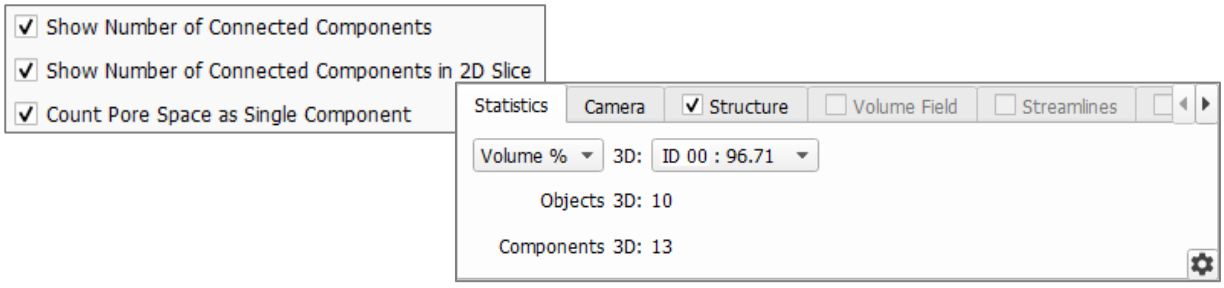
The number of **Objects 3D** is 10, but the number of **Objects 2D** is only 4 (2 grey and 2 red spheres) in the 2D-Slice 126 (move the slider under the Camera (Y,Z) tab). The pore space is not counted as object.



Now, see how the connected components in 2D are counted when checking **Show Number of Connected Components in 2D Slice**. The number of Objects 3D and 2D are the same as before. For **Show Number of Connected Components in 2D Slice**, the pore space and the red-grey touching spheres are each counted as a connected component. Connected components in 2D are 5 (1 grey sphere + 1 partial red sphere (top) + 1 partial red sphere (bottom) + 1 [1 red sphere+1 grey sphere] component + 1 pore space).



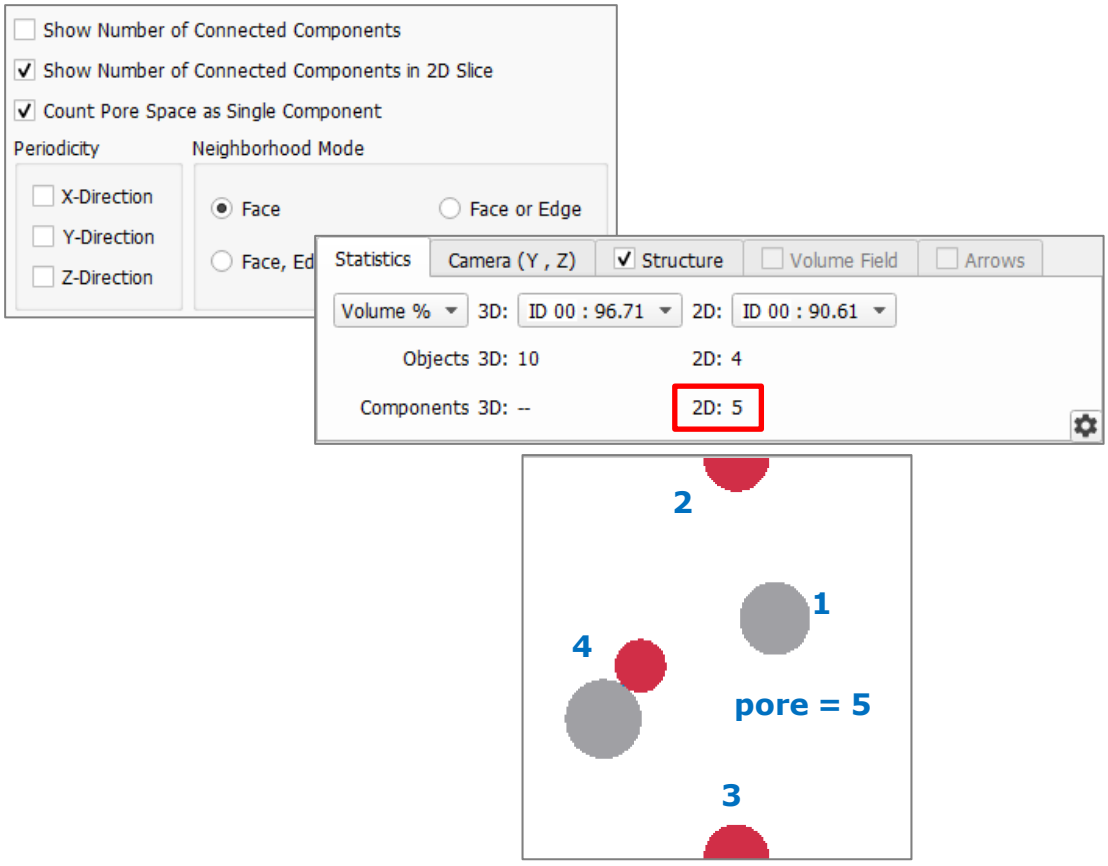
Next, **Show number of Connected Components** is checked and they are counted in 3D. Connected components in 3D are 13 (2 grey spheres + 4 partial grey spheres + 1 red sphere + 4 partial red spheres + 1 [3 red spheres+1 grey sphere] component + pore space).



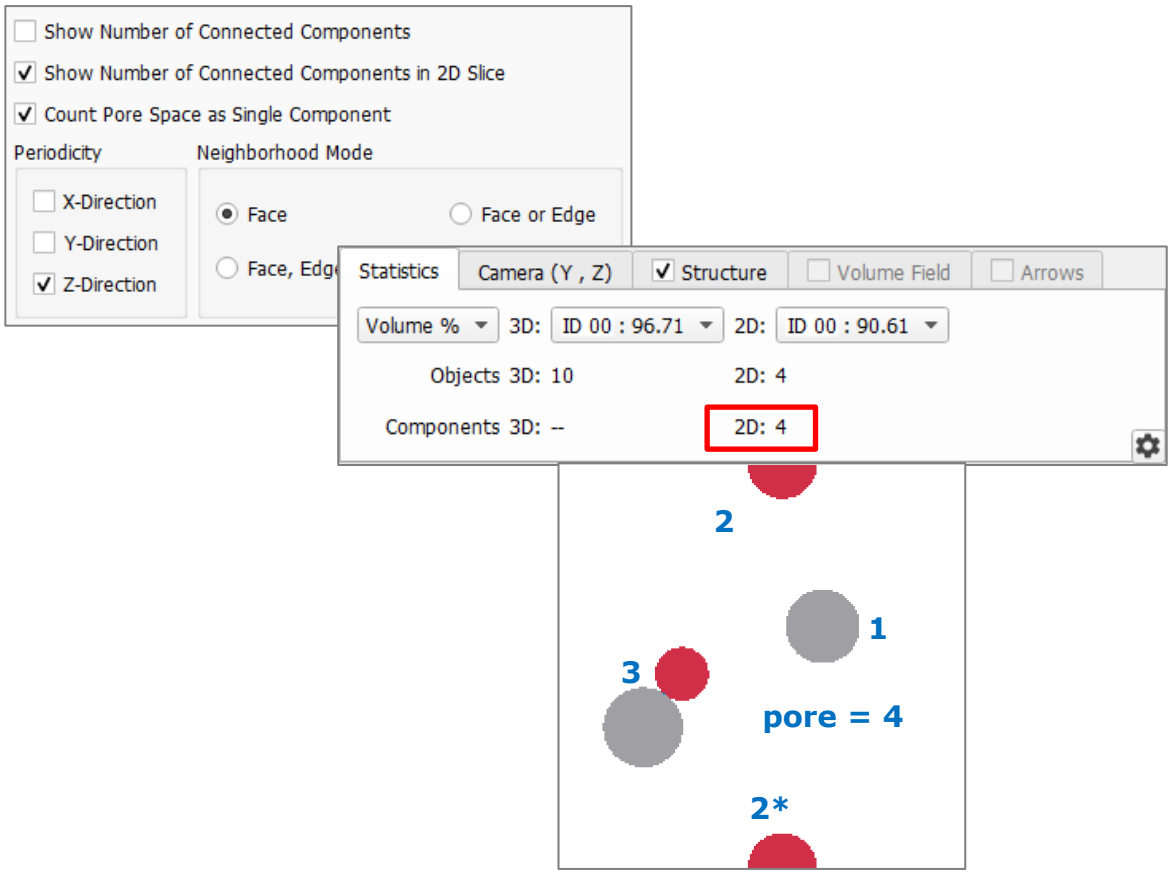
Periodicity, **Neighborhood Mode**, and **Component Mode** define criteria for the connectivity of the components.

For periodic structures, checking **Periodicity** in **X-Direction**, **Y-Direction**, or **Z-Direction** affects the number of connected components. Objects that end on one side of the volume and reappear on the opposite side are counted as being the same connected component, decreasing the final number of connected components.

For example, the structure shown above is periodic in Z-direction, and without checking periodicity, 5 connected components in 2D are counted (#1 grey sphere + #2 partial red sphere (top) + #3 partial red sphere (bottom) + #4 [1 red sphere+1 grey sphere] component + #5 pore).



Next, checking **Periodicity** in **Z-Direction** decreases the number of connected **Components 2D** to 4, because the red sphere at the edge of the domain reappears at the opposite edge and is then considered the same connected component.

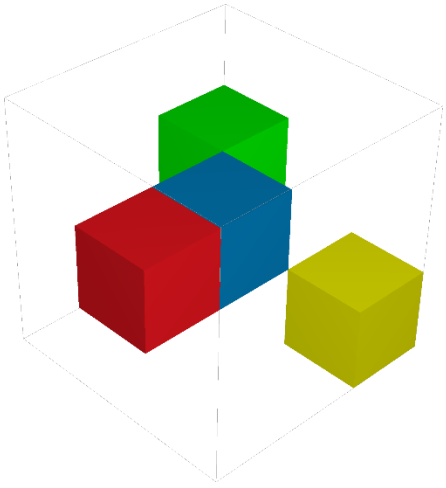


The 4 connected components are: (#1 grey sphere + #2 red sphere (top+bottom) + #3 [1 red sphere+1 grey sphere] component + #4 pore). The number of **Objects** does not change, and the same four objects are detected in 2D. The pore space is not counted in the number of **Objects**.

Neighborhood Mode

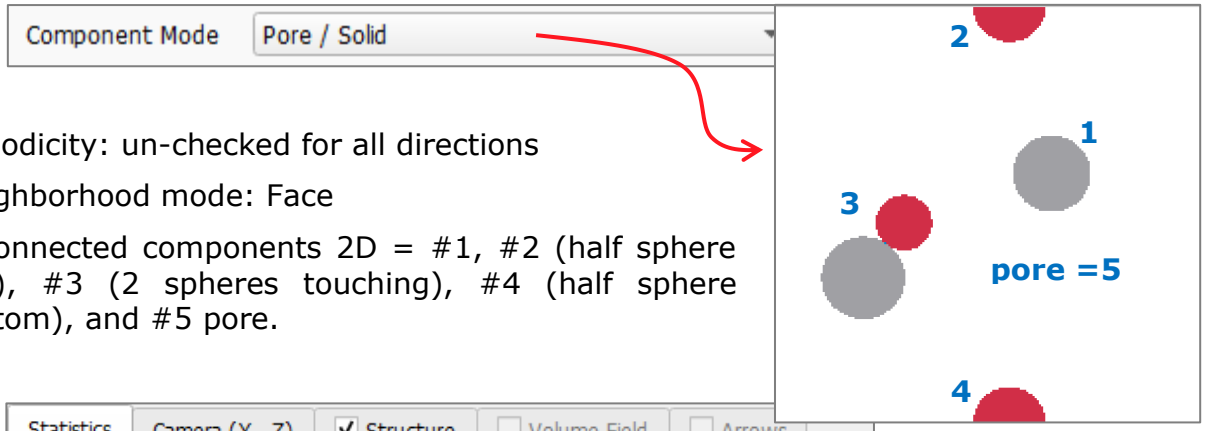
Neighboring structure components can be connected through faces, edges, and corners of voxels, i.e., two voxels of the same color that share a corner point always belong to the same connected component.

Checking **Face** is more restrictive than choosing **Face or Edge**, and this more limiting than selecting **Face, Edge or Corner**.



Component Mode

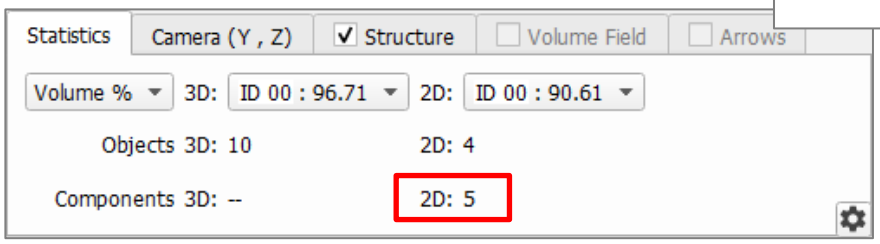
For structures with more than one material, selecting **Pore/Solid** from the **Component Mode** pull-down menu determines whether the components are considered connected or not, based on being empty voxels (background) or solid voxels (structure), regardless of their color. When selecting **Material ID**, the color of the solid voxels (structure) is determinant for the components to be considered connected or disconnected.

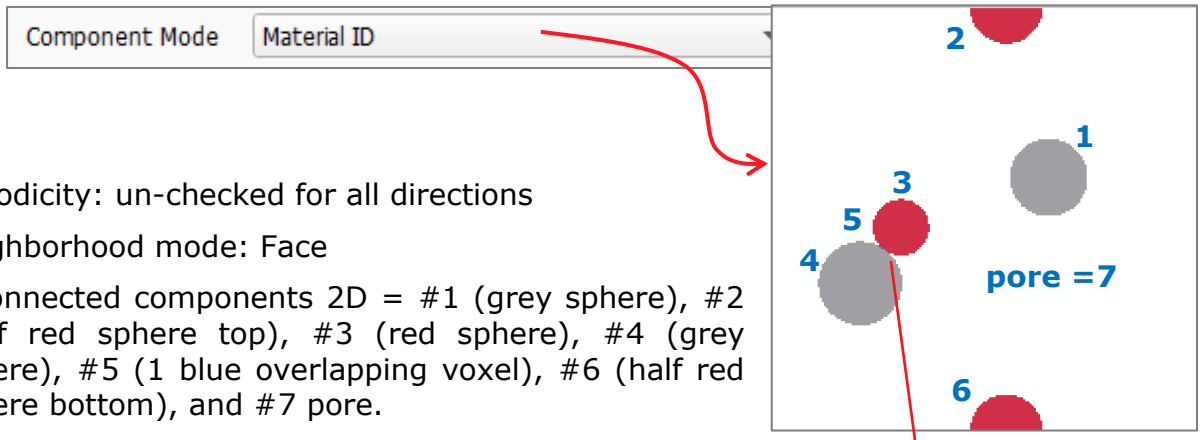


Periodicity: un-checked for all directions

Neighborhood mode: Face

5 connected components 2D = #1, #2 (half sphere top), #3 (2 spheres touching), #4 (half sphere bottom), and #5 pore.

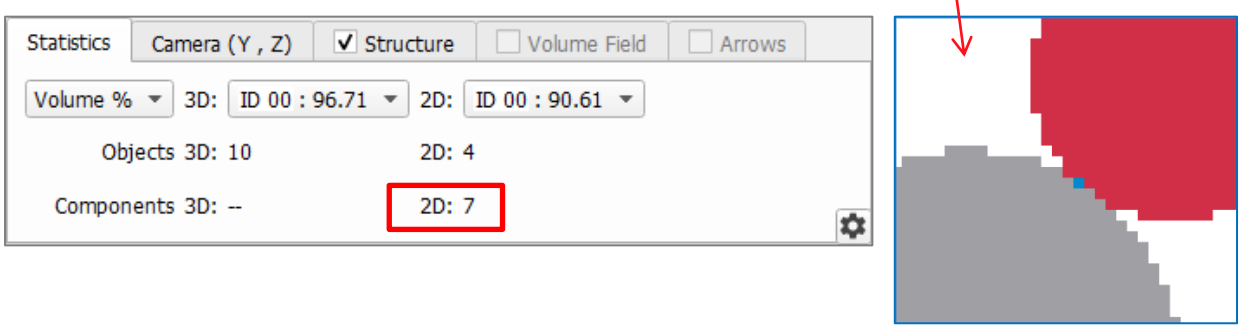




Periodicity: un-checked for all directions

Neighborhood mode: Face

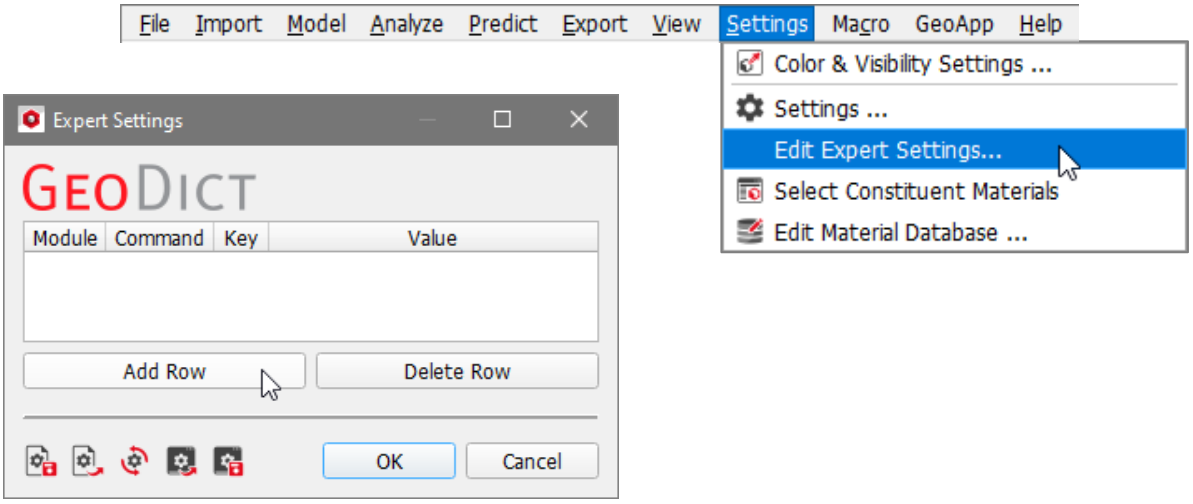
7 connected components 2D = #1 (grey sphere), #2 (half red sphere top), #3 (red sphere), #4 (grey sphere), #5 (1 blue overlapping voxel), #6 (half red sphere bottom), and #7 pore.



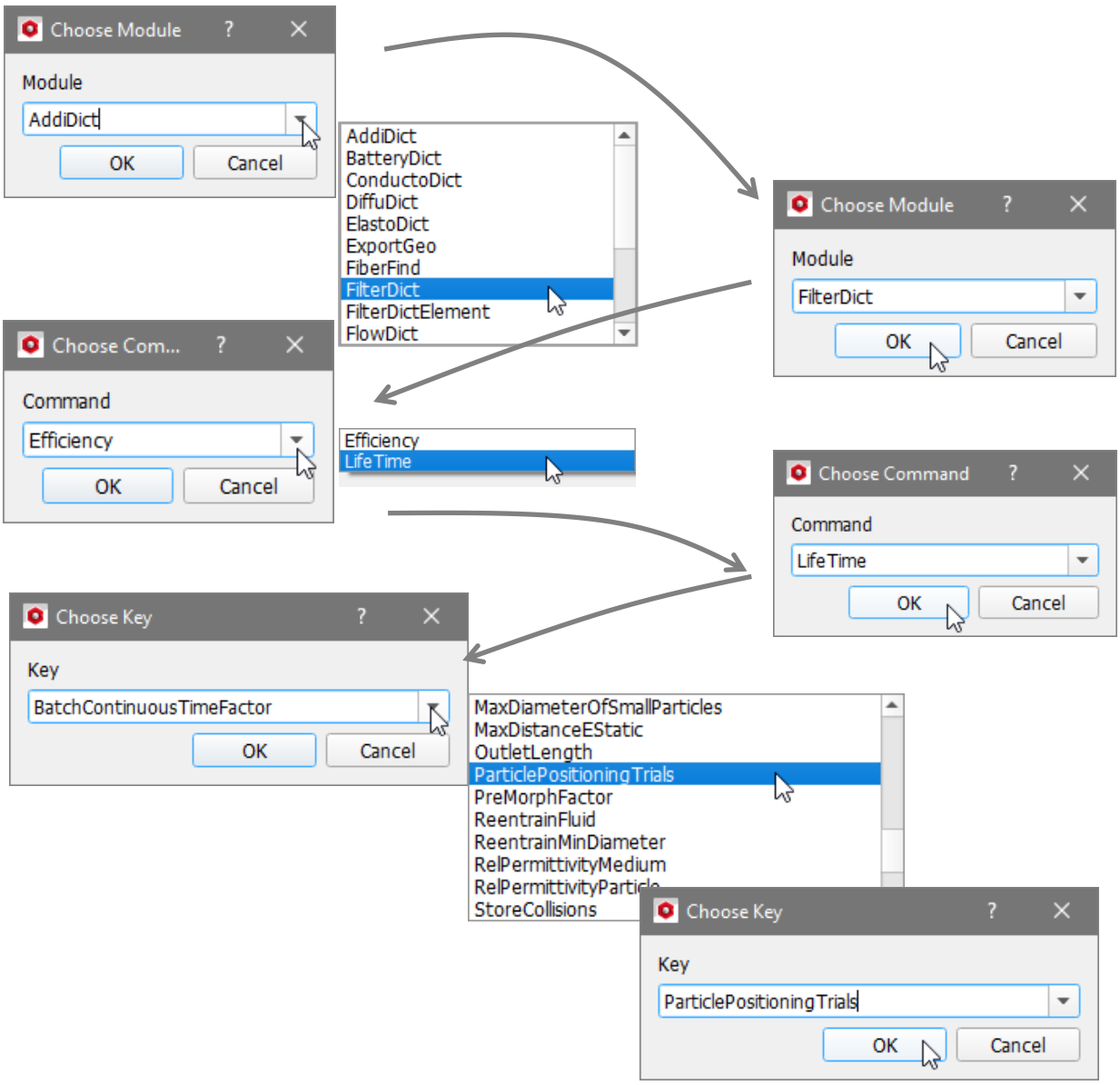
Edit Expert Settings...

For many commands available in GeoDict's modules, additional parameters exist that are not available through the dialog widgets that open in the corresponding modules. These parameters are also not stored in the parameter lists of those commands inside the python macros. By default, no expert settings are set, and well-chosen default values are used.

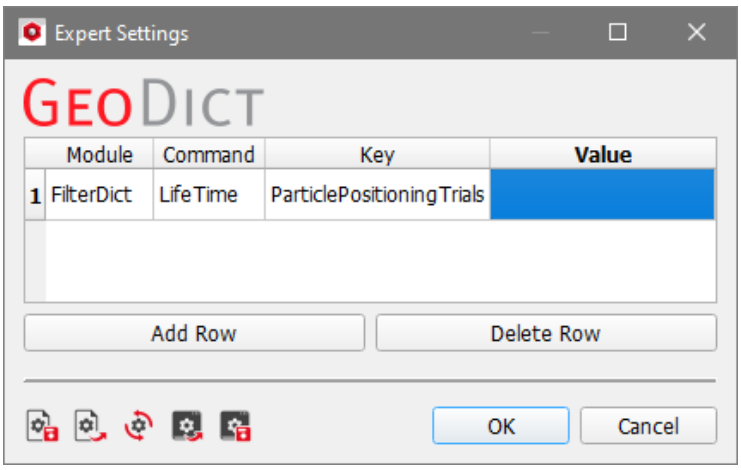
Some expert settings allow to access experimental or unstable features. Others allow to access solver variants that are only useful in very special circumstances. In general, a user should not set any expert settings without consultation of Math2Market.



To activate an expert setting, after selecting **Edit Expert Settings...**, the user clicks **Add Row** to sequentially select the **Module**, the **Command**, and the **Key** that define the expert setting that should be edited.

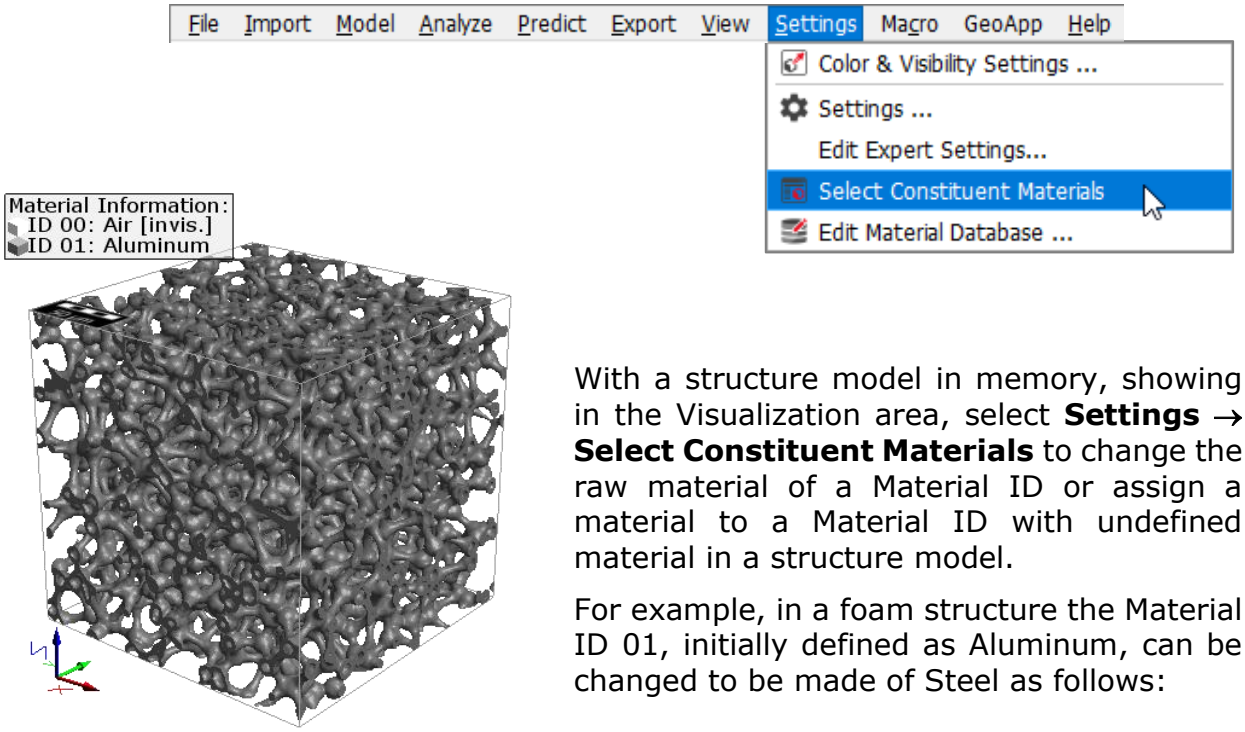


The choices of module, command, and key are entered as columns into the first row. The user can now click the cell under **Value** and manually enter it.



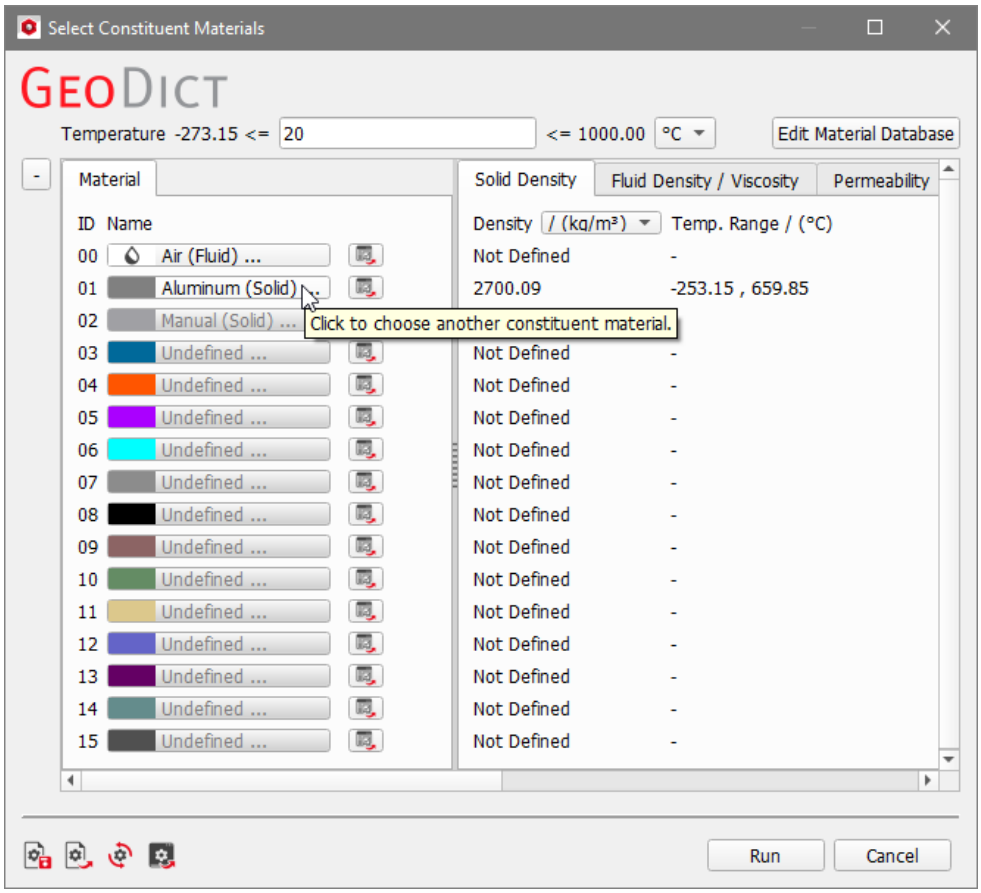
Select Constituent Materials

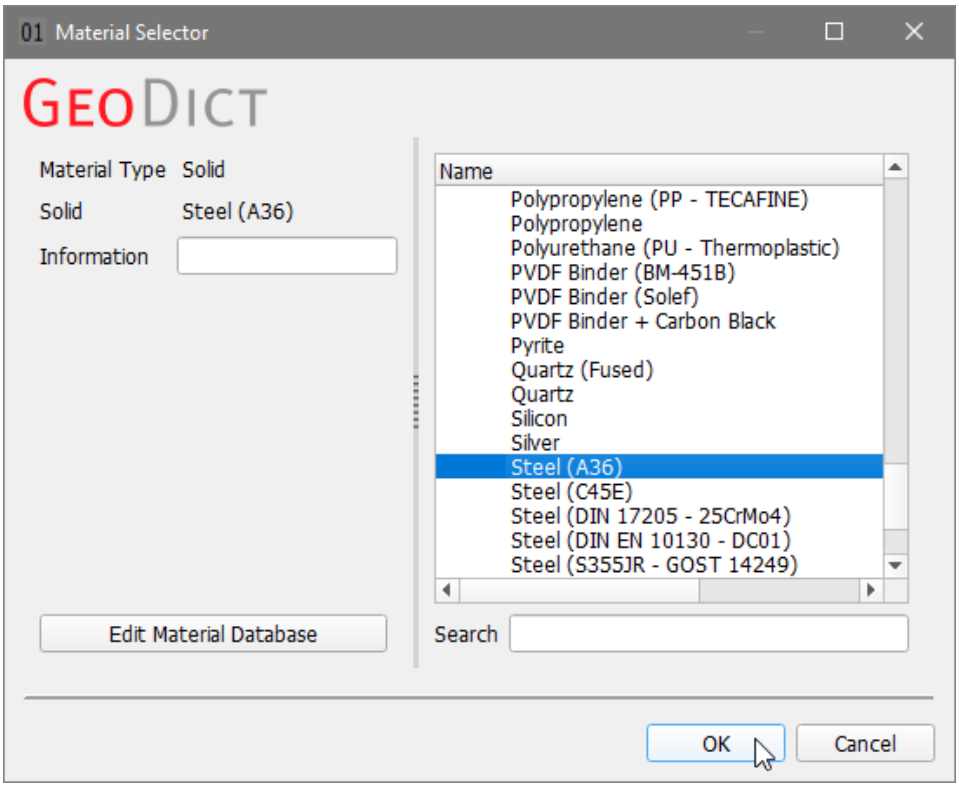
A Constituent Material from the Material Database consists of a name for the raw material and the material's physical properties and represents the properties of a material in a structure model.



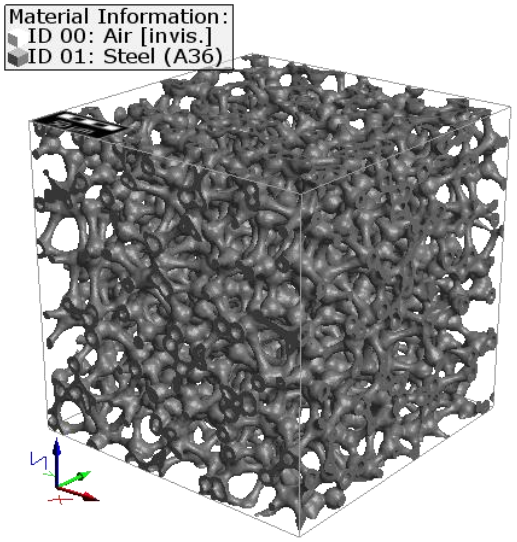
With a structure model in memory, showing in the Visualization area, select **Settings** → **Select Constituent Materials** to change the raw material of a Material ID or assign a material to a Material ID with undefined material in a structure model.

For example, in a foam structure the Material ID 01, initially defined as Aluminum, can be changed to be made of Steel as follows:





If the new material is selected, close the dialog by clicking **OK** in the Material Selector dialog and **Run** in the Select Constituent Materials dialog.

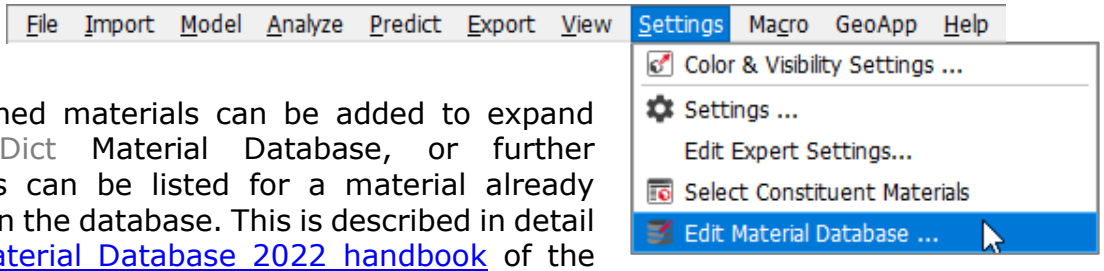


Edit Material Data Base...

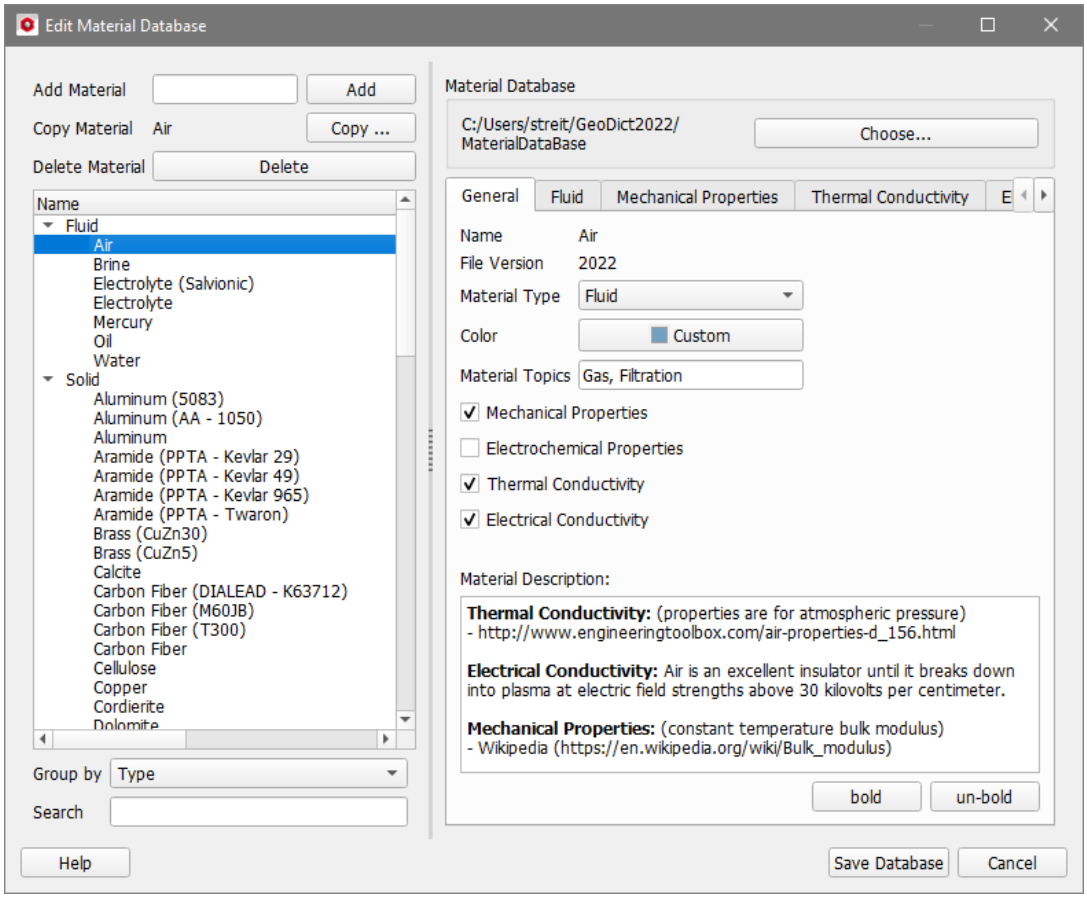
In GeoDict, constituent materials (and their physical properties) are **globally assigned to a structure** and not just to a property predictor simulation.

The GeoDict Material Database is a catalogue of the constituent materials that can be assigned to correctly identify digital materials in the structure models with properties of real materials.

The user can access and edit the GeoDict Material Database from many modules or select **Settings → Edit Material Data Base...** to directly access the catalogue from the menu bar.



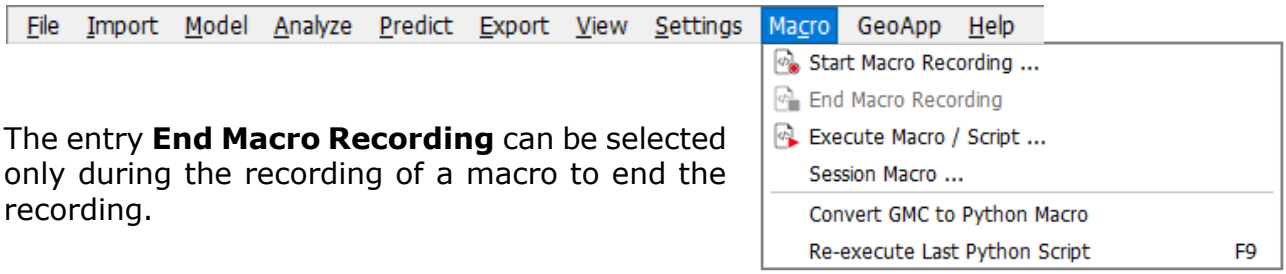
User-defined materials can be added to expand the GeoDict Material Database, or further properties can be listed for a material already included in the database. This is described in detail in the Material Database 2022 handbook of the User Guide.



Each material in the database, together with its properties and description, is saved as a text-file with the name of the material. The user can edit these files in any text editor. The default GeoDict Material Database is located at:

MACRO

The Macro menu contains the entries **Start Macro Recording**, and **End Macro Recording**, **Execute Macro/Script**, and **Session Macro**.

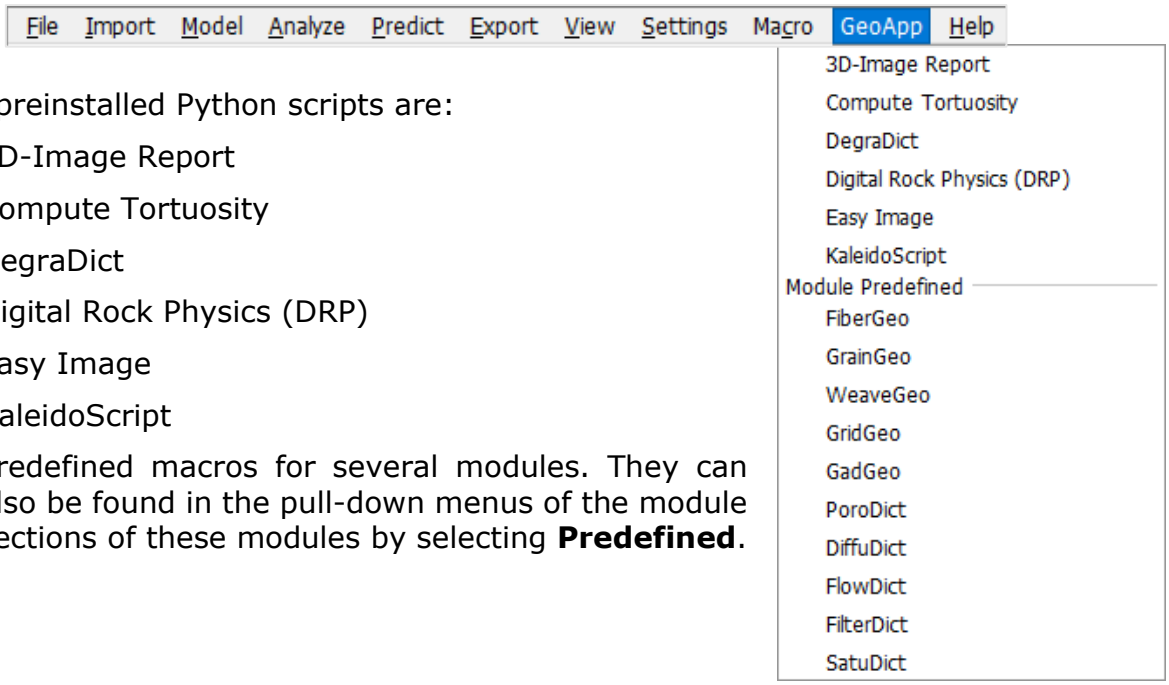


The entry **End Macro Recording** can be selected only during the recording of a macro to end the recording.

Macro recording and execution and the options **Convert GMC to Python Macro** and **Re-execute Last Python Script** are explained in detail in the Automation 2022 handbook of the User Guide.

GeoApp

When selecting **GeoApp** in the menu bar and selecting one of the entries in the pull-down menu, the module section (left of the Visualization area) changes to enter parameters for the execution of pre-installed Python scripts for a variety of applications.



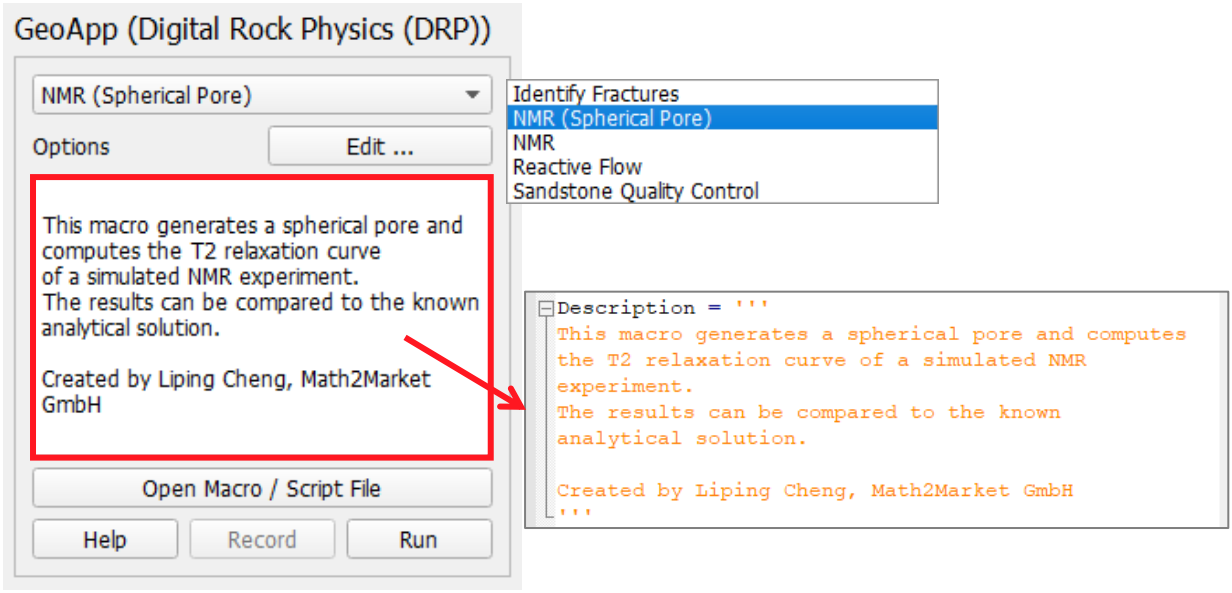
The preinstalled Python scripts are:

- 3D-Image Report
- Compute Tortuosity
- DegraDict
- Digital Rock Physics (DRP)
- Easy Image
- KaleidoScript
- Predefined macros for several modules. They can also be found in the pull-down menus of the module sections of these modules by selecting **Predefined**.

Selecting a GeoApp from the list opens the **GeoApp** section, located left of the Visualization area. It contains a pull-down menu that lists the available Python scripts for the corresponding GeoApp.

When selecting one of the available scripts, the description area displays a report about the script. In the script, this report content can be found inside the apostrophes after **Description = ''' '''** and can be edited at any time after opening the script with a text editor.

For the **NMR (Spherical Pore)** script from the **Digital Rock Physics (DRP)** App, the text in the macro and the description area are shown here.



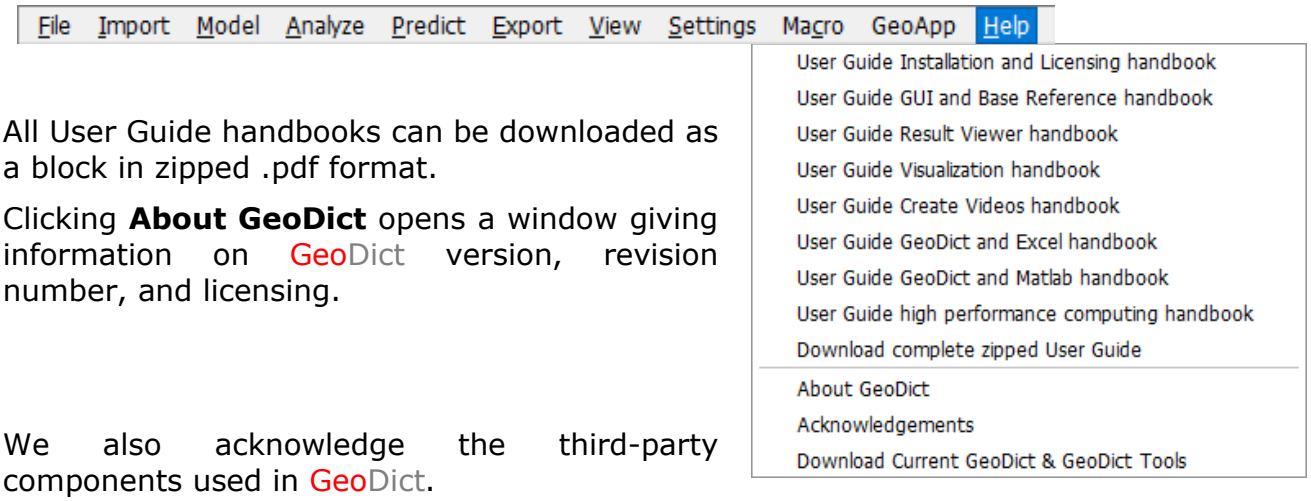
Click the Options' **Edit ...** button to edit the parameters of the macro. To open the GeoApp in an editor, click **Open Macro / Script File**. Clicking **Run** executes the script.

The GeoApp scripts listed in the pull-down menus can be found in the GeoDict installation folder in the subfolder GeoApp or in the subfolder of the corresponding module.

More details about using GeoApps can be found in the GeoApp 2022 handbook of this User Guide.

HELP

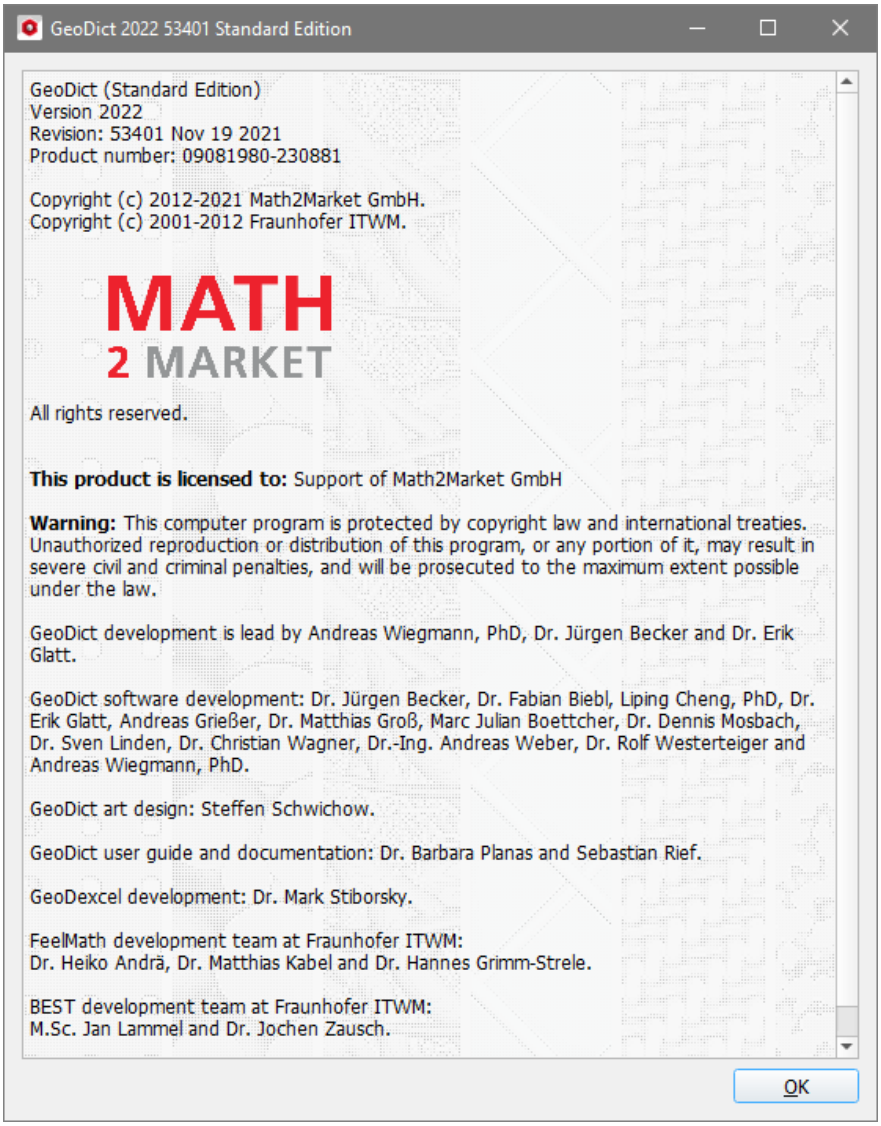
The **Help** menu links directly to several volumes of the User Guide on the GeoDict web page for information on installation and licensing of GeoDict, the introduction to the GUI and the Base Reference, the Result Viewer for the result files, Visualization and video creation in GeoDict, using GeoLab and GeoDexcel and setting up high performance computing.



All User Guide handbooks can be downloaded as a block in zipped .pdf format.

Clicking **About GeoDict** opens a window giving information on GeoDict version, revision number, and licensing.

We also acknowledge the third-party components used in GeoDict.



PROJECT STATUS SECTION

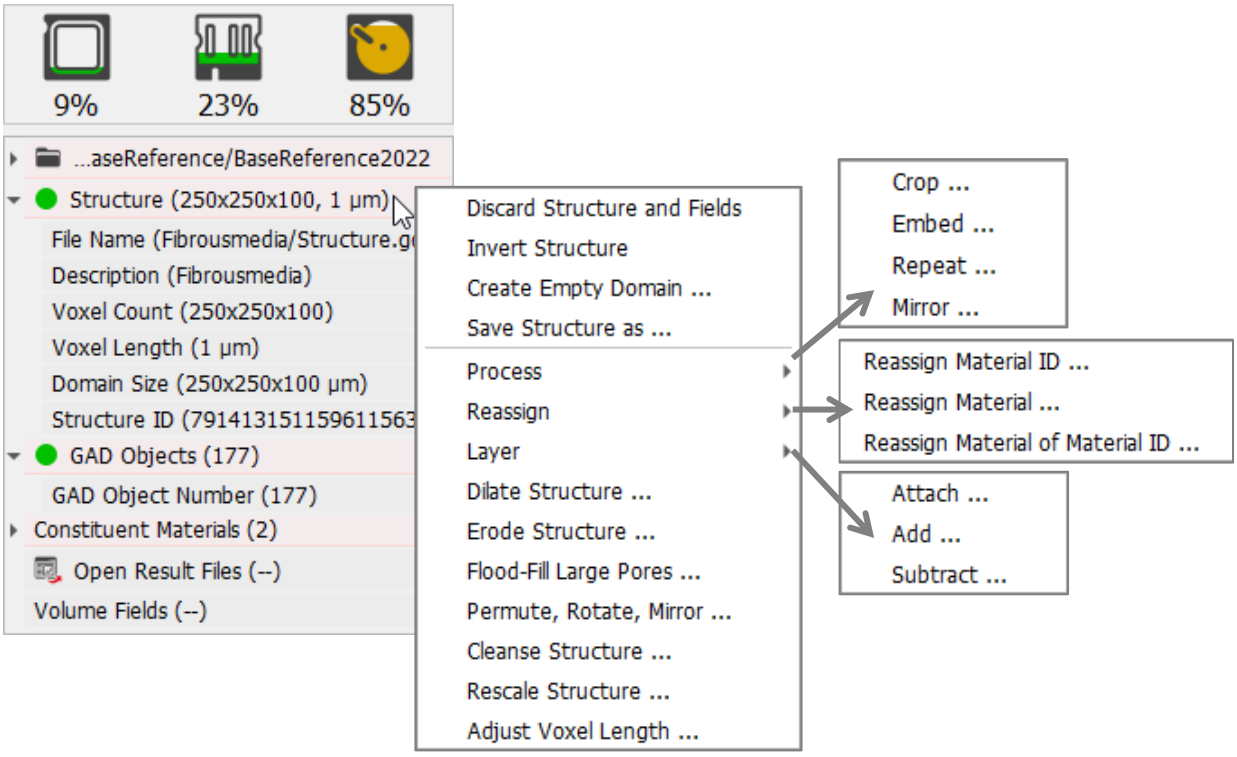
The **project status** section displays the current **CPU** load, the currently used **RAM** and the percentage of **Disk Space** used on the drive where the project folder is located. This refers to all processes running on the computer, not only to GeoDict.

The project folder's path is also shown.

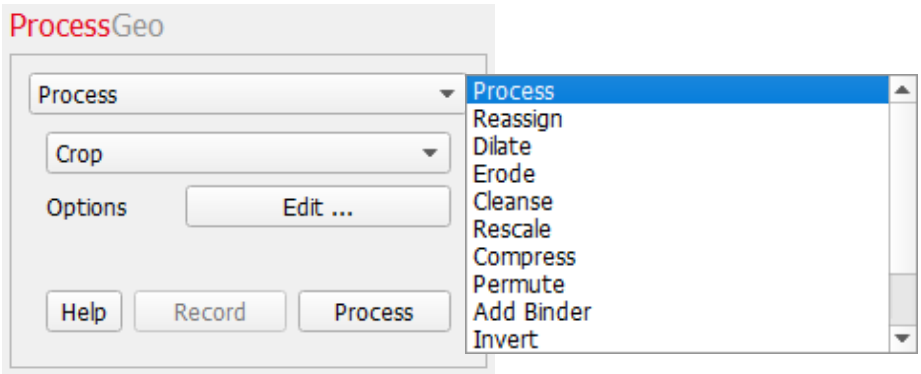
The **Structure** model is identified by File Name, Description, the Voxel Count, the Voxel Length, the Domain Size and the internally hashed **Structure ID** number. A structure generated, e.g., with FiberGeo, GrainGeo, PaperGeo, WeaveGeo, GridGeo, or PleatGeo, with the same parameters and the same random seed, has always the same **Structure ID** number. The **Structure ID** number changes as soon as the structure is modified in any way.

The current **Voxel Length** is shown in the selected units (m, mm, µm, nm, Inch).

Right-clicking on the **Structure** row opens a menu used as a shortcut to apply modifications to the microstructure.

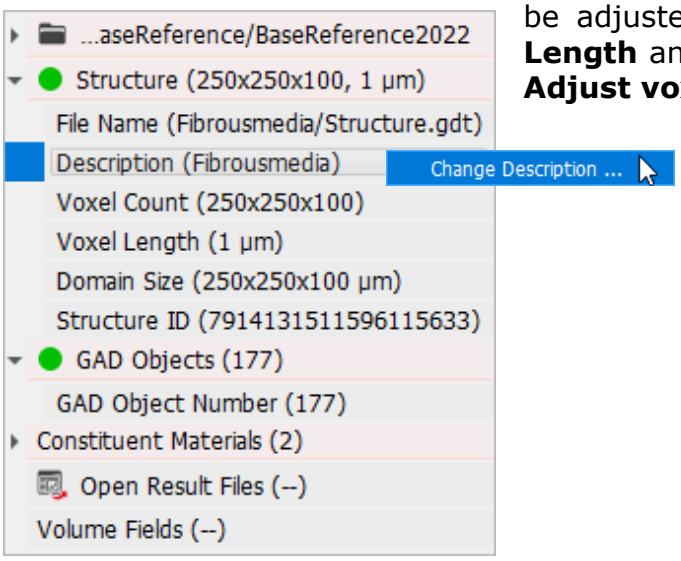


Most of the commands in this menu are shortcuts to several functions included under the **File** menu in the menu bar, in the ProcessGeo module (Model → ProcessGeo), or in the LayerGeo module (Model → LayerGeo).

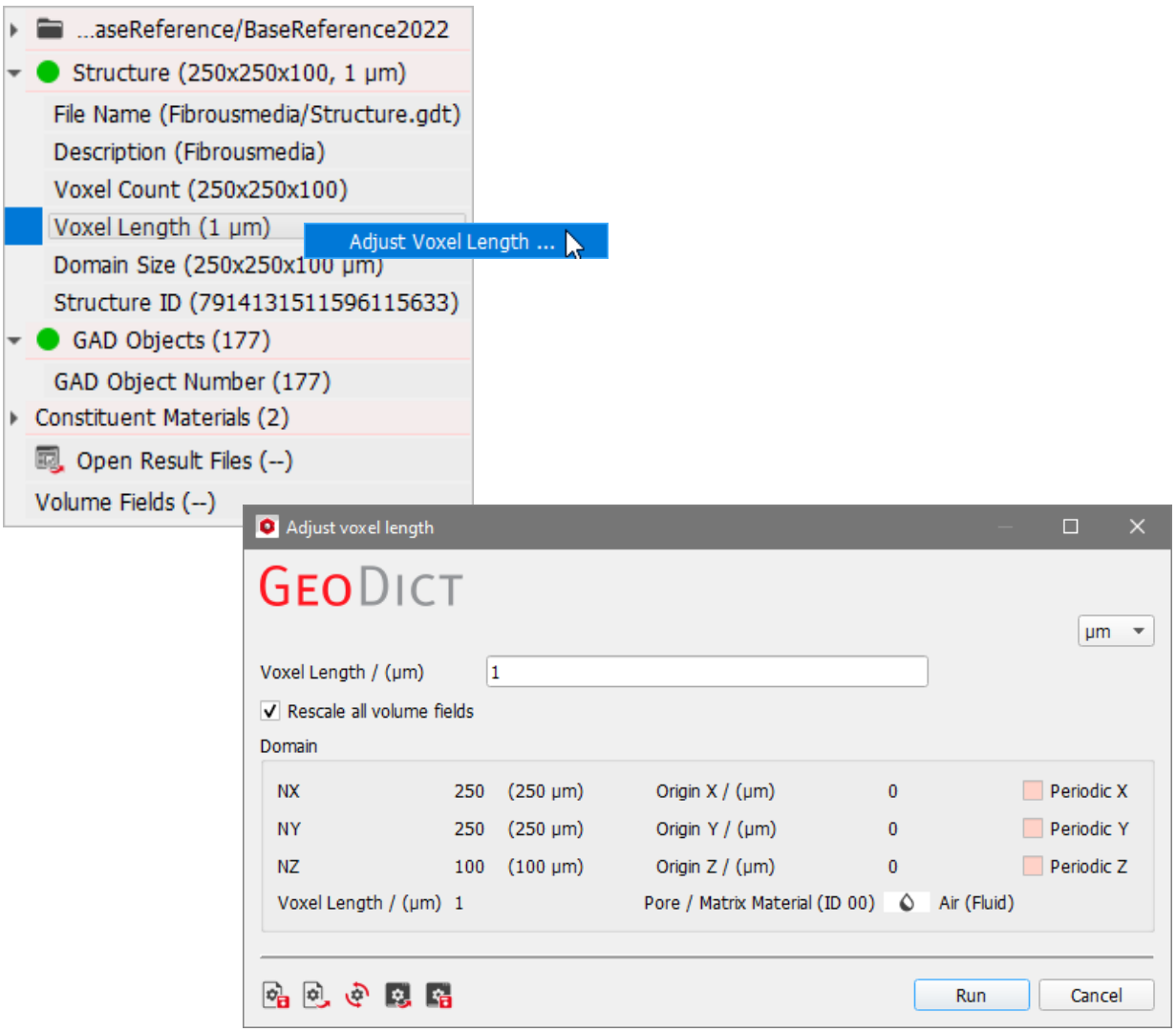


Some of these modifications can be carried out directly from the **Structure** row.

For example, the **Description** of the structure or even the **Voxel Length**, which can be adjusted directly by right-clicking on **Voxel Length** and changing parameters in the opening **Adjust voxel length** dialog.



This change in voxel length occurs on the already generated structure (post-processing). To vary voxel length for the generation of a new structure (pre-processing), the value has to be changed through the **Create → Options - Edit**... button in the module section of the corresponding Geo module (FiberGeo, GrainGeo, WeaveGeo, etc.)

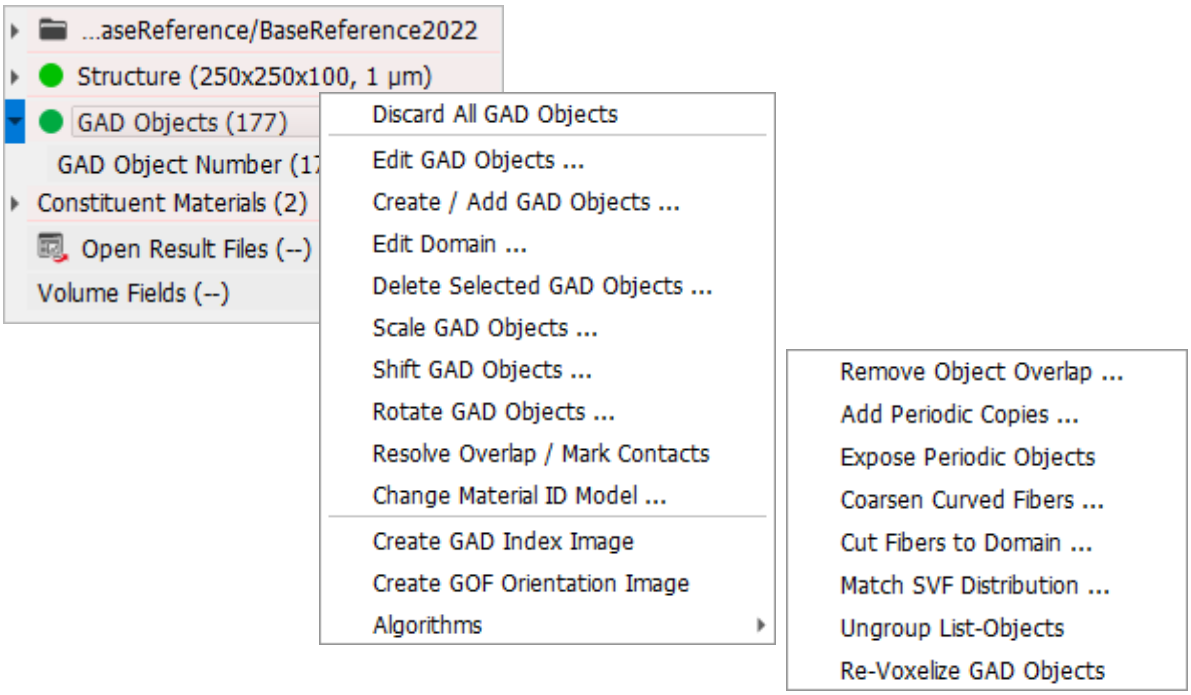


The color dot in front of **Objects** shows whether information about the objects inside of the current structure are available (green dot), or not (red dot).

The dot is yellow when information about objects inside of the current structure is available, but this information does not describe the current structure completely. This may happen, for example, when the structure has been modified after the generation (e.g., with ProcessGeo or LayerGeo).

Also shown in the **Project Status** section is the number of objects (such as fibers, grains, etc.) in the structure (**GAD Object Number**).

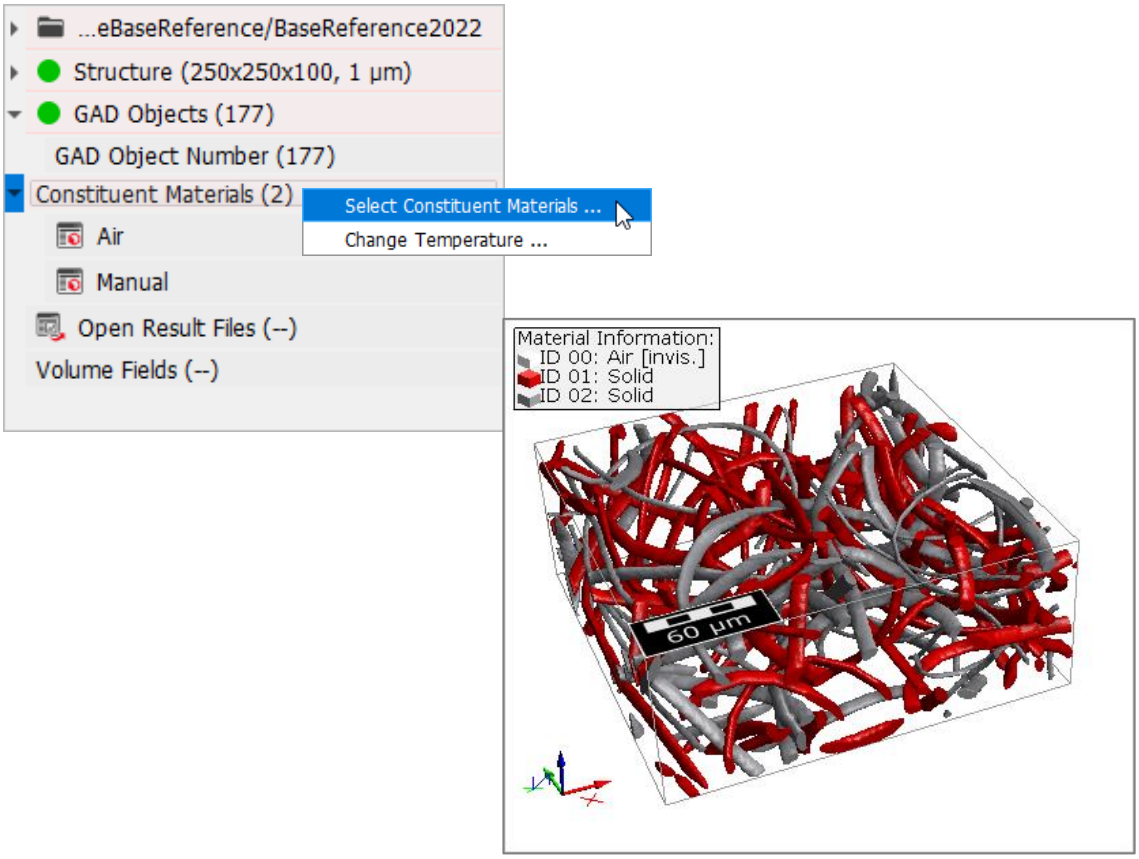
Right-clicking on **Objects** opens a list of possible modifications, like editing the GAD objects or the domain, creating, adding, deleting, scaling, shifting and rotating GAD objects, resolve overlap and mark contacts, change the Material ID model, or to create a GAD index image or an orientation image. All of these modifications can be accessed also from the module GadGeo and are explained in the GadGeo 2022 handbook of the User Guide.



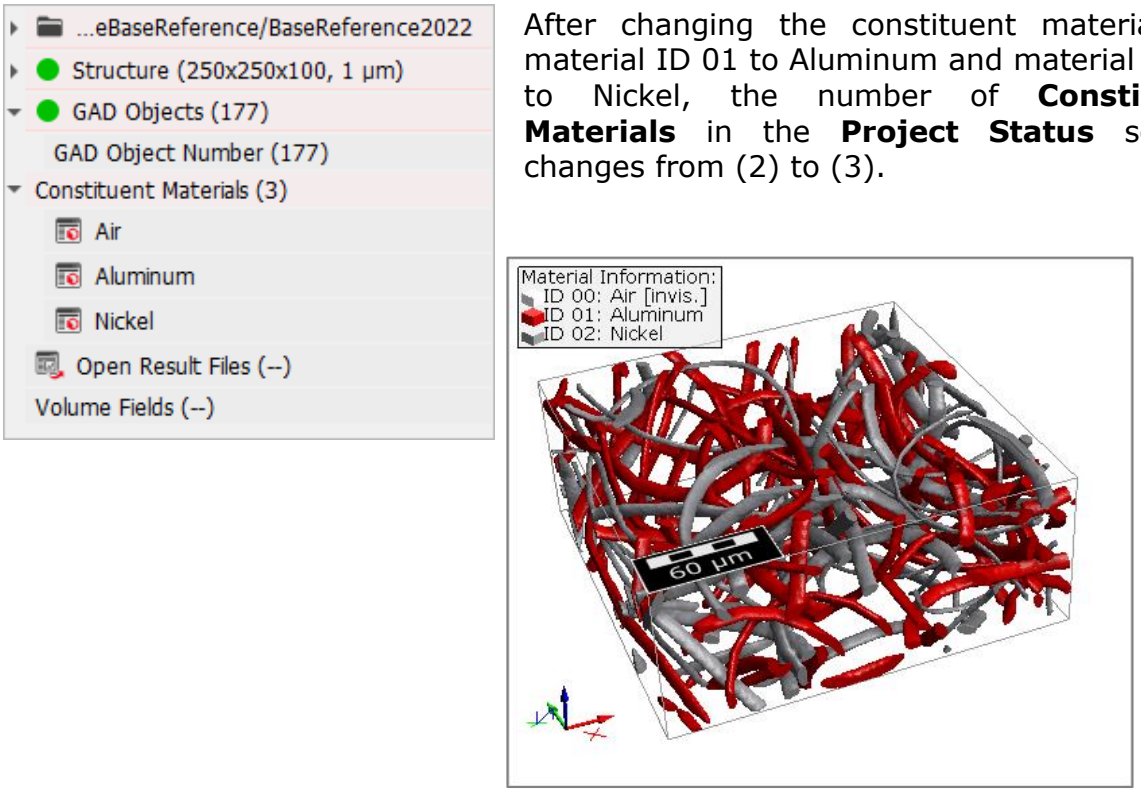
By choosing **Algorithms**, all manipulations of analytic objects, available in the section Algorithms of GadGeo can be accessed.

The next entry in the **Project Status** section is Constituent Materials. This block lists the materials that are present in the structure and are shown in the **Material Information** legend next to the microstructure in the Visualization area.

In the example shown here, two **Constituent Materials** are listed in the **Project Status** section (Air and Manual), corresponding to *Air* and *Solid* in the **Material Information** legend. The fibers with material ID 01 and material ID 02 are set to be made of the same constituent material.



Right-clicking on **Constituent Materials** gives access to the **Select Constituent Materials** dialog and is a shortcut to selecting **Settings** → **Select Constituent Materials** in the menu bar and to the **Change Temperature** Dialog.

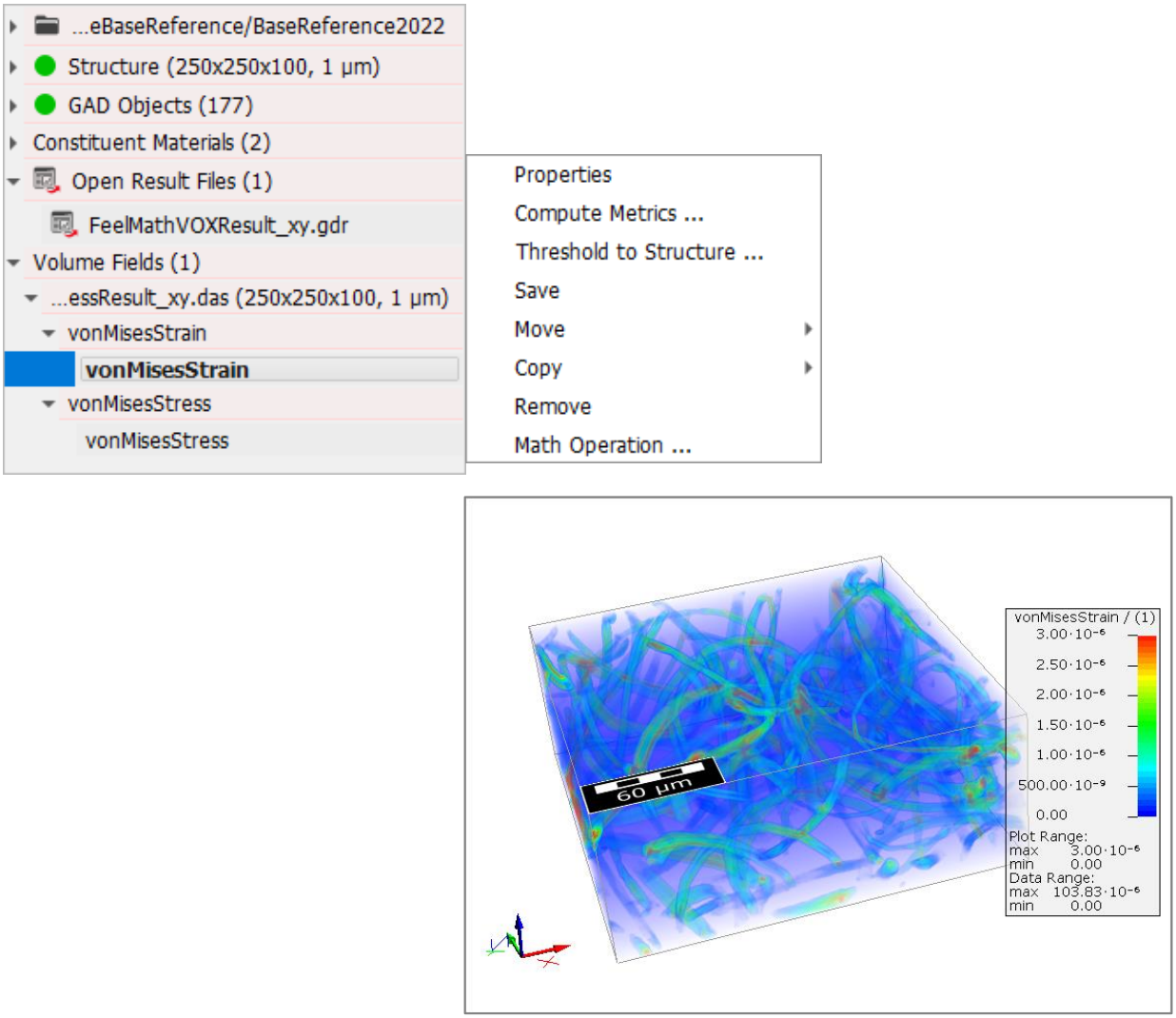


After changing the constituent material for material ID 01 to Aluminum and material ID 02 to Nickel, the number of **Constituent Materials** in the **Project Status** section changes from (2) to (3).

The last two entries in the **Project Status** section are **Open Result Files** and **Volume Fields**.

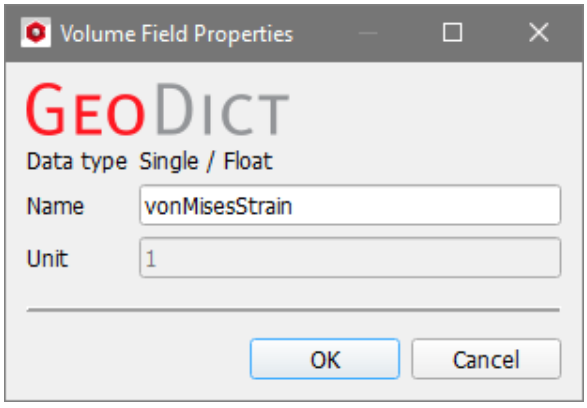
Open Result Files shows the number and names of result files that are currently open in the **Result Viewer**.

After loading a result file and a corresponding volume field (e.g., after an effective stiffness simulation with ElastoDict-FeelMath-VOX), the name of the result file (**Open Result Files**) and the corresponding **Volume Fields** appear in the **Project Status** section, and the loaded volume field can be shown in the Visualization area.

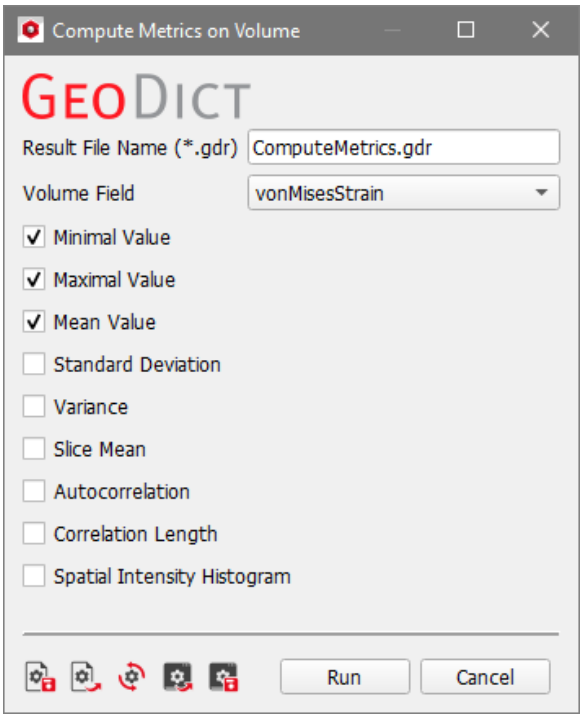


Right-clicking on the volume fields opens a list of options.

Choose **Properties** to get information on the volume field loaded.



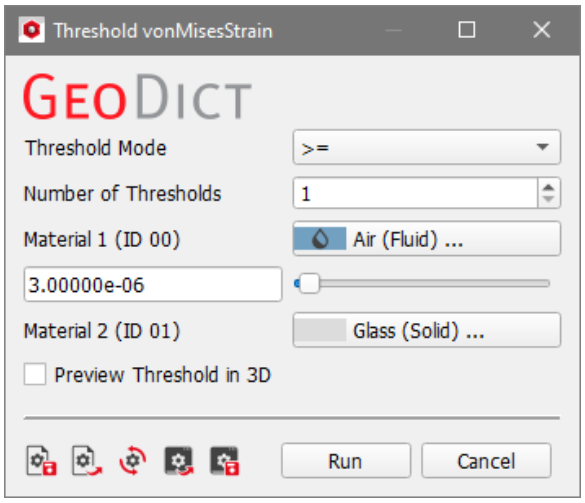
With **Compute Metrics**, access statistical properties of the volume field, like maximum or minimum value, mean, variance, etc.

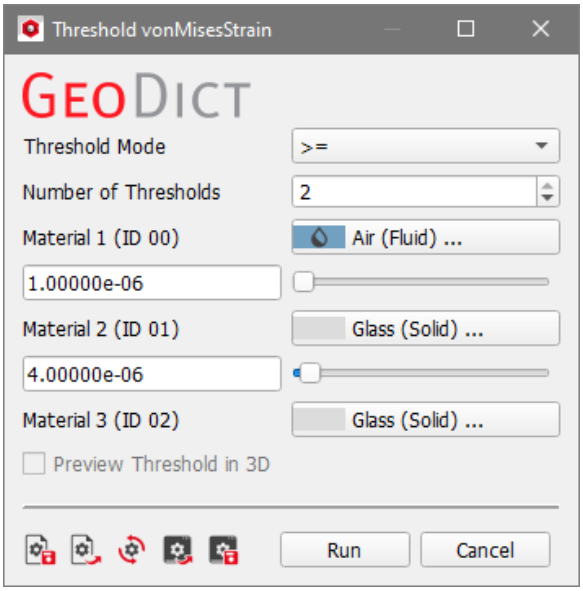


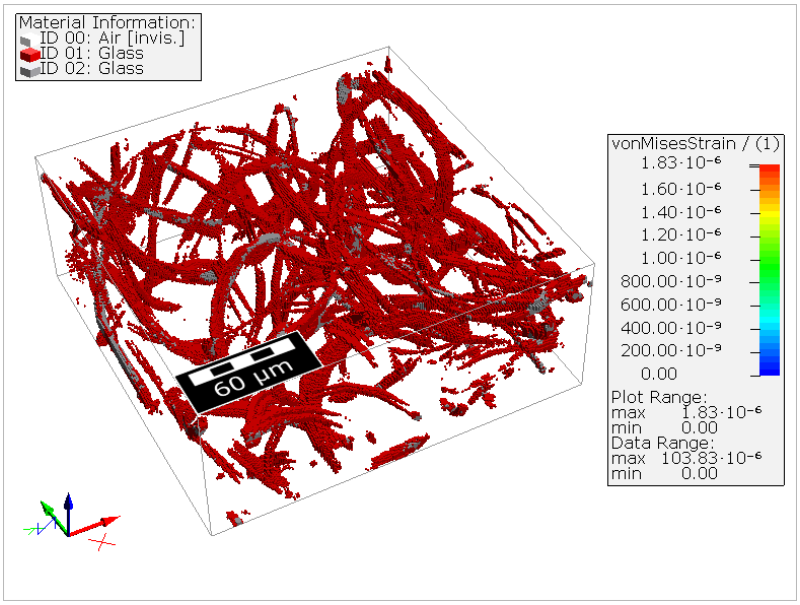
Select **Threshold to Structure** to create a structure with voxels above or below a defined threshold of a volume field. In GeoDict 2022, one or two thresholds can be defined.

For one threshold, check **Preview Threshold in 3D** to visualize the created structure already before clicking **Run**.

Define e.g. 2 thresholds to create a structure with voxels of ID 01 where the von Mises Strain of the fibrous structure is above 1e-06, and with voxels of ID2 at locations with von Mises strain above 4e-06.

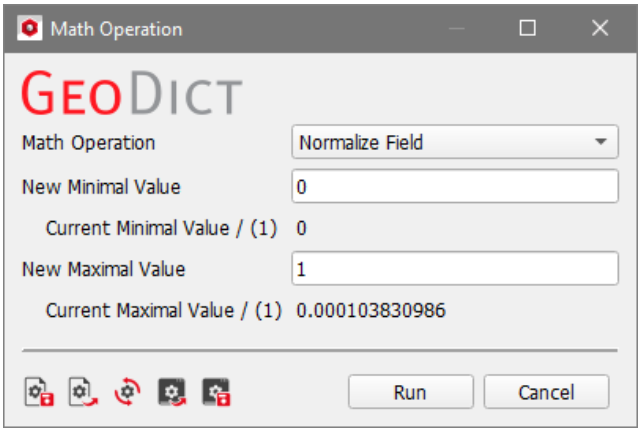




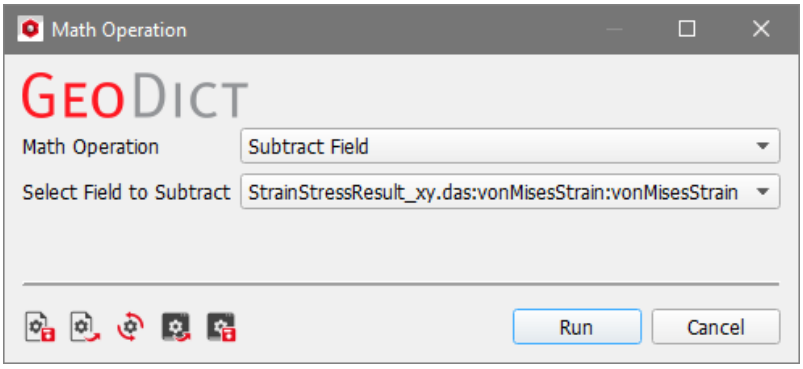


A volume field can be saved as .guf file, moved or copied to another volume field or removed from the GUI.

Choose **Math Operation** to open a dialog that allows to manipulate the volume field in different ways.



- **Normalize Field:** define a new minimum and maximum value and normalize the values of the volume field accordingly.
- **Subtract Field**: choose another volume field, e.g., from another result file, that will be subtracted from the current volume field.

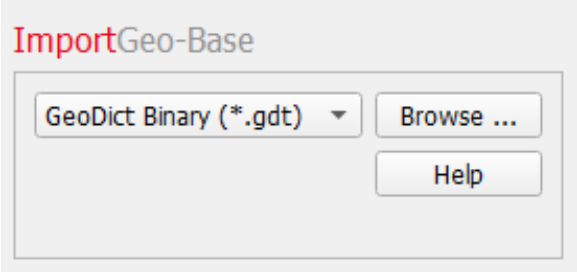


- **Add Field**: choose another volume field that will be added to the current one.

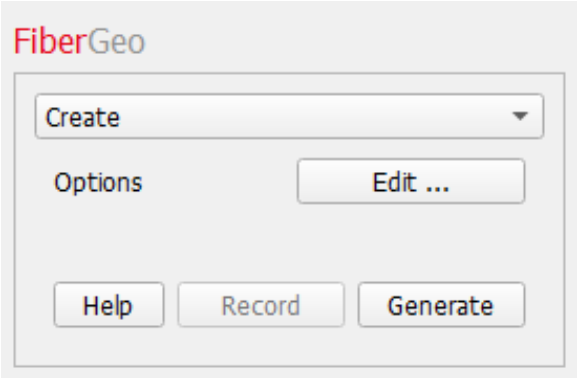
- **Compute Gradient**: compute the gradient for the current volume field.
- **Convert to Data Type**: choose a new data type (single, uInt32, uInt16 or uInt8) and convert all values of the current volume field to this type.
- **Add (Subtract) Constant Value**: add or subtract a constant value from the volume field.

MODULE SECTION

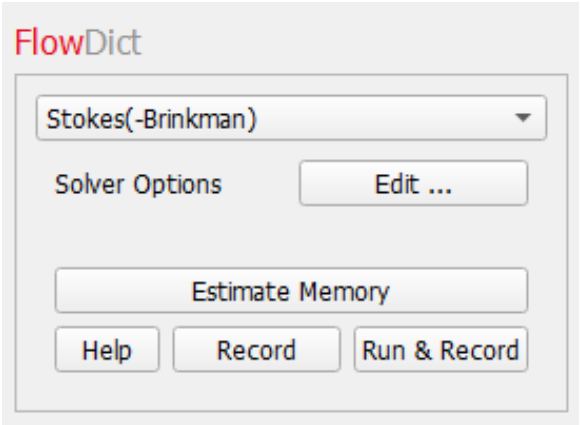
The heading of the **Module** section changes accordingly when selecting to work with the GeoDict modules for which the user has a license (see page 25). The GeoDict modules are organized into modules to **Import** and pre-process files and 3D image data, generator and structure-modifying modules to **Model** microstructures, structure analyzing modules to **Analyze**, properties predictor modules to **Predict**, and modules to **Export** files to other formats.



The module section contains a **Browse...** or **Edit...** button to choose files or edit options necessary for GeoDict's generators, modifiers, or solvers, and a **Help** button directly linking to the User Guide Reference for the module currently in use.



The module section often includes a **Record** button, which is selectable when **Macro → Start Macro Recording...** is selected in the menu bar. Clicking **Record** allows recording the settings and actions of the module without obtaining the results (yet), while **Run & Record** starts the computation and additionally records the action in the macro file.



Depending on the module, the button **Generate**, **Run**, or **Export** starts the actions of the generator, the solver or the export. For ProcessGeo and LayerGeo, the button

specifies the particular modifying process (Reassign, Rescale, Compress, Attach, Erode, Dilate, etc.).

For some modules, the module section includes an **Estimate Memory** or **Estimate Memory & Disk-Space** button, that becomes active for the functionalities that support such an estimation. It allows to estimate the memory (and disk-space) required for the computation before starting the computation.

The use of the modules is explained in each of the module's handbooks.

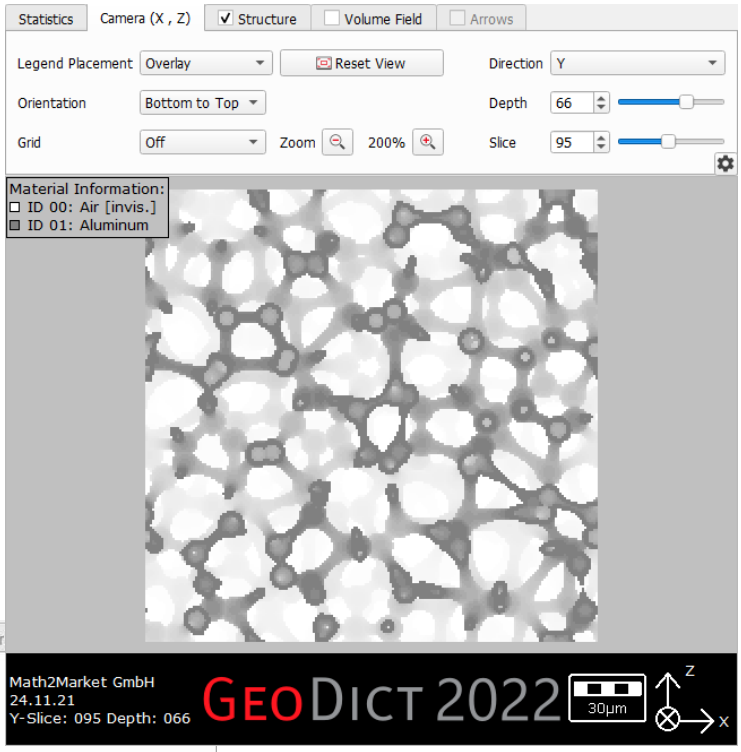
VISUALIZATION AREA AND VISUALIZATION PANEL

Initially, the **Visualization panel** shows information about the image displayed in the **Visualization area**. The image might be of a fibrous-, paper-, granular-, sintered-, pleated-, woven-, or grid-structure created with one of GeoDict's structure generators, an image from an opened *.gdt file, an image imported and segmented with ImportGeo-Vol or ImportGeo-CAD from a stack of 3D image data (µCT, FIB/SEM), or other structure models.

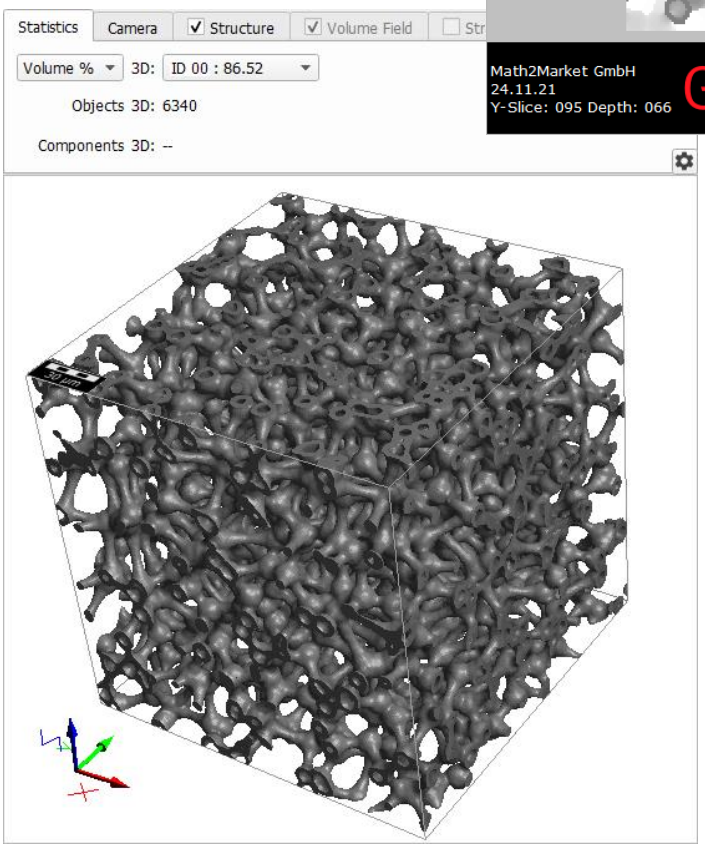
The visualization of computational results changes the panel, by activating other tabs, to access options to visualize the results optimally.

Complete information on visualization of structures and results in GeoDict, and all options, is available in the GeoDict Visualization 2022 handbook of the User Guide.

In 2D Cross Section view, zoom in and out smoothly by keeping the right mouse button clicked and moving the mouse forward and backward. Or zoom stepwise by clicking the **Zoom** buttons on the **Camera** tab.



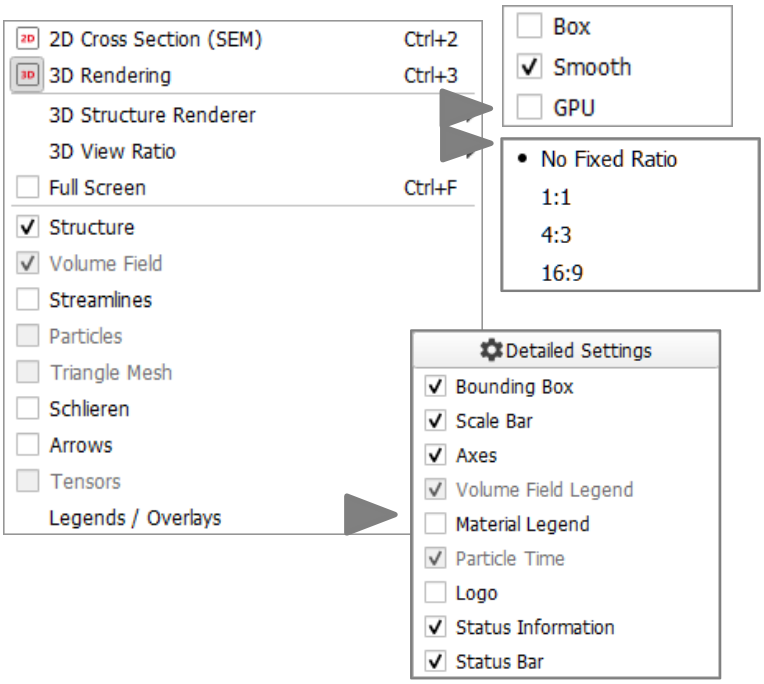
In 3D Rendering, zoom by keeping the right button pressed and simultaneously moving the mouse forward. By moving the mouse backward, the image zooms out. Or zoom in and out by scrolling the mouse wheel.



The visualization display and the data shown in the panel change if different parameters or settings are selected in the **View** menu and in the **Settings** → **Settings...** menu, see page 31.

Select to view the structure in **2D Cross Section (SEM)** or **3D Rendering** mode.

In **3D Rendering**, render the structure on the graphics card (**GPU**) or the main processor (**Box** with raycasting or **Smooth** with raycasting). Volume raycasting is an image-based volume rendering technique that computes 2D images from 3D volumetric data sets.



Select **Full Screen** to make the Visualization area occupy the entire computer screen. Pressing the **Esc** key on the keyboard returns the program to the normal display.

When un-checking **Structure**, the complete structure disappears from the display. In the same way loaded results, like **Volume Fields**, **Streamlines, Particles, Triangle Mesh, Schlieren, Arrows and Tensors** can be switched on and off in the visualization.

To start the visualization of results, a result file must be loaded through **File** → **Load Volume Field ...** or **Load Particles ...** in the menu bar, or directly by loading from the **Visualization** tab of the GeoDict **Result Viewer**.

Among the **Legends / Overlays**, unchecking **Bounding Box** makes the border surrounding the domain disappear in **3D Rendering**. Unchecking **Scale Bar** or **Axes** make the scale bar and/or the coordinate stencil in the lower left corner disappear from the display while in **2D Cross Section (SEM)** or in **3D Rendering**.

Unchecking **Volume Field Legend** and/or **Material Legend** hides the legends of a volume field or for the constituent materials present in the structure.

The particle time, displayed for a particle simulation, the display of the GeoDict logo, the status information or the display of the status bar can be switched on and off as well.

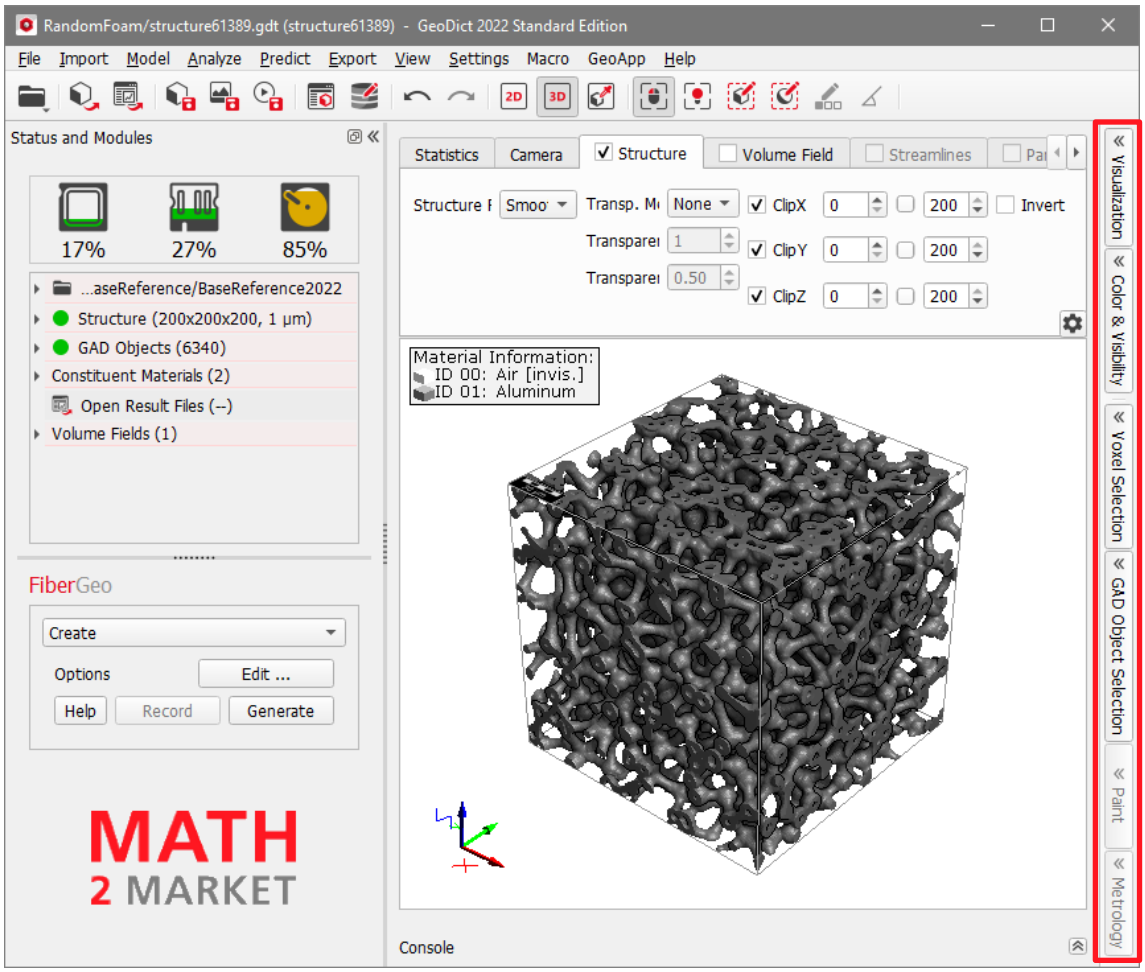
More detailed information about visualization in GeoDict can be found in the Visualization 2022 handbook of the User Guide.

GUI Sidebar

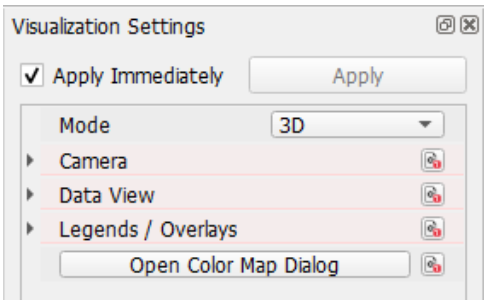
Starting with GeoDict 2020, many of the options that were previously available only under the **View** menu in the menu bar, have moved for convenience of usage to the sidebar to the right of the GUI.

In GeoDict 2022, dialogs for **Visualization**, **Color & Visibility Settings**, the editing and modifying functions (**Voxel Selection**, **GAD Object Selection** and **Paint** mode) and the measuring of distances and angles (**Metrology**) can now also be opened directly from the GUI sidebar.

This sidebar now controls all visualization settings, editing, modifying, and measuring functionality centrally. It can be expanded and collapsed by clicking on the « icon on the tabs.



When expanded, the sidebar panel can be un-docked by clicking the icon at the top of the open panel and, so, turned into a dialog that can move around.



Information about the **Visualization** tab and the **Color & Visibility** tab from the GUI sidebar can be found in detail in the Visualization 2022 handbook of the User Guide.

The functionality of the tabs **Voxel Selection**, **GAD Object Selection** and **Paint** is explained below.

WHAT ARE VOXELIZED AND ANALYTIC STRUCTURE MODELS?

Objects in structure models in GeoDict can be described in:

- **GAD format**: An analytic description including the properties of gad-objects, like their diameter, position and material properties, written to an ASCII-file.
- **GDT format**: A 4-bit volume representation of the structure that contains the voxel geometry. The new GDT format, available since GeoDict 2019, can contain also the analytic description of the objects (if available when the structure is saved).

Editing and modification of structure models can be done on the structure's voxel geometry description or analytic description.

Simple and complicated microstructures can be edited by manual drawing, e.g., to correct problematic boundary effects. Among other applications, voxel and analytic data editing can be used to remove artifacts from 3D structures built from imported 3D-image data (micro-CT, nano-CT, SEM, …).

For structure models created using GeoDict's generator modules, undesired fragments of the structure can be easily modified or eliminated, without having to reset the parameters and generate again.

This direct editing or modification of voxelized and analytic structure models is a complement to the GadGeo module. GadGeo generates and edits on the analytic level, on structures with available analytic information, whereas editing is also applicable to structure models with voxelized formats.

Structure models can be manually edited with GeoDict, using the following icons in the toolbar:

GDT – 3D		Edit the previously selected **voxels.**
GAD – 3D		Edit the previously selected **analytic objects**.
GDT – 2D		**Edit** in a way similar to the Windows standard editor **Paint**. Observe results in 3D (edited objects are three-dimensional)

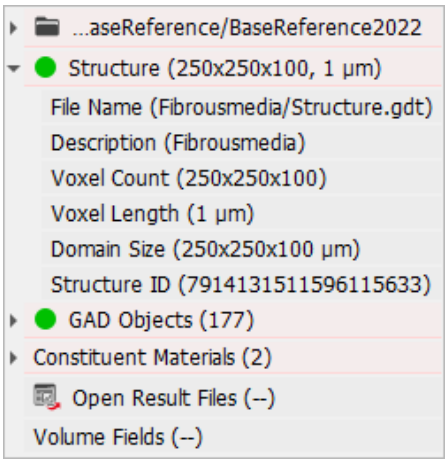
Part of the functionality for structure editing can be accessed also by a right mouse click in the visualization area, see page 70.

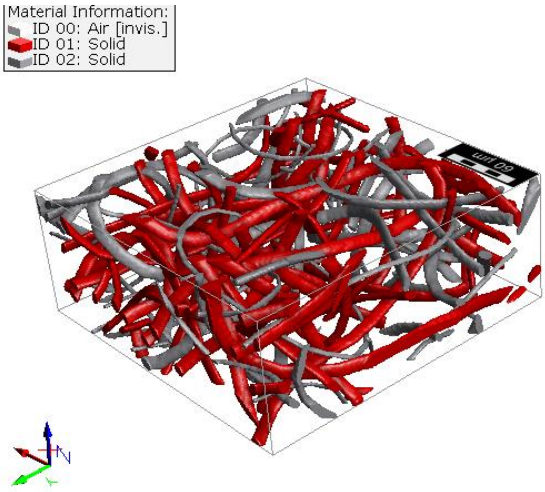
Here, as a simple structure example, a fibrous media model is generated with FiberGeo and then the structure model is saved in GDT format and in GAD format. The structure model contains curved fibers of two different raw materials, initially set as Manual (Solid).

Below follow examples to edit and modify this fibrous media model structure in both formats.

VOXEL SELECTION AND EDITING FOR GDT FORMAT

With the new GDT format .gdt files can contain also analytic object information. If the fibrous material model in GDT format is loaded, the same information as for the same structure model having been saved in GAD format (see below) is shown in the project status section.

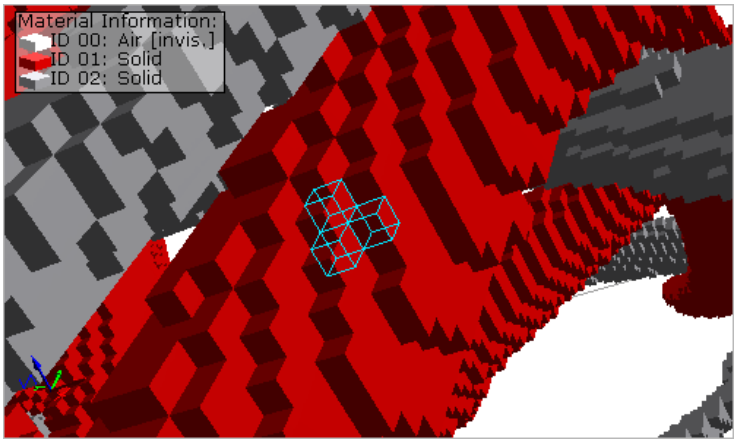




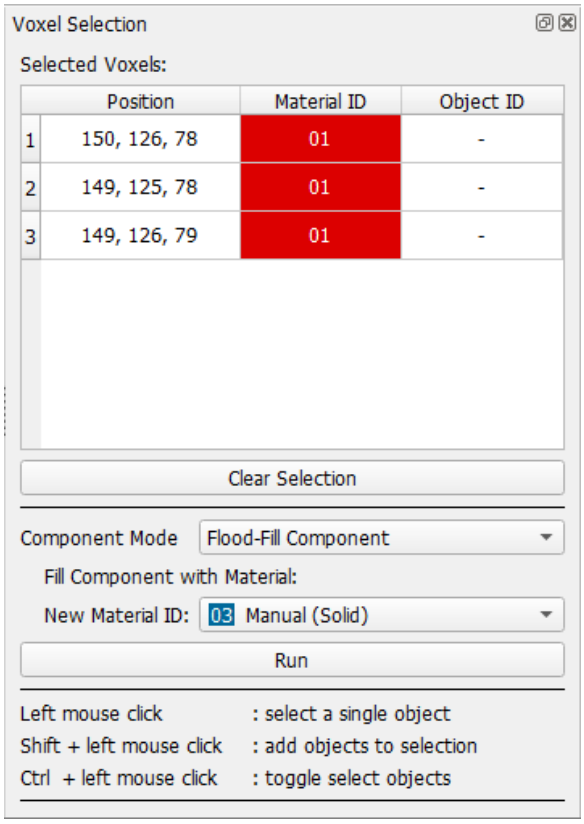
We now want to edit the structure by editing the voxels. By changing the voxel structure, the analytic object information is not modified, and therefore the analytic object description in the model is lost. The initially green dot before **Objects** turns red, if one of the operations listed below is applied.

The voxels forming a fiber in the structure model are edited in 2D Cross Section (SEM) view or in 3D Rendering, as follows:

1. Select voxels:
   a. Zoom into the structure by pressing and holding the right mouse button while moving the mouse back and forth or scroll the mouse wheel.
   b. To enter the Voxel Selection mode, click the « icon in the GUI sidebar or the  icon in the toolbar. The **Voxel Selection** dialog opens.
   c. Click on the voxel(s) that should be edited. For several voxels, press and hold the Shift key on the keyboard while clicking the voxels. A cyan-colored frame appears at the edges of the selected voxel(s).



At the same time, the parameters defining the voxel(s) (Position as X, Y, Z and Material ID) appear in a table in the **Voxel Selection** dialog.

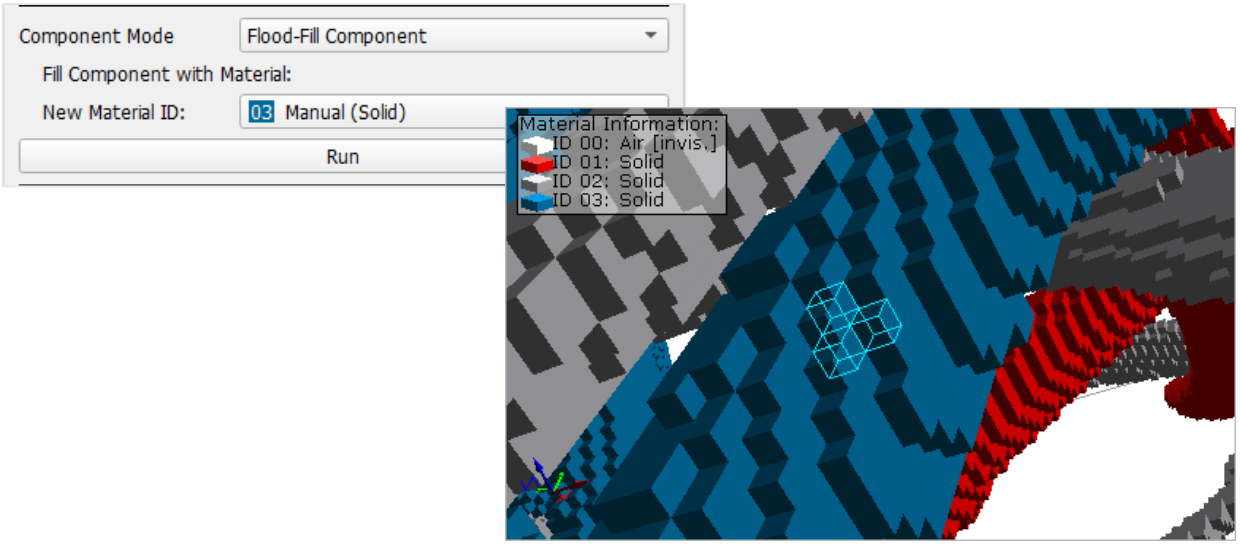


d. If a voxel is mistakenly selected, click again on that voxel.

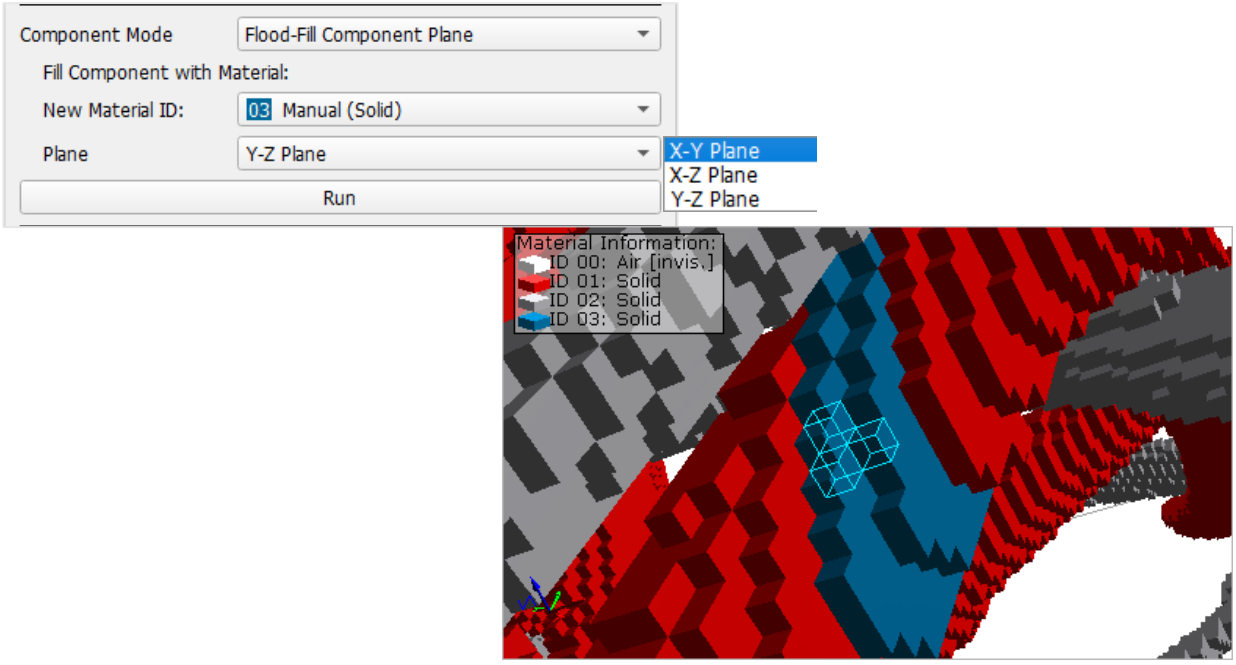
e. Clicking **Clear Selection** in the **Voxel Selection** dialog removes all voxels from the selection.

2. Edit voxels by selecting one of the **Component Mode** commands and clicking **Run**:

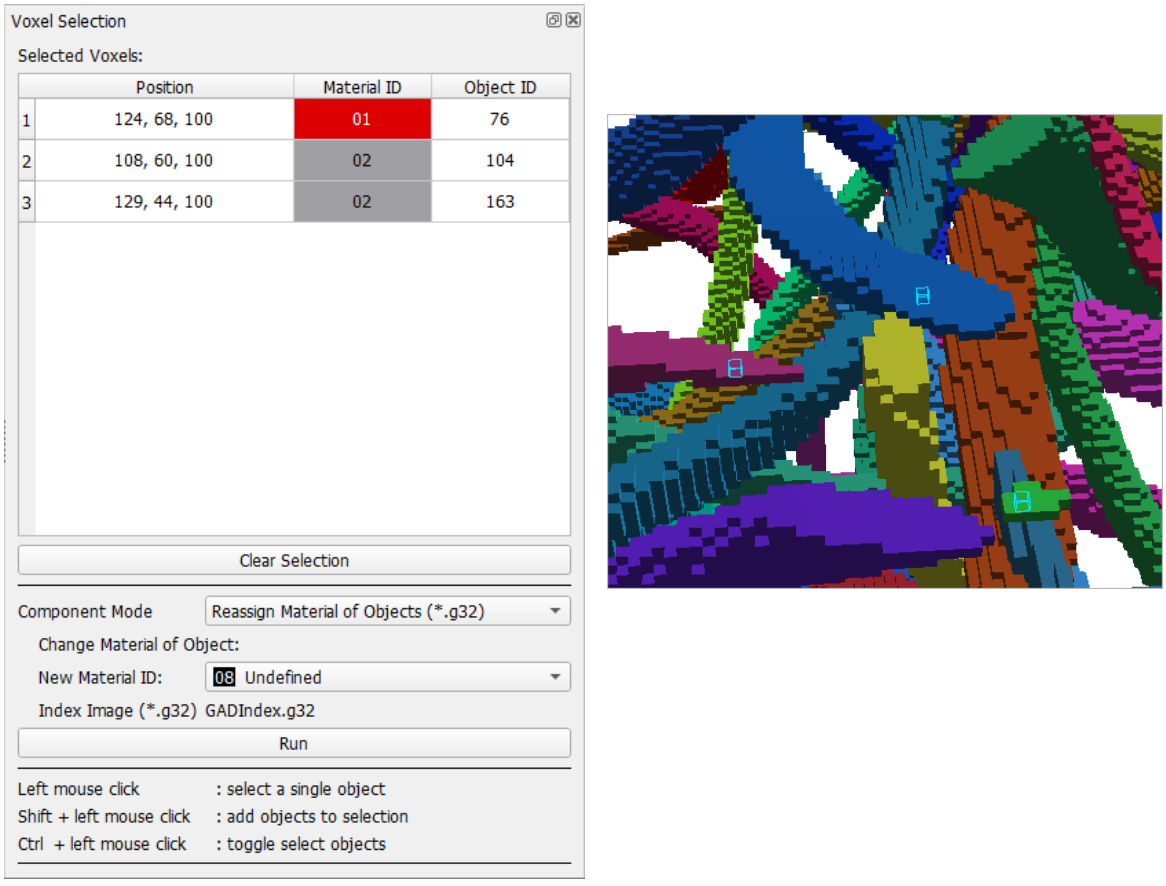
a. **Flood-Fill Component**: fill the selected voxels and the components connected to them (see page 35) with a **New Material ID** chosen from the pull-down menu.



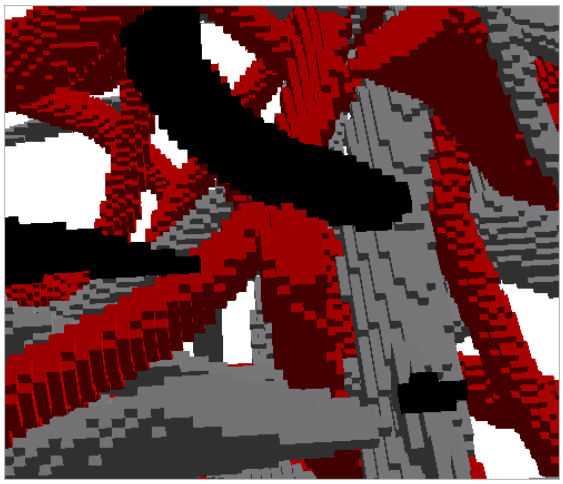
b. **Flood-Fill Component Plane**: fill the selected voxels and the components connected to them with a **New Material ID** only in the **Plane** chosen from the pull-down menu.



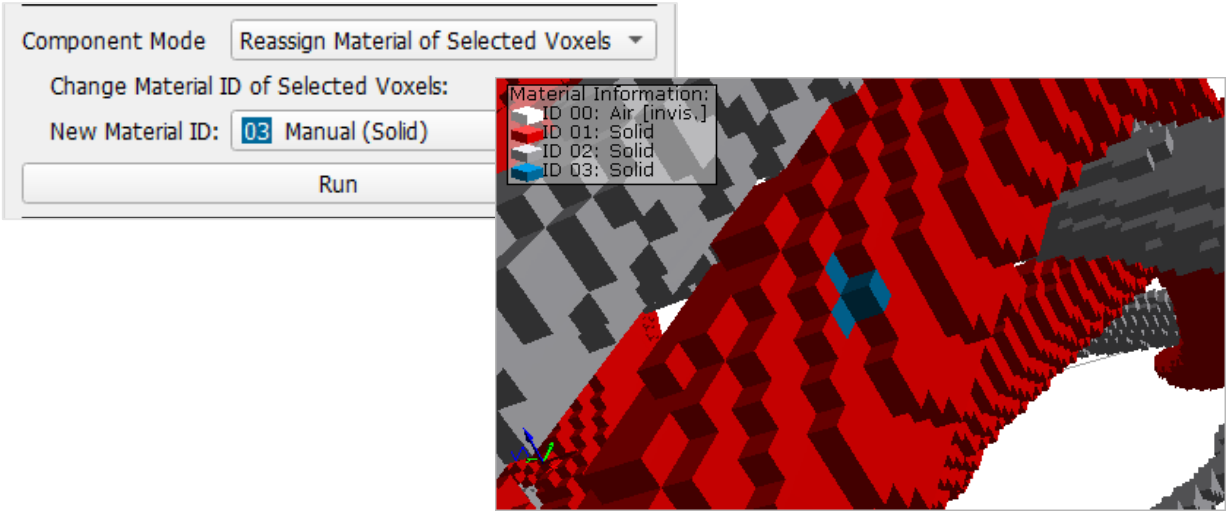
c. **Reassign Material of Objects (*.g32):** If a *.g32 file with object indices is loaded in the GeoDict GUI (e.g., created by right clicking on Objects in the Project Status Section and selecting Create GAD Index Image, see page 50), the Object ID is additionally shown for each voxel selected.



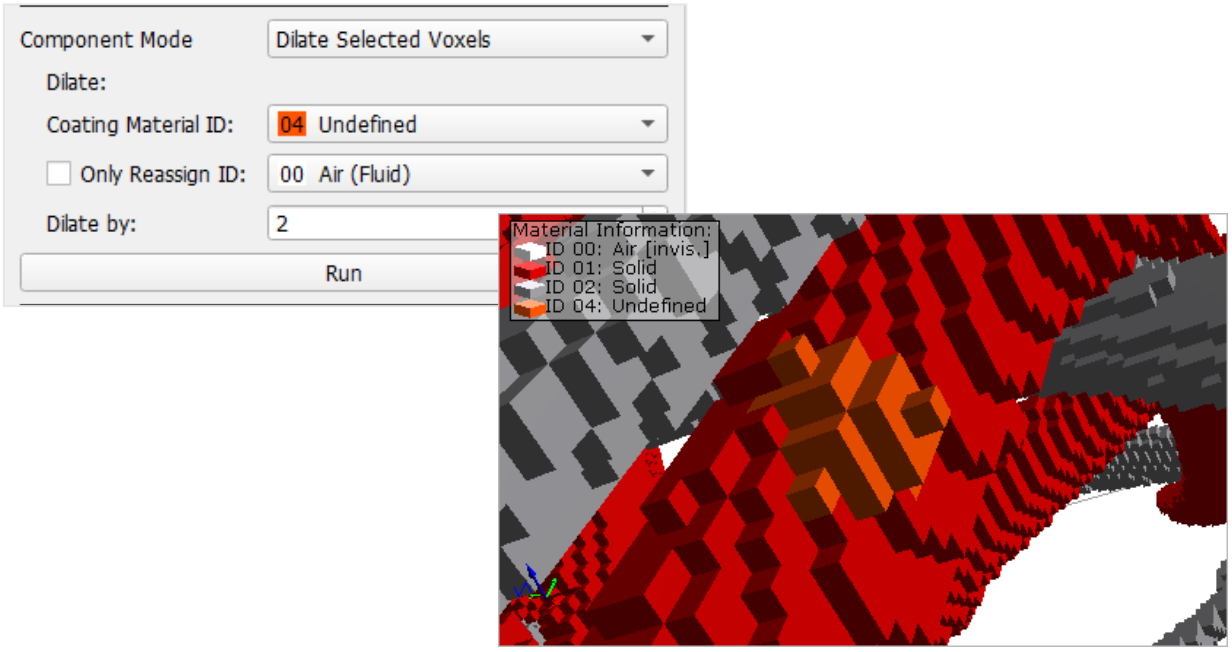
Select a **New Material ID** and click **Run**, to assign the new material to all voxels that belong to the same Object ID as the voxels selected (here Object IDs 76, 104 and 163).



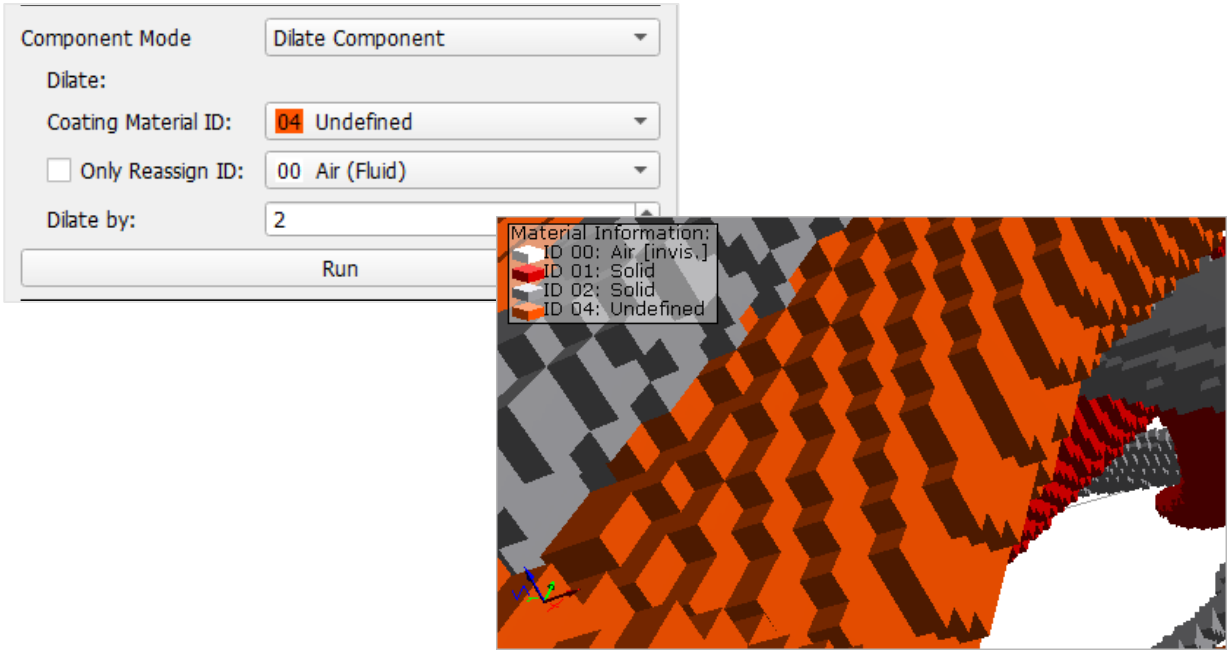
d. **Reassign Material of Selected Voxels**: The material ID of the selected voxels can be changed by selecting a **New Material ID** from the pull-down menu.



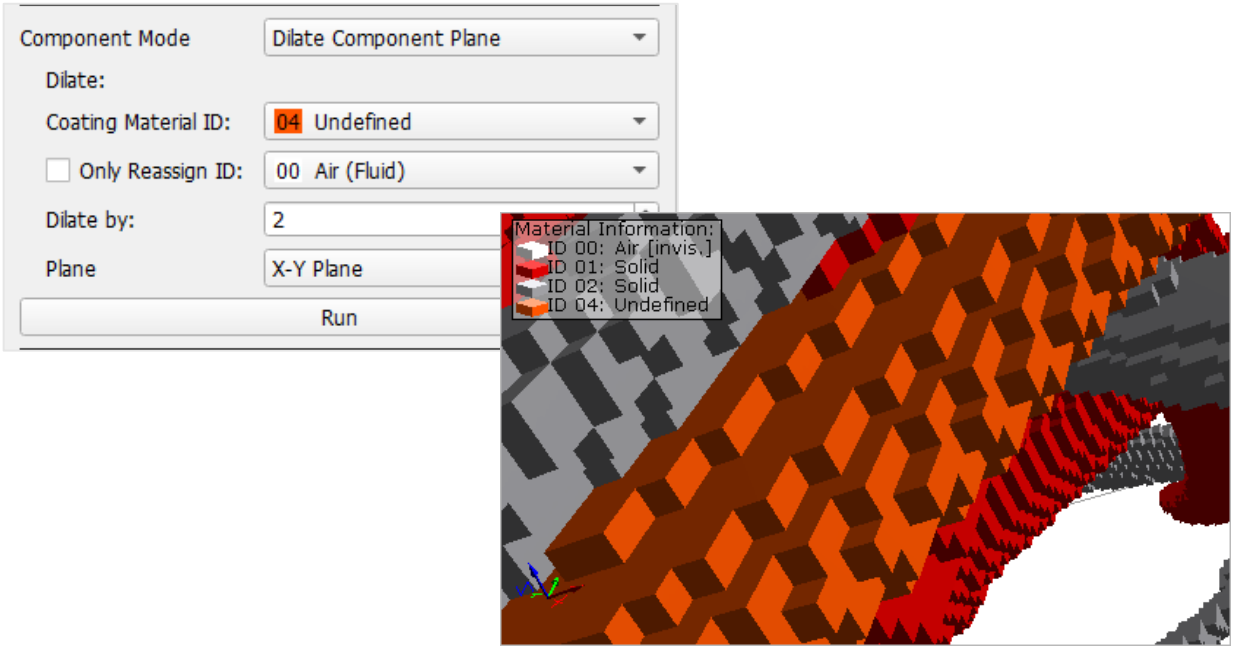
e. **Dilate Selected Voxels**: It is possible to dilate the voxels by coating them with another material chosen from the **Coating Material ID** pull-down menu by a certain number of voxels (**Dilate by**)



f. **Dilate Component**: Also possible is to dilate the selected voxels and the components connected to them with the **Coating Material ID** by a certain number of voxels (**Dilate by**)



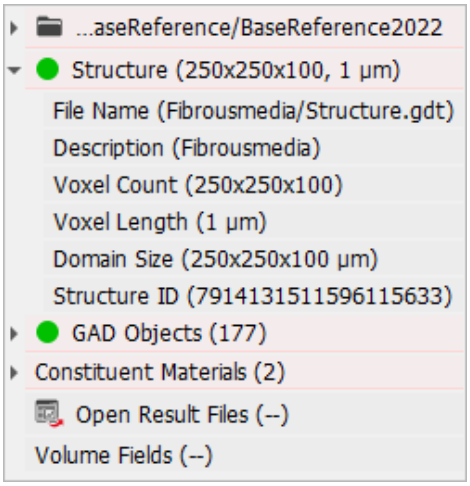
g. **Dilate Component Plane**: Dilate the selected voxels and the components connected to them only in the **Plane** chosen from the pull-down menu with the **Coating Material ID** by a certain number of voxels (**Dilate by**)



All these operations can be undone by clicking the  icon or CTRL+Z.

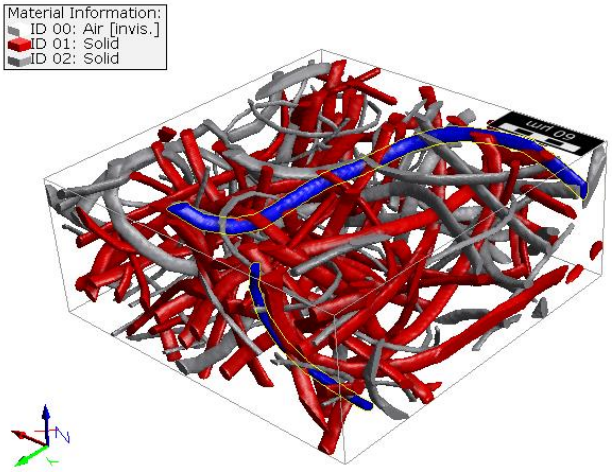
GAD Object Selection and editing for GAD format

The same fibrous media model as in the section above is edited, but now the analytic objects are modified. This is possible if a structure in GAD format is loaded, or a structure in GDT file format with analytic object information contained in the GDT file. The information that appears in both cases in the **Project Status**, is equivalent.

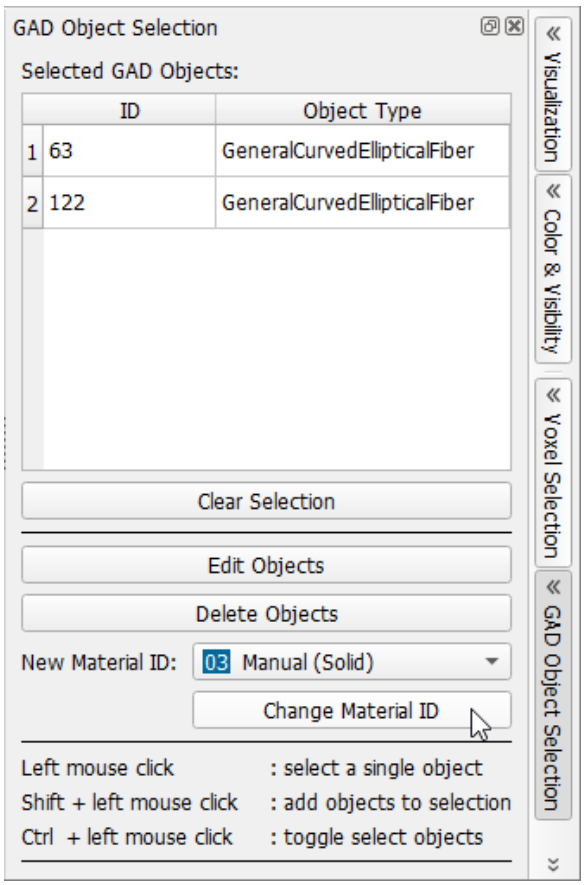


In contrast to editing the voxel structure, editing the analytic objects preserves the analytic object information in the file.

The analytic objects (fibers) in this fibrous structure model can be edited, while visualizing the material model in 2D Cross Section (SEM) view or in 3D Rendering, as follows:

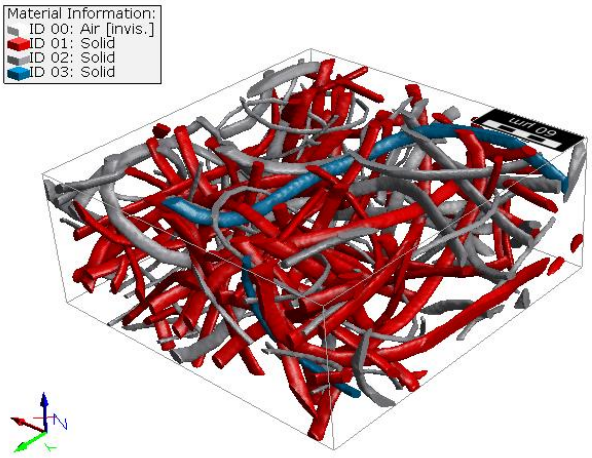


1. Select analytic objects:
   a. To enter the GAD Object Selection mode, click the « icon in the GUI sidebar or the  icon in the toolbar. The **GAD Object Selection** dialog opens.
   b. The upper table shows the **ID** number and the **Object Type** of the selected fibers.
   c. Click on the fiber that should be edited. For several fibers, press and hold the Shift key on the keyboard while clicking the fibers. The selected fiber(s) appear(s) highlighted.
   d. If a fiber is mistakenly selected, press and hold the CTRL key and click on the fiber again.
2. Edit analytic objects:
   a. When clicking **Delete Objects**, all selected fibers, which are listed in the upper table, are deleted and taken out from the structure model.
   b. **Change Material ID:** The material ID of the selected objects can be changed by selecting a new material ID from the pull-down menu and clicking **Change Material ID**.



The selected fiber(s) still appear(s) highlighted (and perhaps makes it difficult to see the change in the material) until the user clicks **Clear Selection**.

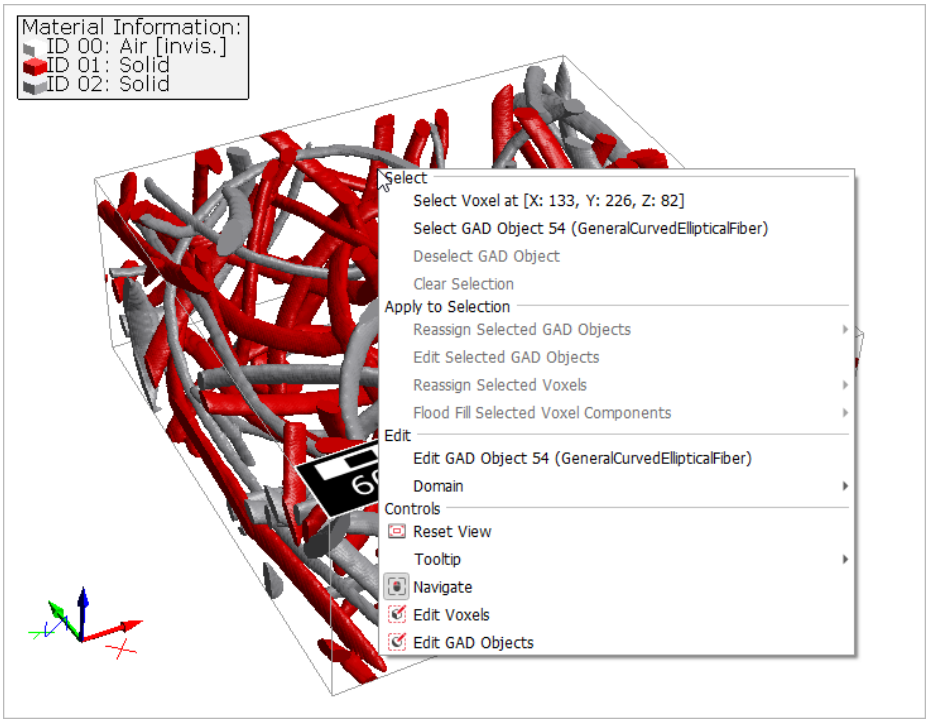
Now the fibrous structure model contains fibers of three different materials.



SHORTCUT TO SELECTION AND EDITING FOR GDT AND GAD

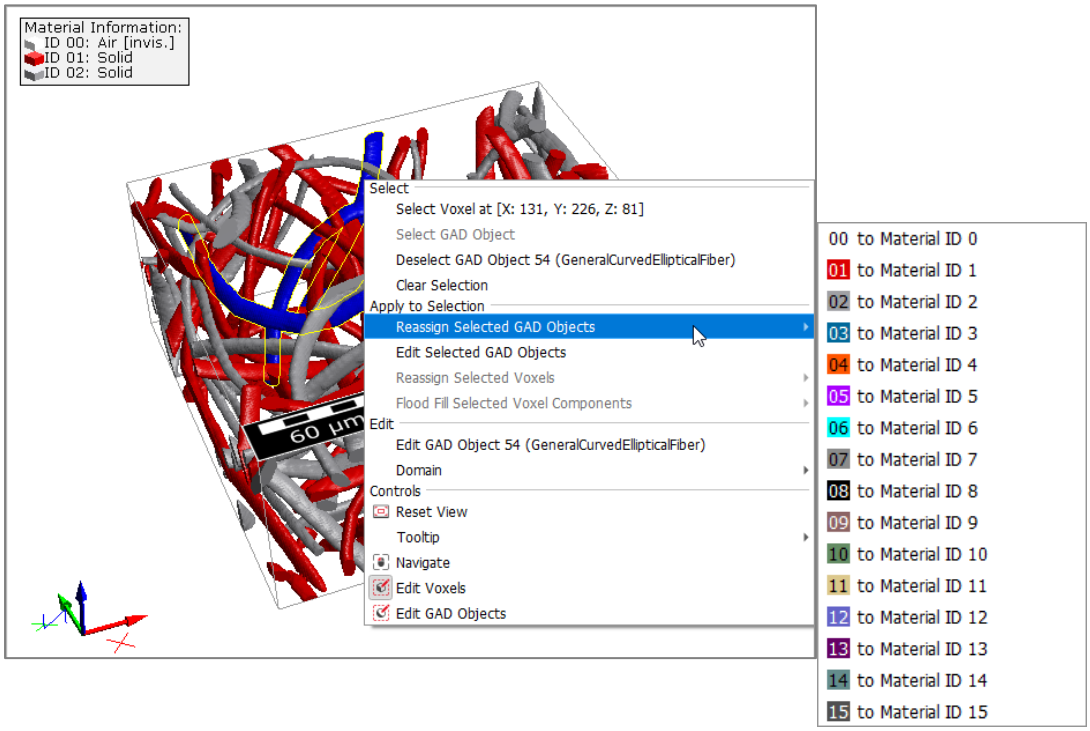
In GeoDict 2022, part of the selection and editing functionalities explained above can be accessed directly by a right mouse click in the structure shown in the Visualization area.

In this way, voxels or GAD objects can be selected and are added to the **Voxel Selection** dialog or the **GAD Object Selection** dialog.



Previously selected GAD objects can be removed from the dialog (**Deselect GAD Object**), or the selections of both dialogs can be removed completely (**Clear Selection**).

Choose **Reassign Selected GAD Objects** to assign a new material ID to the selected objects.

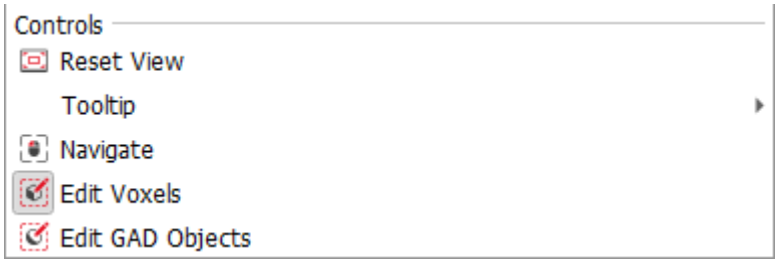


With **Edit Selected GAD Objects**, all objects listed in the **GAD Object Selection** dialog can be modified at once. **Edit GAD Object** allows to modify only the currently selected object, here object 54.

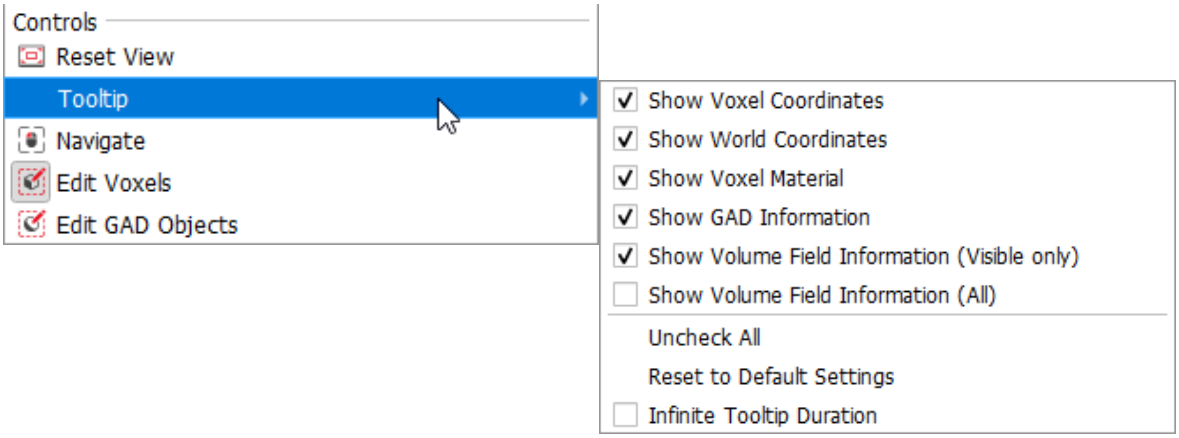
Voxels listed in the **Voxel Selection** dialog or the whole components connected to them, can be reassigned to a new Material ID with **Reassign Selected Voxels** or **Flood Fill Selected Voxel Components**. Choose the new Material ID for the operation.

By a click with the right mouse button on the structure, it is also possible to **Edit** the **Domain** and to access the ProcessGeo functionalities **Crop** and **Embed**.

Select the options available under **Controls**, to **Reset View** settings according to the startup-settings (see the Camera tab on the Visualization panel), to switch between the icons of the toolbar for the mouse functionalities (**Navigate**, **Edit Voxels** and **Edit GAD Objects**),



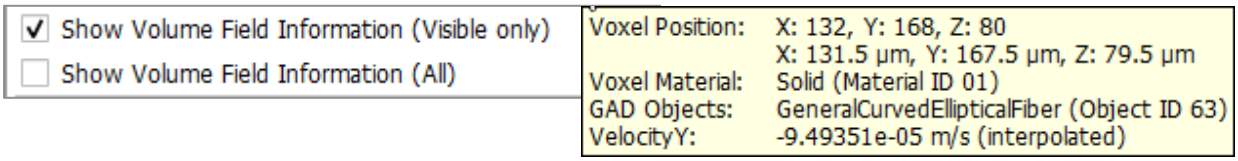
and to change the settings for the **Tooltip** shown for the structure.

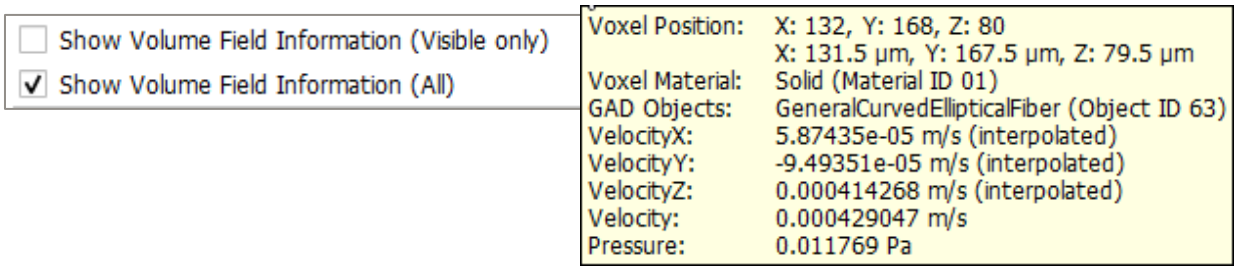


Choose, which information should be shown for the position of the mouse pointer in the structure. For the position of a voxel, the coordinates can be shown in number of voxels in each direction (**Show Voxel Coordinates**) or as coordinates with respect to the origin of the structure (**Show World Coordinates**).

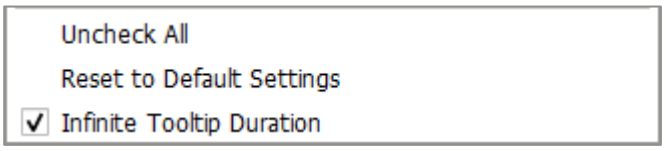
Check **Show Voxel Material** to add the material information to the tooltip. Check **Show GAD Information**, to show the number and object type of the GAD object the voxel belongs to (only shown if analytic object data is available for the structure).

Select **Show Volume Field Information (Visible Only)** or **Show Volume Field information (all)** to show the value of the currently selected volume field, or of all volume fields available, at the current position, if a volume field is loaded for the structure.





Use **Uncheck All** to deselect all boxes of the Tooltip options, or **Reset to Default Settings** to reload the GeoDict default settings for the tooltips.



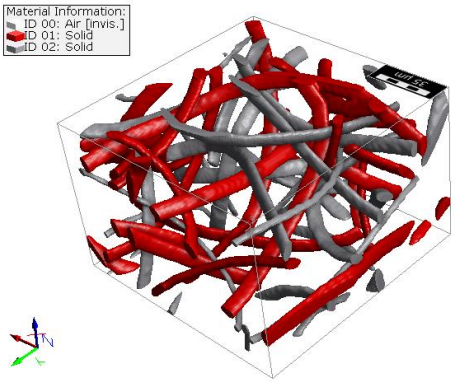
Check **Infinite Tooltip Duration** to prevent the tooltip from vanishing after a few seconds.

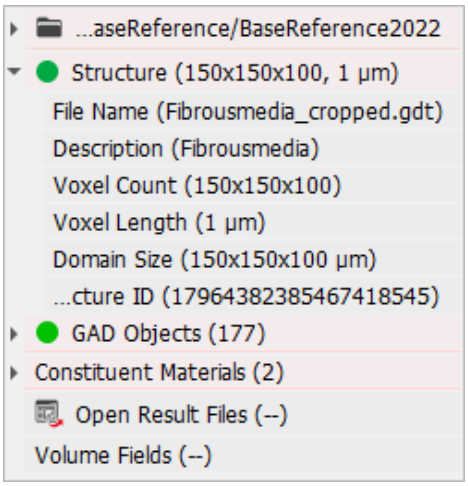
PAINT

The **Paint Mode** editing works in a way similar to the Windows standard editor **Paint**. Editing is always done in 2D (View → 2D Cross-Section (SEM)) and the effects can be seen later in 3D (View →3D Rendering).

Paint Mode can be used for GDT files and for GAD files. However, using the paint mode on a GAD file or GDT file with analytic object information terminates the analytic data character. This can be observed in the green dot turning red in the **Project Status** section after applying the paint mode.

A fibrous media model with analytic object information is edited with **Paint Mode**.





The **Paint** mode is used as follows:

1. Select **View** → **2D Cross-Section (SEM)** in the menu bar or click the 2D icon in the toolbar.

   In the Visualization panel, above the Visualization area, click the Camera (Y, Z) tab and use the **Direction** pull-down menu and the **Slice** slider to navigate to the location where the editing should take place. Here is direction Z and slice 90 selected.

2. Click the **Paint** tab on the GUI sidebar or the  icon in the toolbar to open the **Paint Settings** dialog The **Paint** tab is greyed out and not accessible when the structure is viewed in 3D rendering.

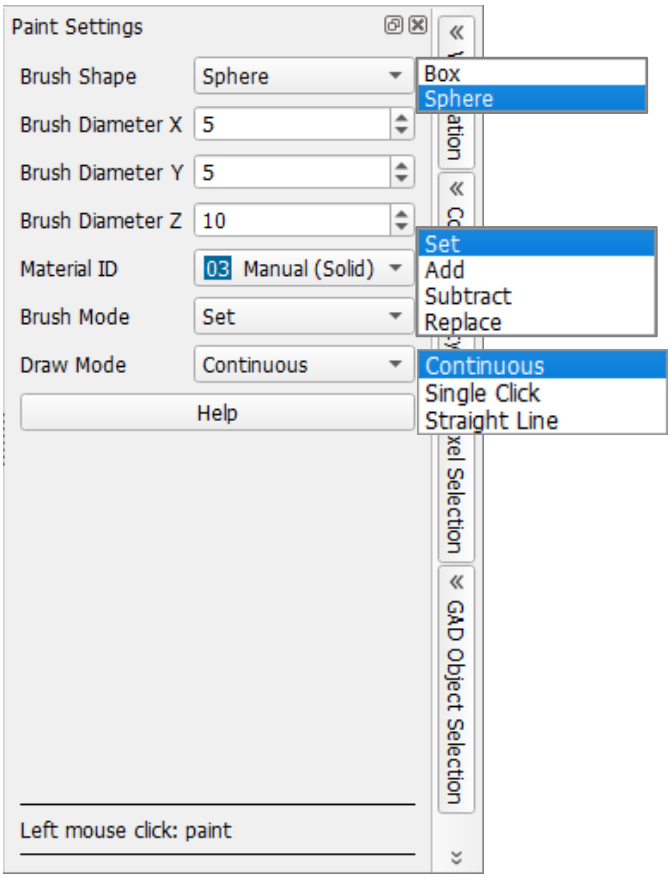
3. In the opening **Paint Settings** dialog, editing is done using a brush and its size and shape are set in the **Brush Shape** pull-down menu and in the **Brush Length (Diameter) X**, **Brush Length (Diameter) Y** and **Brush Length (Diameter) Z** boxes.

   The brush length is given in voxels.

   The brush shape can be a **Box**, with the side lengths entered in Brush Length X, Y, and Z, or a **Sphere** (Ellipsoid) with the diameters entered in Brush Diameter X, Y, and Z.

   The Material ID of the material to edit is chosen from the **Material ID** pull-down menu.

   The choice of **Brush Mode** in the pull-down menu determines the working technique for the brush. With **Set**, the selected material replaces the original material. With **Add** and **Subtract**, material is added to or subtracted (removed) from the original material. With **Replace,** material of a selected ID is replaced by a new material.



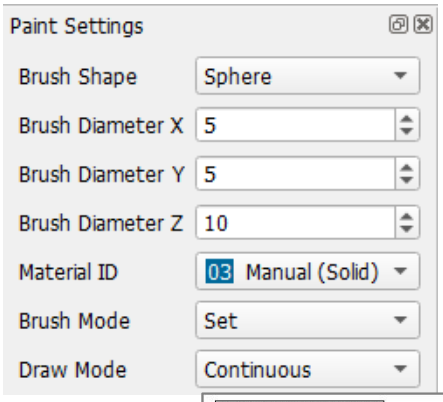
   The Draw Mode defines whether the brush stroke is applied for **Continuous** Drawing, for a **Single Click** or for drawing a **Straight Line**.

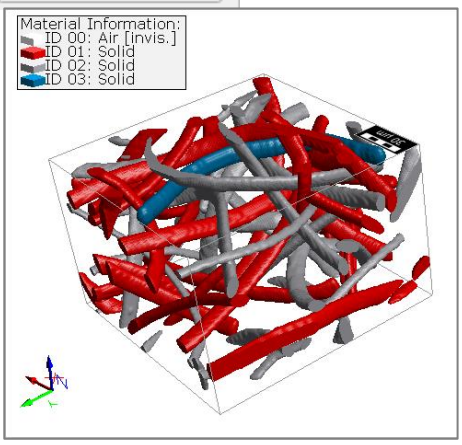
4. The brush strokes, in the selected shape, size, and Material ID (here Sphere, diameter 5 x 5 x 10 voxels, Material 03), are applied by pressing (for **Continuous Drawing** and **Drawing Straight Lines**) and by clicking (for **Single Click Drawing**) with the left mouse button in the desired position.

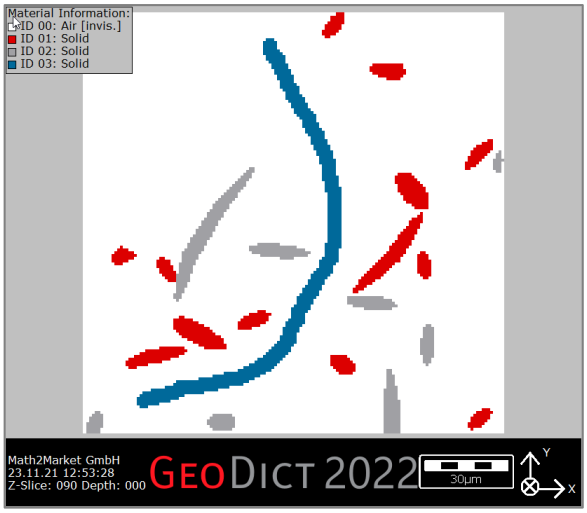
   Strokes at different spatial locations are applied by selecting a different **Direction** (X, Y, or Z) and/or a different **Slice** in the Visualization panel, above the Visualization area.

   For **Draw Mode Continuous**, press the **left mouse button** while dragging the mouse. Moving the mouse too fast results in an irregularly dashed line.

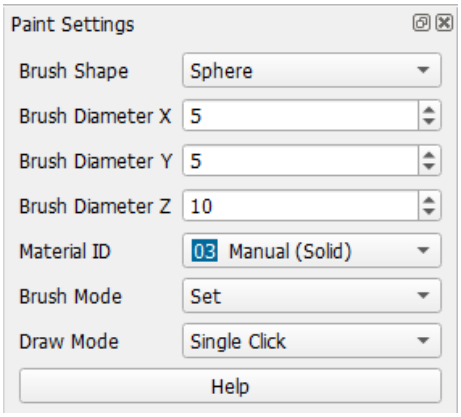
   The effects of editing (in 2D view) are observed as soon as the left mouse button is released. Here, voxels of material ID 00 have been replaced by voxels of Material ID 03, which are blue. After editing, close the **Paint Settings** dialog and switch to 3D rendering.

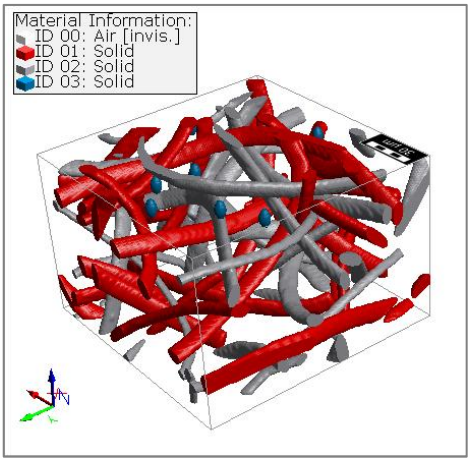


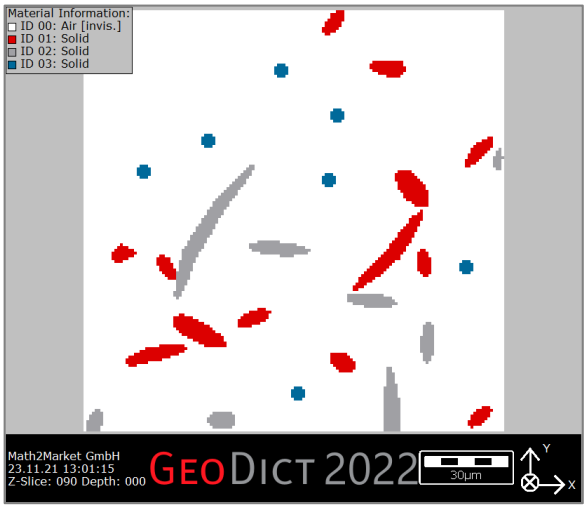




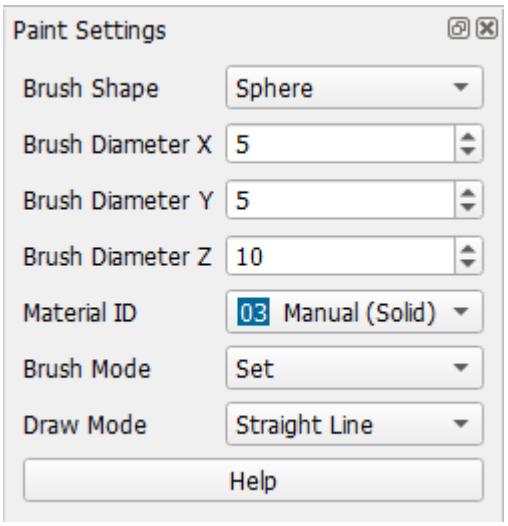
Use **Draw Mode Single Click** by clicking the left mouse button in different locations of the 2D view of the structure model. The effects of editing (in 2D view) are observed as soon as the left mouse button is released. After editing (in 2D view), close the Paint Settings dialog and switch to 3D rendering.

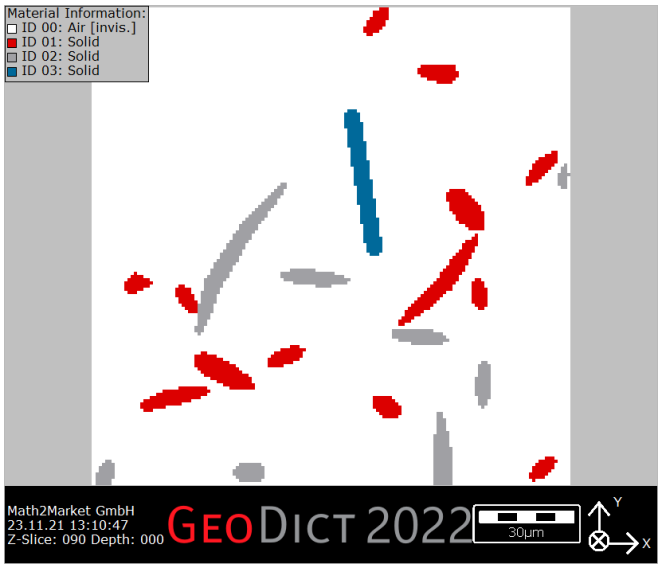


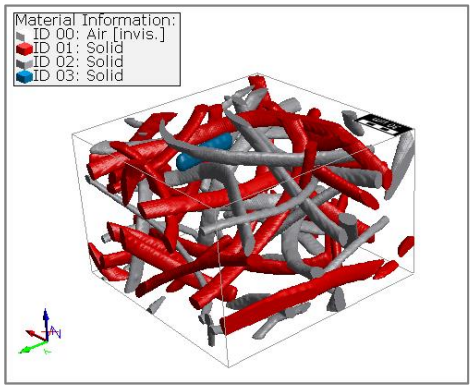




Use **Draw Mode Straight Line** by clicking the left mouse button and drawing the line to the desired end point while holding the mouse button clicked.



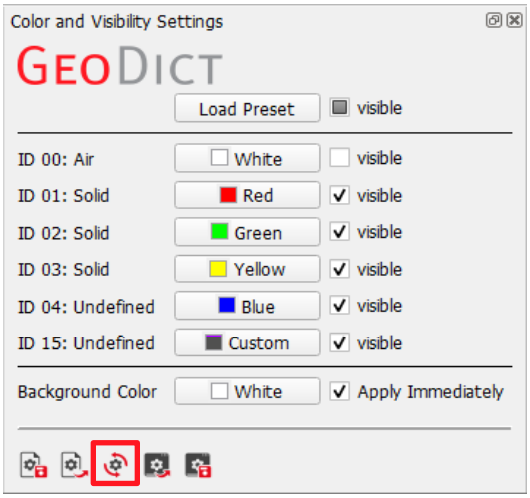




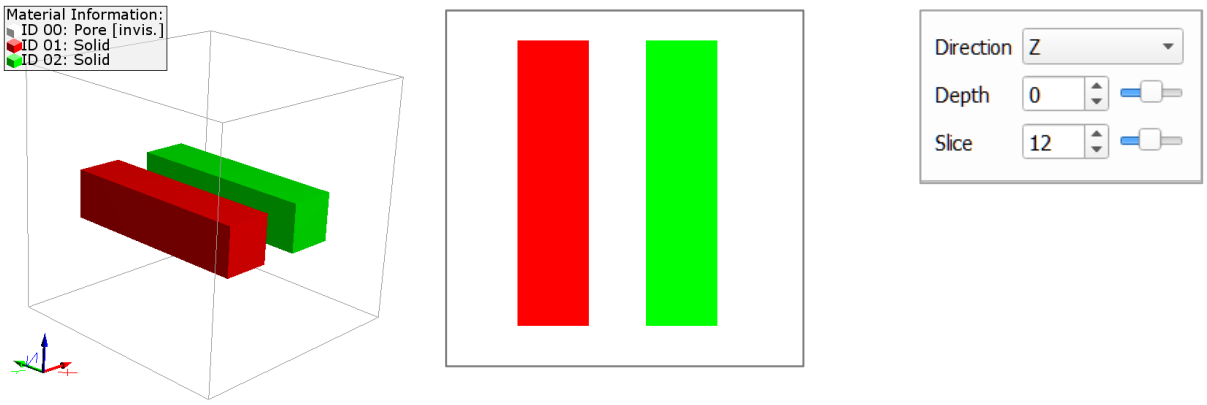
The brush modes **Set**, **Add**, **Subtract** and **Replace** may be selected from the pull-down menu **Brush Mode**. When using Set, Add, or Subtract, material intersections occur. In these areas, the Material ID of the intersection or the subtraction is given by adding or subtracting the binary numbers of the Material ID codes column-wise.

In the following example, to better observe material intersections, the GeoDict built-in red-green-yellow-blue color scheme is used.

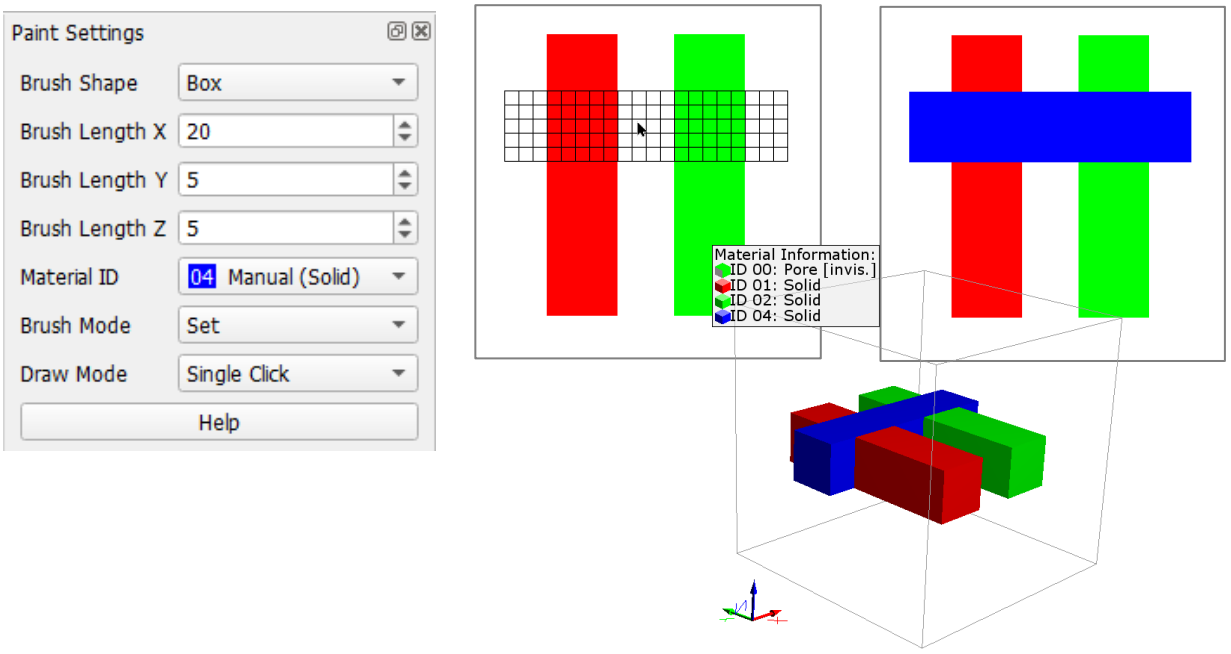
This color scheme is obtained by selecting **Settings → Color & Visibility Settings...** and clicking the icon at the bottom of the dialog (**Load built-in default settings**).



For this example, two slabs were created with 5x20x5 voxels each.

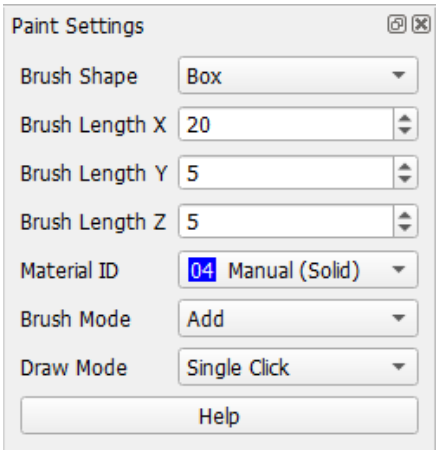


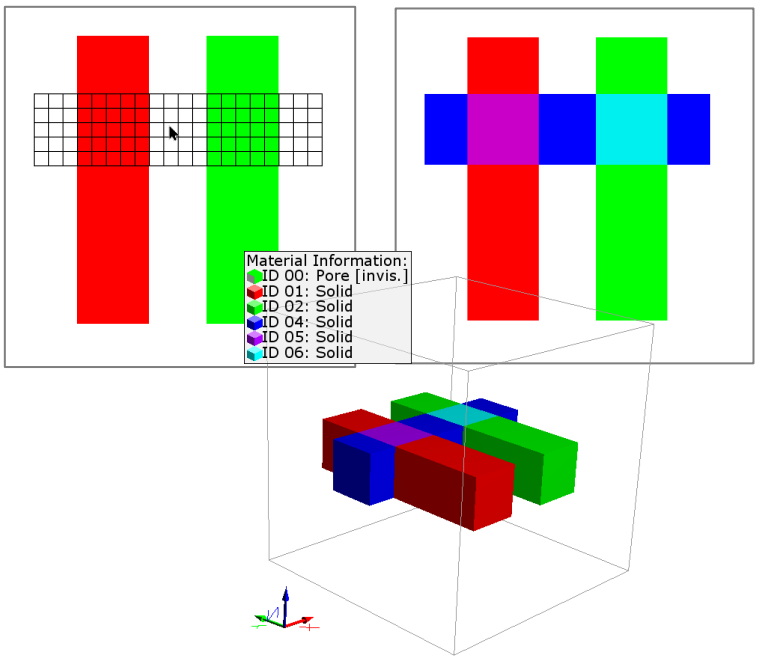
In **Set** mode, the chosen Material ID completely fills the voxels, so that original materials are replaced. The replacement of material is clearly seen in 3D rendering:



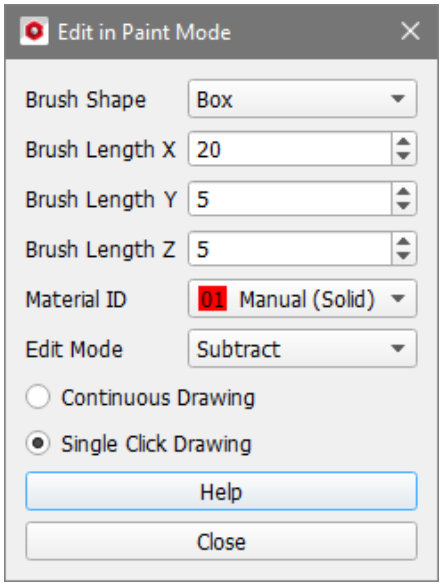
In **Add** mode, the selected Material ID does not fill the voxels, but an intersecting material is built.

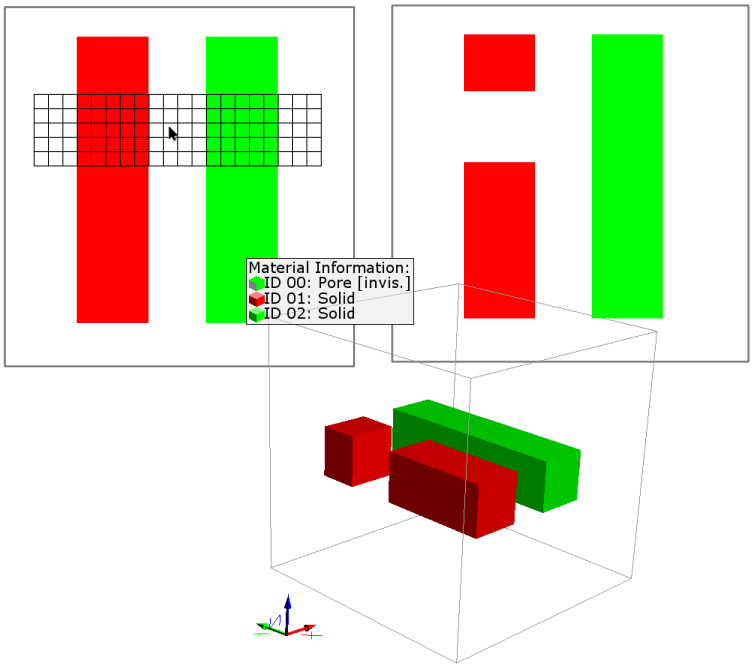
According to GeoDict's rules on coloring intersecting materials (see below page 80), adding voxels of blue material to original red material results in violet-colored intersected voxels. Blue material added to original green material results in cyan-colored intersected voxels. The intersecting materials are also seen above in 3D rendering.



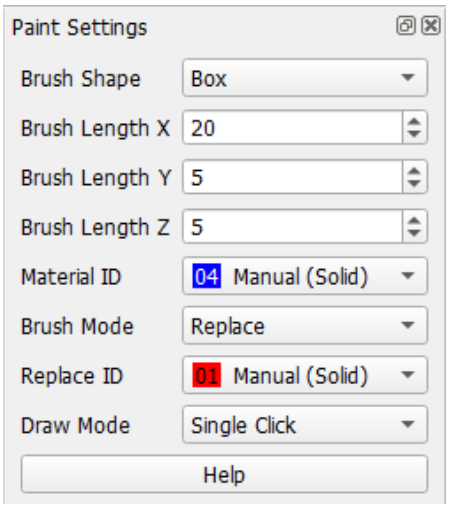


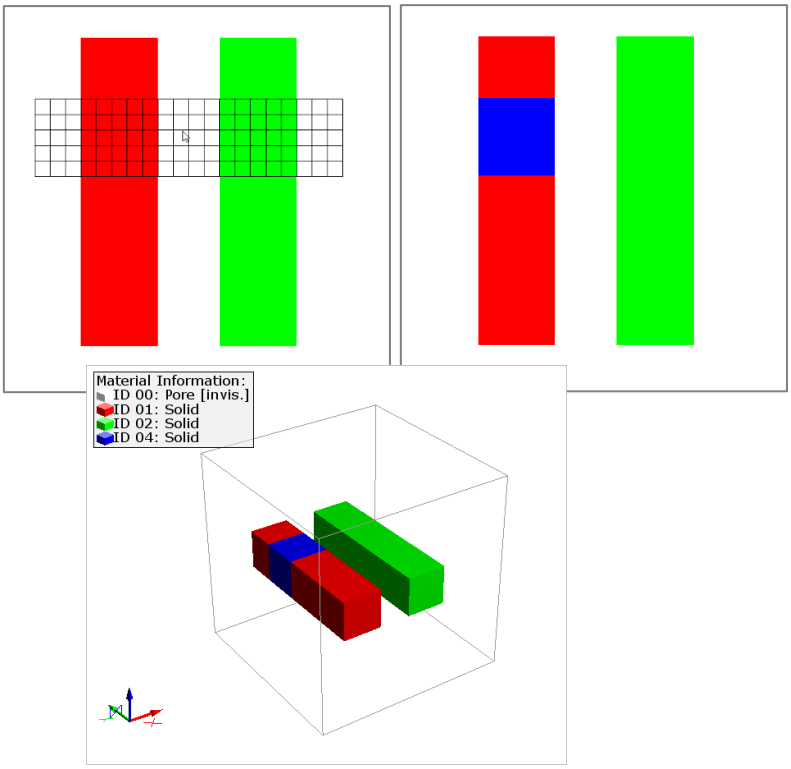
In **Subtract** mode, the selected Material ID is bit-wise subtracted from the existing structure where the brush is applied (see below page 80).





In **Replace** mode, the selected Material ID replaces the Replace ID, not selected Material IDs are unaffected by the modification.





Intersecting Material IDs for Add and Subtract Modes

With the GeoDict built-in color settings, 16 Material IDs are available.

In **Add** and in **Subtract** edit mode, when two materials intersect or are subtracted, the Material ID of the intersection or the subtraction is given by adding or subtracting the binary codes corresponding to the Material IDs.

Binary addition rules				
1	+	1	=	1
1	+	0	=	1
0	+	1	=	1
0	+	0	=	0

Binary subtraction rules				
1	-	1	=	0
1	-	0	=	1
0	-	1	=	0
0	-	0	=	0

The addition or subtraction of Material IDs is done column-wise, as follows:

0	0	0	1	01
+	+	+	+	+
0	0	1	1	03
=	=	=	=	=
0	0	1	1	03

0	0	0	1	01
-	-	-	-	-
0	0	1	1	03
=	=	=	=	=
0	0	0	0	00

Examples of Material ID and binary codes of intersection materials obtained by adding:

First material		Second material		Intersection material	
Material ID	Binary code	Material ID	Binary code	Material ID	Binary Code
02	0010	04	0100	06	0010 + 0100 = 0110
03	0011	04	0100	07	0011 + 0100 = 0111
03	0011	05	0101	07	0011 + 0101 = 0111
05	0101	01	0001	05	0101 + 0001 = 0101

Examples of Material ID and binary codes of intersection materials obtained by subtracting are:

First material		Second material		Intersection material	
Material ID	Binary code	Material ID	Binary code	Material ID	Binary code
01	0001	01	0001	00	0001 – 0001 = 0000
05	0101	02	0010	05	0101 - 0010 = 0101
03	0011	01	0001	02	0011 - 0001 = 0010
04	0100	01	0001	04	0100 – 0001 = 0100

METROLOGY

With the **Metrology** functionality, distances and angles can be measured in the 2D View of a structure.

Select **View** → **2D Cross Section (SEM)** in the menu bar.

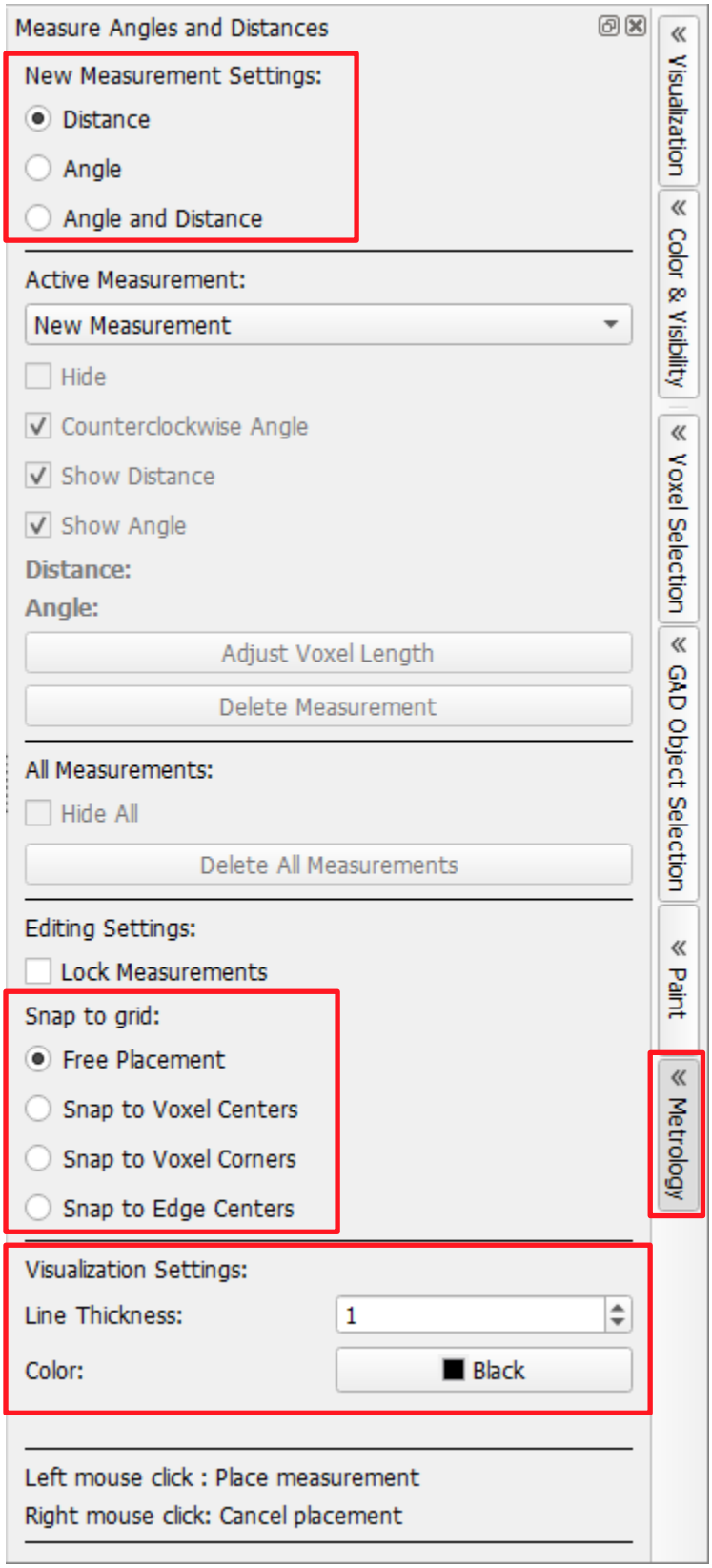
Click the **Metrology** tab on the GUI sidebar or click the icon in the toolbar to open the **Measure Angles and Distances** dialog.

In the **Camera** tab of the Visualization panel, choose the **Direction** (**X**, **Y** or **Z**) and the **Slice** of the structure for the measurement.

To start a new measurement, first select from the **New Measurement Settings** if a **Distance**, an **Angle** or **Angle and Distance** should be measured.

Next, in **Snap to grid**, define if points should be selected freely in the structure (**Free Placement**), or be snapped to the nearest voxel centers, voxel corners or edge centers.

In the **Visualization Settings**, choose the **Line Thickness** and **Color** for the visualization of the measurement.



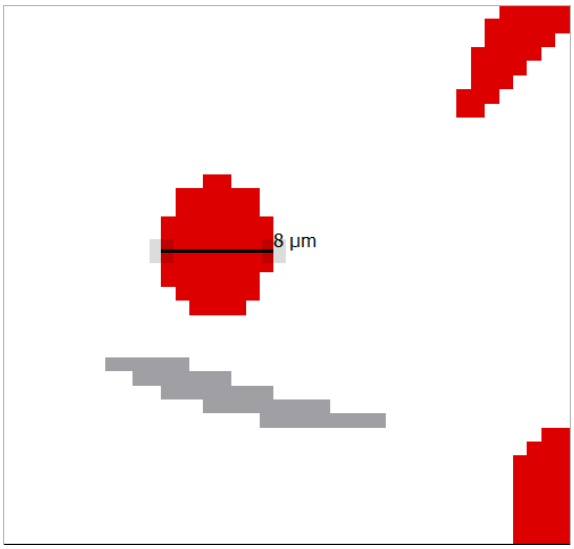
To start measuring, click with the left mouse button at the position, where the measurement should be started and draw the line to the desired end point.

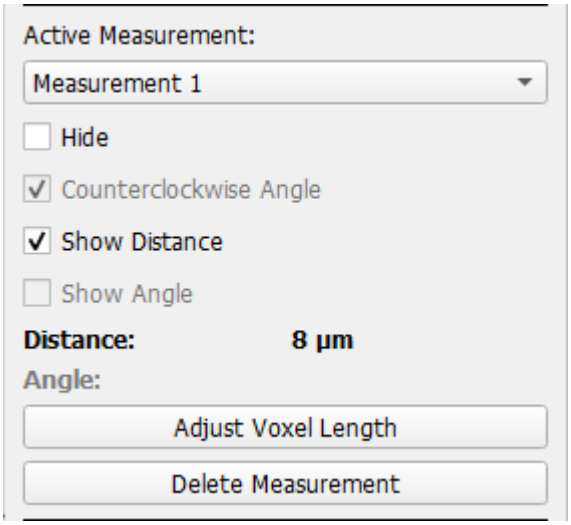
In the example shown here, the diameter of the red fiber in x-direction is measured.

For the **Active Measurement**, the measured distance and/or measured angle is shown.

Check **Hide** to hide the measurement and the text, or uncheck **Show Distance**, to hide only the text.

With **Delete Measurement**, the measurement currently active is deleted from the panel.



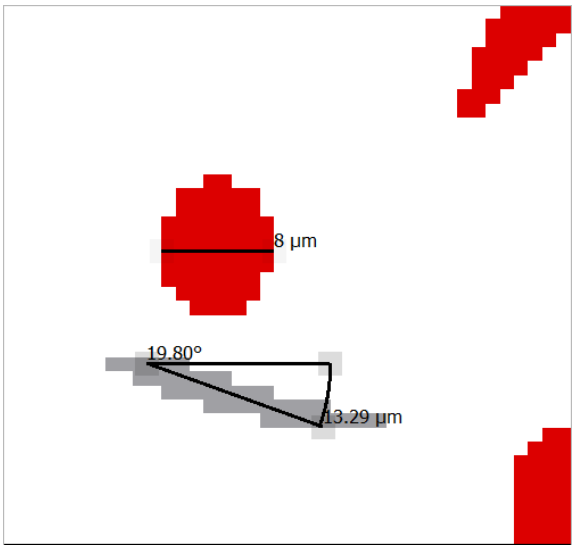


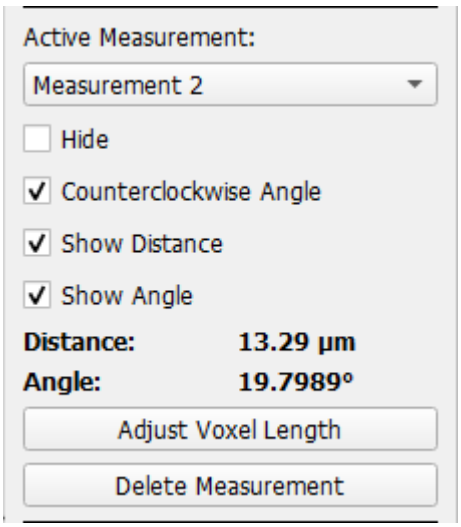
These options are especially helpful when several measurements are available in the panel.

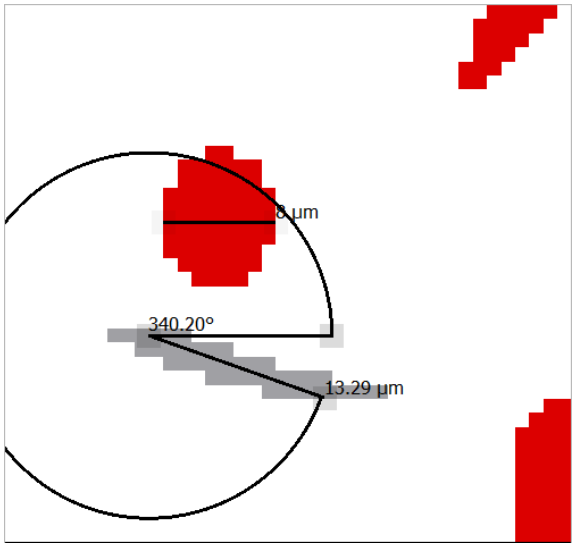
Create e.g., a second measurement, measuring the length of the gray fiber segment and its angle to the x-axis.

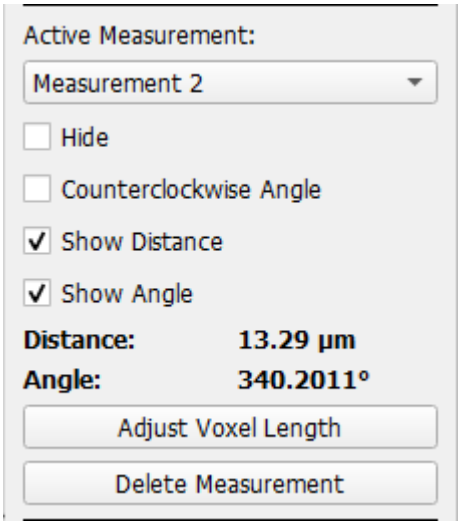
Use the check boxes to show only one of the measurements or part of it.

In case an angle is measured, the angle of the segment is shown counterclockwise, as long as **Counterclockwise Angle** is checked.



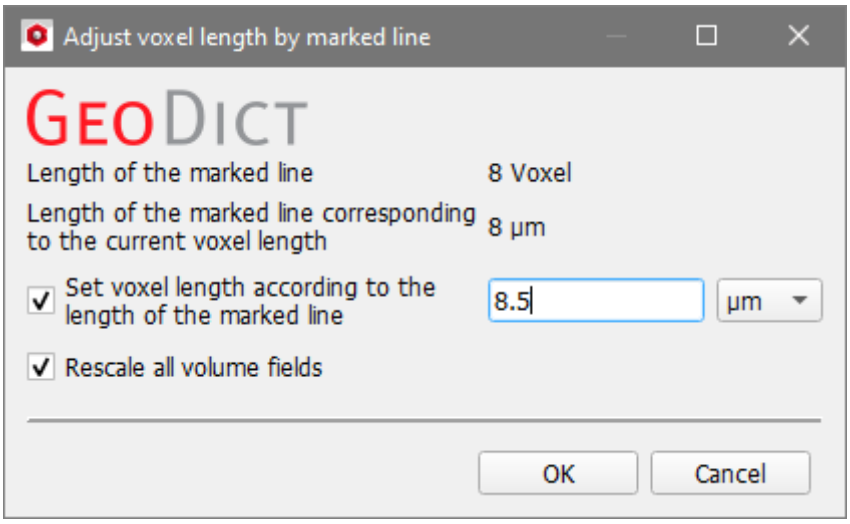




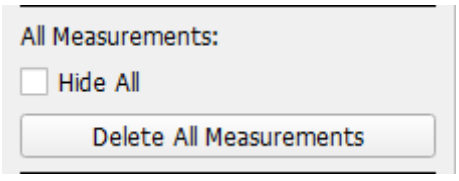


Clicking **Adjust Voxel Length**, a dialog to change the voxel length of the structure opens.

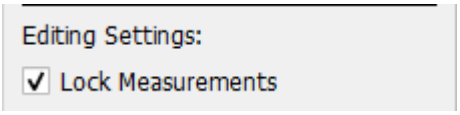
Enter the desired length of the measured line (in the example 8.5 µm instead of the 8 µm measured in Measurement 1) and click **OK**. The voxel length of the whole structure is rescaled to match the desired length. Check **Rescale all volume fields**, to rescale also the volume fields to the new voxel length.



In the **All Measurements** part of the panel, all available measurements, can be hidden or deleted.



Choose **Lock Measurements** in the **Editing Settings** part of the panel to move the whole line of a measured distance and/or angle to another location. If **Lock Measurements** is unchecked, the end point of the measurement can be modified.

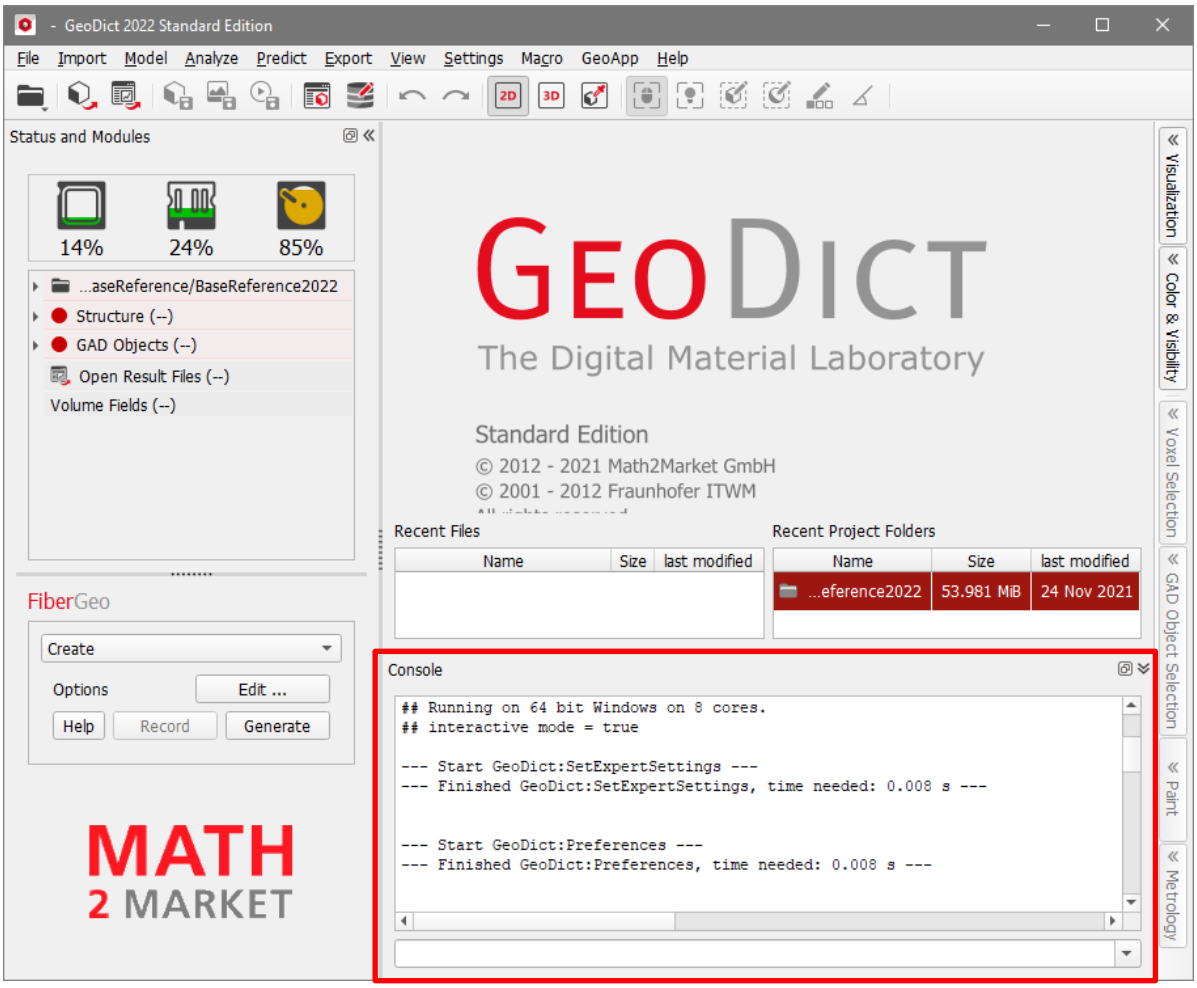


CONSOLE

Starting with GeoDict 2020, the console window that used to appear when starting GeoDict has moved for convenience of usage to a panel located at the bottom of the GUI, under the Visualization area. The **Console** panel is a textual GUI window and log viewer. The console allows to read the system logs, help find certain ones, monitor them, and filter their contents. Additionally, the user can enter and execute python commands directly in the console (for more details, see the Automation 2022 handbook of the User Guide).

The console panel can be expanded and collapsed by clicking on the ⏫ and ⏬ icons.

When expanded, the panel can be un-docked and turned into a dialog that can move around. Undocking is done by clicking the ⧉ icon, located left from the ⏬ icon after expanding.



https://doi.org/10.30423/userguide.geodict2022-basereference

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