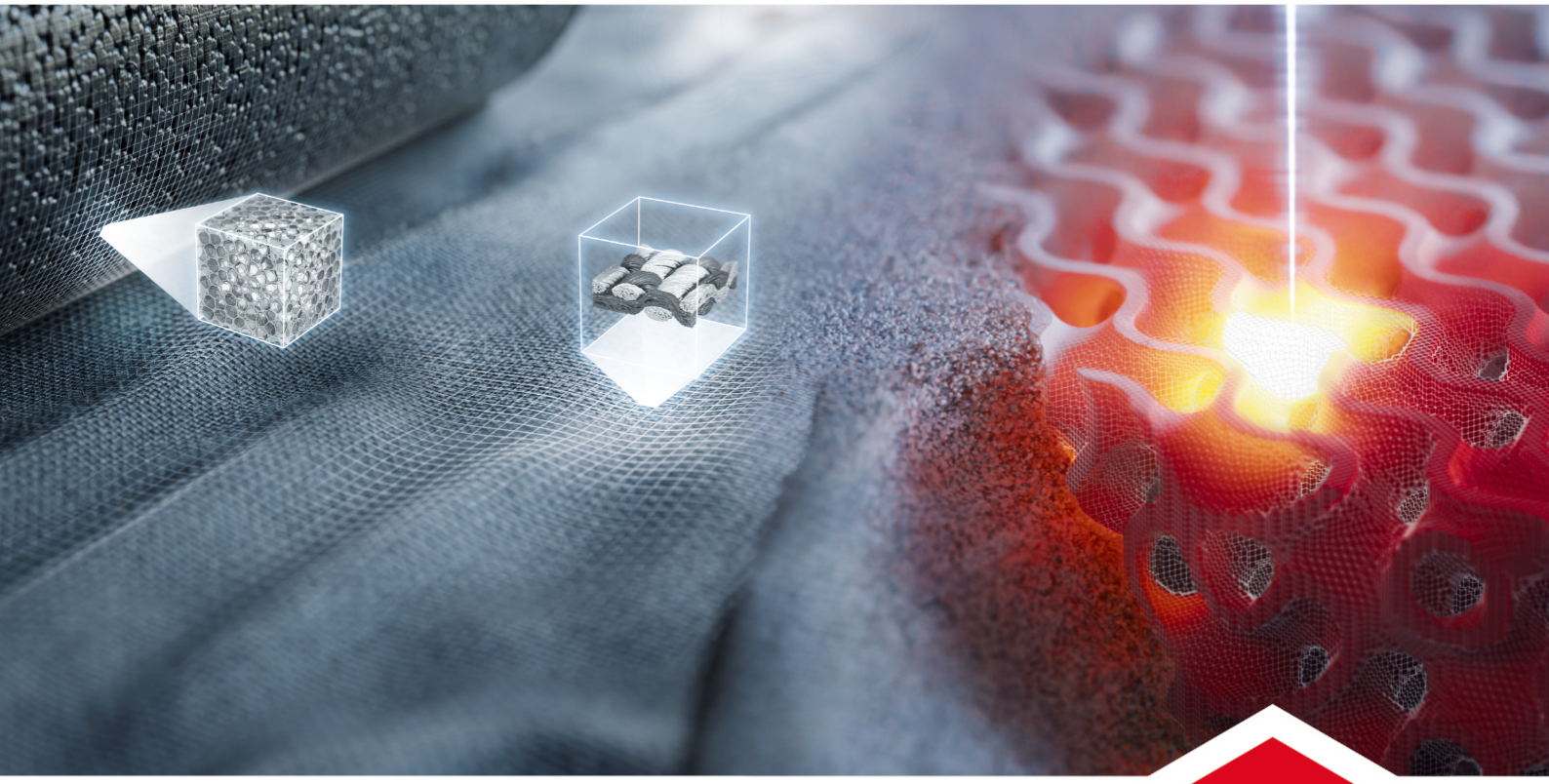
GeoDict

The Digital Material Laboratory



Digital Material R&D

FOR MATERIAL AND COMPONENT DEVELOPMENT

MATH 2 MARKET

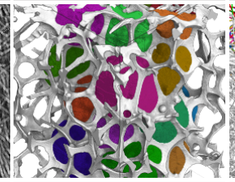
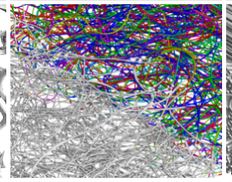
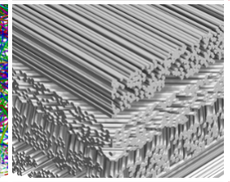
GeoDict: Revolutionizing Material Analysis, Research & Development

GeoDict stands as a pioneering digital platform in Materials Science and Engineering, delivering unparalleled problem-solving capabilities and innovative insights through microscale analysis and modeling of complex materials.

The GeoDict software, Math2Market's solution for digital material design and analysis, represents an integrated platform that revolutionizes Materials Science by way of microscale visualization, modeling, and analysis of complex material structures.

GeoDict's robust simulation capabilities offer precise predictions of the performance of designs under various conditions. GeoDict facilitates efficient modeling of material properties and phenomena, and fosters innovation in Materials Science, with a userfriendly interface and powerful algorithms.

GeoDict bridges the gap between theoretical principles in Mathematics and Physics and practical applications in Material Sciences and Engineering, enhancing precision and reliability. GeoDict provides a key toolset for those in Materials Science Research & development, to drive forward their work and projects.

Digitalize »	Analyze »	Validate »	Design »	Next Generation Material
				
Model a material from scratch or import scans of an existing material to understand and improve it. Create a digital material model.	Analyze the material geometry and compute physical properties of the material. Extract statistical data to create a Digital Twin.	Replicate the material and its properties in the computer through a Digital Twin. Validate the Digital Twin by comparing with real experiments on the existing material	Modify the Digital Twin to create a variety of Digital Prototypes and compute their properties. Loop and optimize to find the new material with the desired properties.	Manufacture the next generation material based on the digital design. The materials of the future are within reach. We help you develop them faster.
Digital Material	Statistical Model	Digital Twin	Digital Prototypes	This is innovation through simulation

The Material Design Process

The interplay between the geometry of the microstructure, properties of the constituent materials, and properties of the resulting materials forms a fundamental nexus in Materials Science and Engineering. This intricate relationship serves as the cornerstone for advanced material design and optimization in GeoDict.

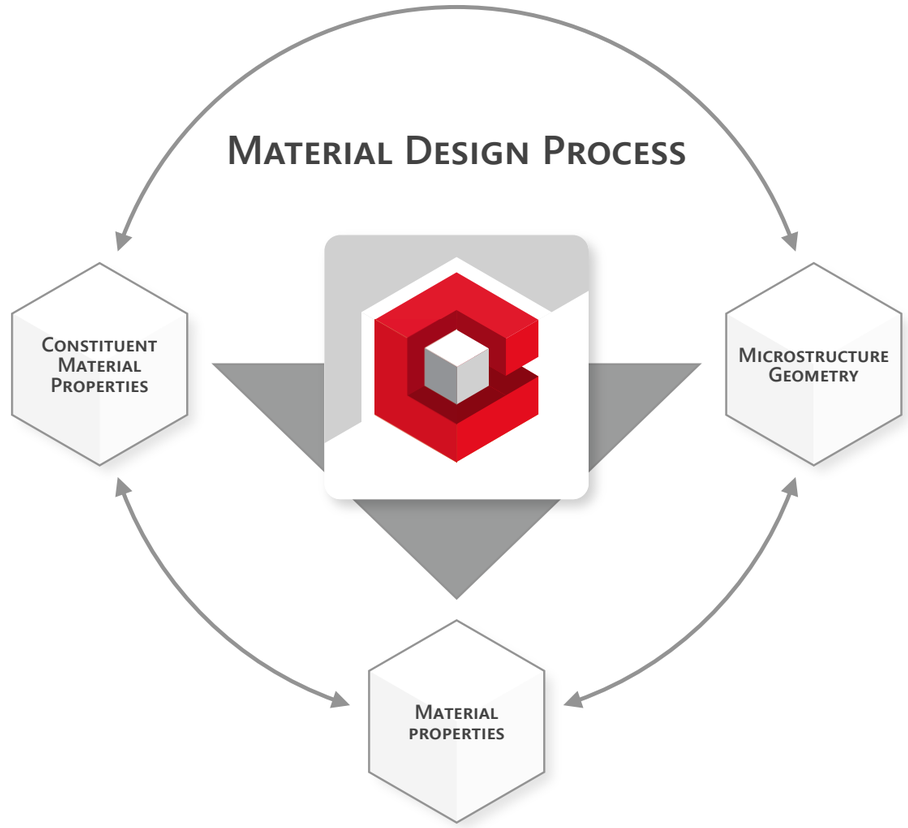
The geometry of the microstructure, such as the arrangement of phases, pores, and interfaces, critically influences a material's performance. GeoDict's expertise lies in the potential to harness this geometry as a lever to tailor material properties. By manipulating microstructural features, the tool enables the design of materials with specific mechanical or thermal properties, or other attributes.

Equally pivotal are the properties of the constituent materials. GeoDict empowers researchers to input these properties from its database and predict resulting material behaviors. This predictive capability opens avenues to choose optimal constituent materials for a desired outcome, thus circumventing exhaustive and costly trial-and-error approaches.

Moreover, GeoDict opens the door to the reverse approach: deriving constituent material properties based on the material characteristics and geometry from its results. This reverse inference unlocks insights into the underlying composition of complex materials, accelerating the understanding of intricate systems.

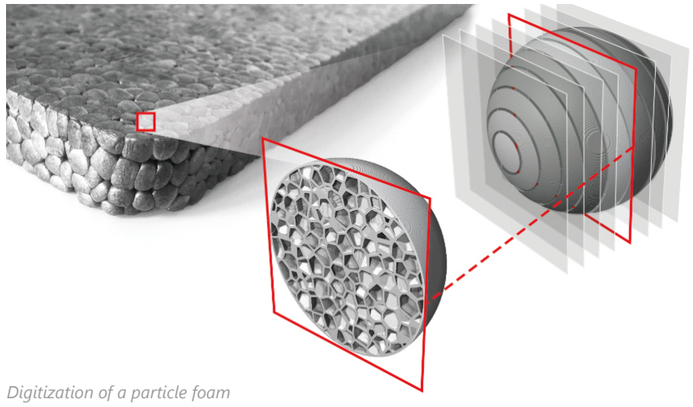
In certain cases, GeoDict even enables the estimation of geometrical properties from known material properties and from the properties of the constituent materials. This versatile bi-directional prediction transforms the way new materials may be conceptualized and designed.

In essence, GeoDict's unique capability to interrelate microstructure, constituent materials, and resultant properties empowers materials engineers to innovate with unprecedented precision and efficiency. It transforms the field by enabling systematic exploration, efficient optimization, and the modeling of materials with tailored functionalities, all while unraveling the intricate threads that weave Materials Science together.



Innovation through Simulation

GeoDict, by Math2Market, offers tailored solutions for R&D professionals in Materials Science. Among its features stand out the detailed material analysis, specialized applications, a user-friendly interface, and true-to-life 3D modeling. Advantages encompass high precision, easy integration, comprehensive scientific support, and continuous innovation, providing benefits such as improved efficiency, data-driven decision making, scalability, and costeffectiveness.



Digitization of a particle foam

GeoDict Features

GeoDict offers a robust suite of features tailored to the requirements of R&D professionals working with composites, foams, nonwovens, ceramics, metals, plastics, and medical-technical materials.

- **Detailed Material Analysis:** GeoDict provides in-depth analysis capabilities to investigate key material characteristics, such as permeability, conductivity, stiffness, and diffusivity.
- **Specialized Application:** GeoDict is designed specifically for the simulation of materials such as composites, foams, nonwovens, ceramics, metals, plastics, and medical-technical materials, and delivers precise, reliable results.
- **User-friendly Interface:** GeoDict offers an intuitive interface, simplifying navigation and operation and enhancing user productivity.
- **True-to-Life Material Modeling:** Build 3D material models with GeoDict to create accurate simulations for reliable, practical outcomes.

Why choose GeoDict?

GeoDict offers several key advantages over other material simulation software options:

- **Precision:** Advanced algorithms confer GeoDict unparalleled accuracy in data interpretation and modeling.
- **Easy Integration:** GeoDict integrates seamlessly with existing software tools, enhancing workflows and reducing time spent on configuration and data preparation.
- **Support and Training:** Our commitment to our clients extends beyond providing a superior software solution. We offer ongoing scientific support and training to ensure maximal benefits from GeoDict.
- **Continual Innovation:** GeoDict remains a leading solution for simulations in Materials Science by continually fine-tunning the software based on user feedback and industry advancements.

Benefits of GeoDict

Investing in GeoDict is more than a software decision; it's a strategic move towards better efficiency, informed decision-making, scalability, and cost-effectiveness.

- **Improved Efficiency:** GeoDict reduces time spent on data analysis and simulation, leading to increased productivity and faster turnaround times.
- **Better Decision-Making:** With its precise and detailed material analysis, GeoDict supports data-driven decision-making processes.
- **Scalability:** No matter the size of the project, GeoDict can handle it, providing a reliable tool for all material development needs. We offer efficient cloud solutions for further scalability.
- **Cost-Effective:** GeoDict's comprehensive capabilities and seamless integration make it a cost-effective solution that provides a significant return on investment.

GeoDict Workflow for Material Development

Easy-to-use

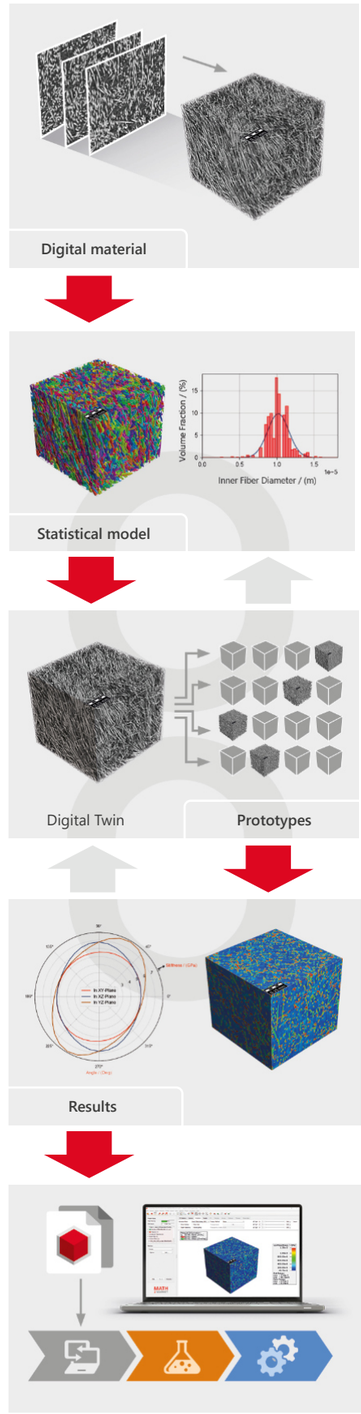
- User-friendly, intuitive graphical user interface
- Seamless integration into existing IT infrastructure
- Complete automation and reiteration - thanks to Python
- Voxel grid renders elaborate, strenuous meshing obsolete

Advanced and powerful features

- Analysis, property prediction, and visualization directly on computed tomography (CT) scans and focused ion beam-scanning electron microscopy (FIB-SEM) scans
- Structure generators: fast, realistic modelling of microstructures with random elements that enables serial digital testing
- Artificial Intelligence for identification of binder and fibers, and fiber distribution analysis
- High storage efficiency: simulations on structures of 64 billion voxels and more are possible on single computers or in clusters

Accurate property prediction

- Accurate prediction of material behavior, such as (anisotropic) stiffness tensor, permeability or thermal and electrical conductivity, based on the material microstructure
- Unmatched range of physical parameters that are predicted by GeoDict.
- Prediction of complex material behavior such as large deformations, and damage, as well as fracture behavior and fatigue at microstructure level



1. Data acquisition

Import: Import and segment µCT und FIB-SEM 3D-scans of existing materials. Import and visualize STL- and CAD-data to generate analytical models. Handling and processing of 3D material models.

Modeling: Create 3D material models of fiber microstructures through input of geometric and textile parameters (e.g. fiber orientation, fiber length, fiber volume content, tex, crimp). Build complex material models by overlaying and combining other models (e.g. pores, inclusions, pure resin layers).

2. Analysis

Each individual fiber is identified by means of Artificial Intelligence. Fiber length distributions, fiber orientations, fiber curvature, fiber diameter, and many other geometric and structural properties are analyzed.

Extract this statistical data to create a statistical model of the material with just a few clicks - the Digital Twin.

3. Modeling & Design

Generate a myriad of digital prototypes with modified properties in the shortest possible time using the Digital Twin. Identify and evaluate complex functional interactions through variation of individual parameters such as the fiber volume content.

Automate the generation of digital prototypes and the variation of parameters through scripts for enhanced productivity.

4. Simulation & Prediction

The behavior of a digital prototype is simulated and predicted under different boundary conditions. In this way, (anisotropic) stiffness tensors are determined or the deformation is tracked on the micro level.
If required, remodel the prototype repeatedly in a loop, until the desired prototype properties and behavior are reached.

The prototypes with behavior closest to the targeted material properties are manufactured for testing in the laboratory.

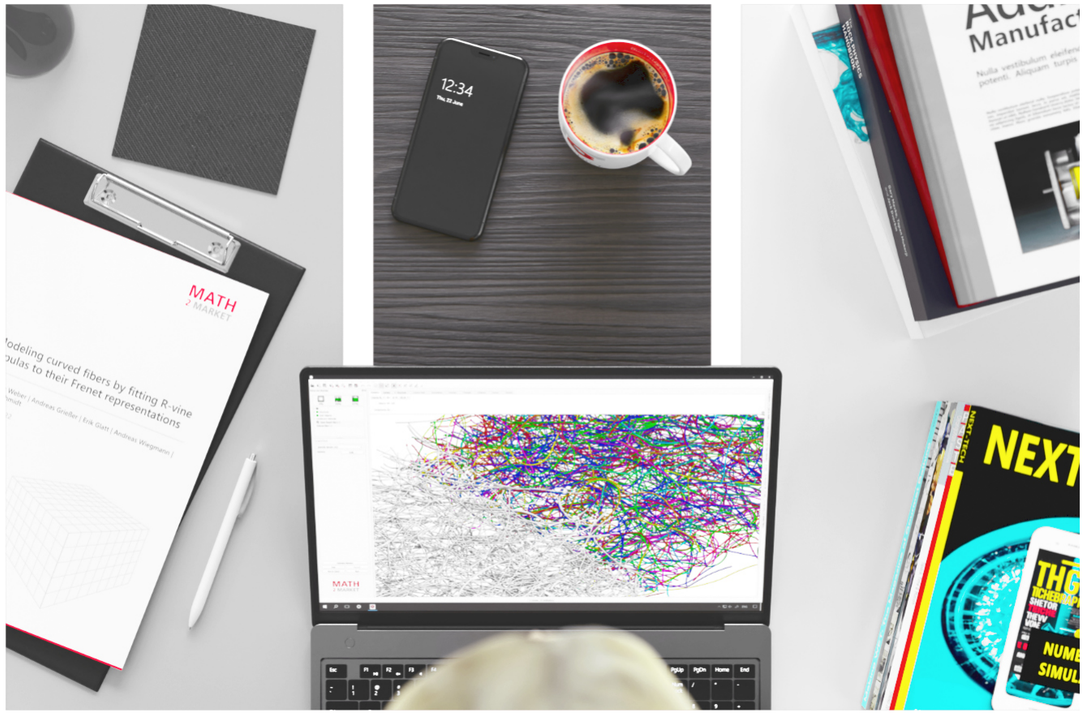
5. Export

Export the simulation results from GeoDict to other software packages. Visualize results as high-resolution images, in videos, or integrate them into PowerPoint presentations.

Integrate GeoDict simulation results into CAE tools, FEM and CFD software - for example, through embedded interfaces to MATLAB®, Python, and Microsoft Excel®.

Example of GeoDict workflow for the development of a glass-fiber-reinforced thermoplastic

GeoDict in Industrial and Academic Settings



R&D Professionals

As an R&D professional, challenges often involve developing innovative materials while reducing the time and cost of experimentation. GeoDict, with its advanced simulation capabilities, allows to create and test materials in a digital environment. It provides in-depth material analysis, speeding up the process of fine-tuning material properties. It's a reliable partner to enhance innovation and reduce time-to-market in material development.

All the desired properties of the material are simulated from the desk. No need to purchase small quantities of sample materials, to setup large production machines for small test quantities and to evaluate properties with the usual experimental deviations.

GeoDict qualifies and quantifies the needed material properties with rigorous precision.

Production Managers

In production, efficiency, quality, and cost-effectiveness are key. GeoDict's simulation capabilities predict how materials will behave during the production process, helping identify potential issues before they occur. GeoDict helps to optimize the use of raw materials, minimize waste, and improve quality control. It's a powerful tool to achieve the required production efficiency and sustainability goals.

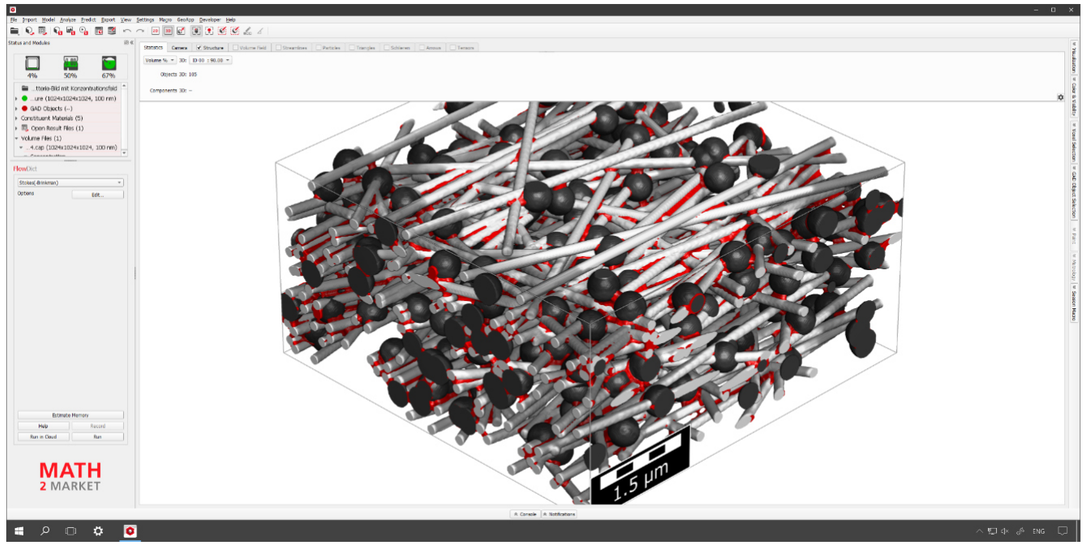
As you know, errors in production quickly develop into large costs. Before even encountering any of these errors, GeoDict is brought into play to conduct studies using Design of Experiments methods and estimate the impact of these errors on product quality. Moreover, GeoDict is a great tool for quality control and helps to effectively monitor particular relevant parameters. For example, from automated analysis of CT scans.

Academic Researchers

In the world of academic research, the boundaries of material science are continuously pushed and tested. GeoDict supports research studies with its true-to-life 3D material modeling and its precision in the analysis of numerous material characteristics. Its ability to handle complex simulations allows exploring novel research areas and deepen the understanding of material behavior. GeoDict, with its ongoing updates and enhancements, is a steadfast ally in the pursuit of academic excellence.

By calculating material properties using physical models on microstructures, GeoDict is a crucial tool for all material scientists. The relevant parameters for the design of novel materials are easily determined and optimized for future usage cases while maintaining full control of all related input values.

Usability: A Core Strength of GeoDict



GeoDict has gained notable acclaim due to its unique fusion of advanced simulation capabilities and an exceptionally intuitive user interface. This software has been purposefully crafted to demystify the intricacies of complex material simulations and analyses, presenting itself as an accessible and user-friendly tool suitable for individuals of all skill levels. Whether you're a novice venturing into the world of simulations or a seasoned expert, GeoDict's user-centric approach ensures effortless navigation through sophisticated simulations, seamlessly translating complex data into valuable insights.

The coupling of sophistication and simplicity within GeoDict delivers a powerful material simulation tool that prioritizes usability. This steadfast commitment to user-friendly design underscores Math2Market's unwavering dedication to providing accessible solutions to the Materials Science community, enabling the realization of advanced simulations without the typical steep learning curve. GeoDict empowers a diverse user base by striking the perfect equilibrium between technical prowess and an approachable interface, making it a cornerstone in the realm of material science innovation.

User-friendly Interface

One of the fundamental aspects of GeoDict's usability lies in its intuitive interface. A clean, organized layout facilitates easy navigation through its comprehensive suite of features. The process to set up, run simulations, and interpret results has been streamlined, reducing the learning curve and enhancing productivity.

Interoperability

GeoDict has been built with interoperability as a key feature. It seamlessly integrates with other software tools commonly used in material development and research, creating a unified workflow. This simplifies data management and enhances efficiency.

Comprehensive Support

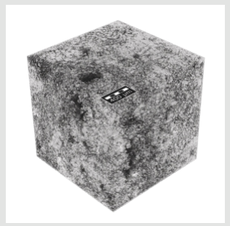
GeoDict's usability extends beyond its software design. Math2Market provides robust customer support, including detailed user manuals, video tutorials, and access to our team of experts for more complex scientific queries. We offer dedicated training courses to master GeoDict and exploit its full potential.

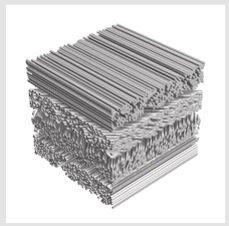
Customization

The flexibility of GeoDict allows for customization to meet individual project needs. Users choose from a wide array of parameters and settings to tailor their simulations, offering a personalized experience.

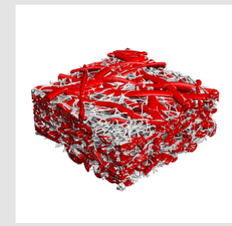
This is INNOVATION through SIMULATION

ImportGeo

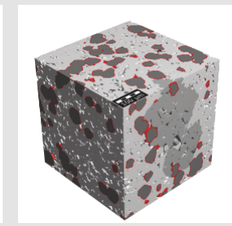


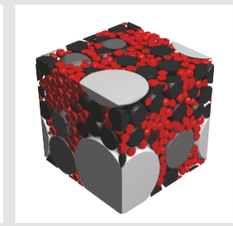


FiberGeo

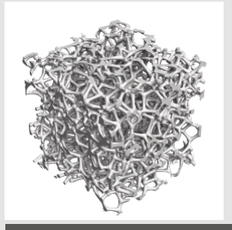


PaperGeo

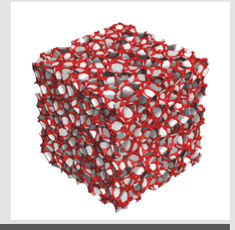


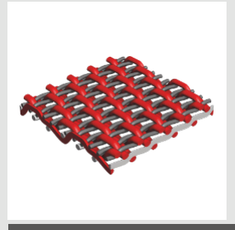


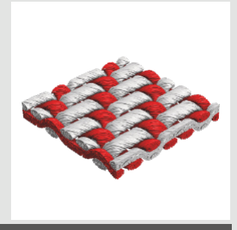
GrainGeo



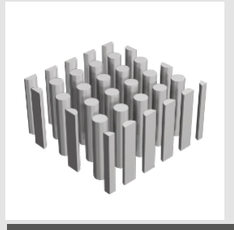
FoamGeo



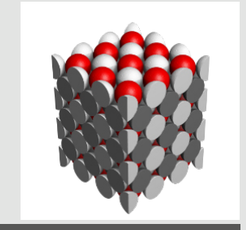


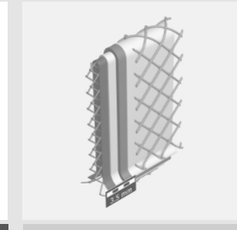


WeaveGeo

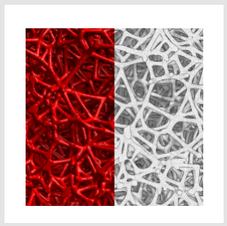


GridGeo

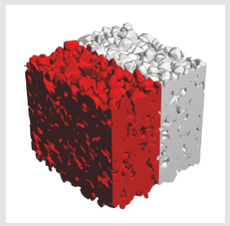




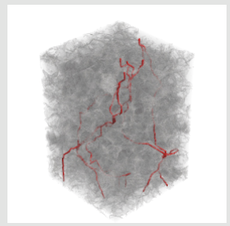
PleatGeo



MeshGeo

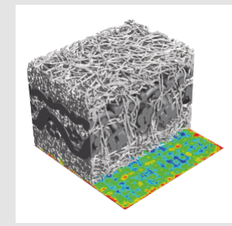


ExportGeo

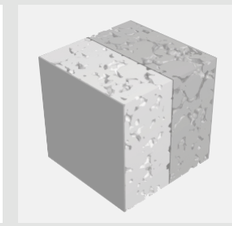


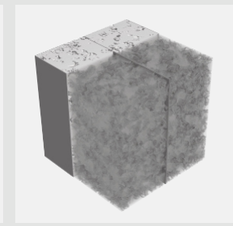
PoroDict

This is **Innovation** through **Simulation**

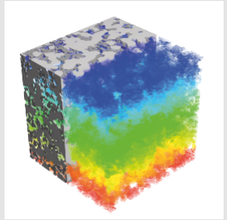


MatDict

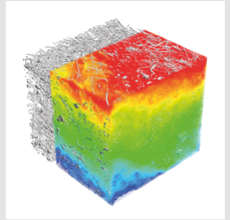




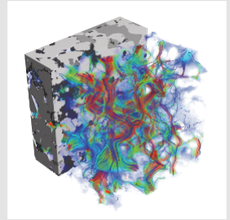
BatteryDict

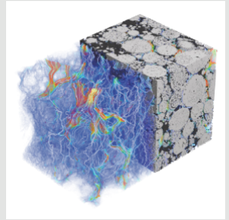


DiffuDict

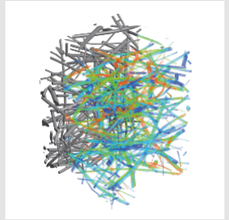


ConductoDict

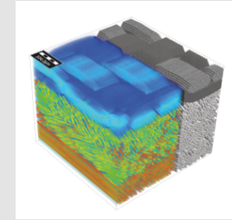


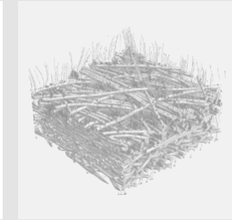


FlowDict

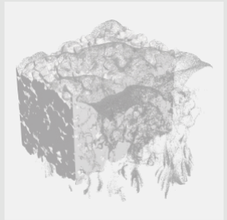


ElastoDict

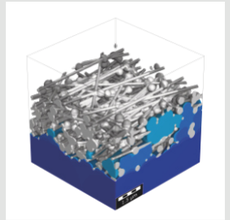




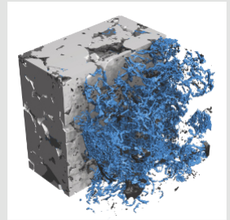
FilterDict Media & Element

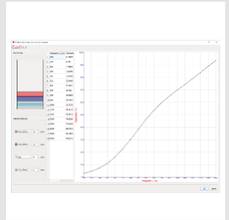


AddiDict

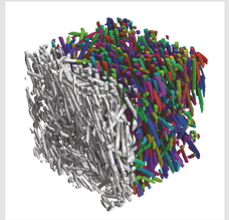


SatuDict





AcoustoDict



FiberFind AI

GrainFind

GeoDict Modules

GeoDict is used worldwide for R&D and production in industrial and academic settings mainly in the fields of Digital Material R&D, filtration, digital rock physics, batteries, and fuel cells.

The modular setup of the GeoDict software is essential to its versatility and adaptability to the specific requirements of diverse applications. In this way, GeoDict is a customized solution, tailored to the development or research task of the user.

GeoDict Modules

GeoDict Base

The GeoDict Base package contains the basic features and modules of the GeoDict software. It includes a graphical user interface, advanced visualization capabilities, and tools for fine-tuning and transforming 3D images and material models. Also included are a Python integration for workflow automation and modules for interface with Matlab® and Microsoft Excel®. Overall, the Base package provides a comprehensive set of tools to create, analyze, and manipulate 3D images and material models.

GeoDict's Base Package comes fully equipped with the following essential modules:

- **GeoLab**: Matlab® interface for GeoDict.
- **GeoDexcel**: Analyze GeoDict results with Microsoft Excel®.
- **ProcessGeo**: Powerful 3D image and material model processing tools.
- **LayerGeo**: Combine and layer segmented 3D images and models.
- **ImportGeo-Base**: Import data in various GeoDict formats.
- **ExportGeo-Base**: Export to GeoDict and other formats (*raw, *png, *am).
- **GadGeo**: Create and manipulate 3D material models with ease.

Short fiber-reinforced polymer in an engine carrier.

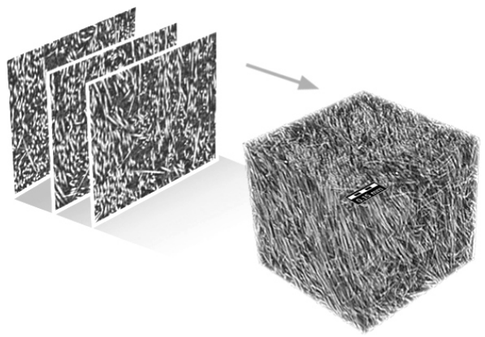
ImportGeo-Vol

Import

GeoDict offers the option to import / load a variety of file formats. Its ImportGeo-Vol module handles the following file formats: *.raw, *.vol, *.rek, *.vox, *.vgi,*.iass, *.am, *.txm, *.bmp, *.gif, *.jpg, *.mng, *.pbm, *.pgm, *.png, *.ppm, *.tif, *.tiff, *.xbm, *.xpm and GeoDict specific formats. The add-on ImportGeo-CAD module is required for the import of *.stl files.

3D Image Processing

GeoDict's ImportGeo-Vol module offers various image editing and processing features, including file import and domain editing tools such as rotation, cropping, and slice extraction. The module includes various image filters e. g. for denoising, edge detection, and contrast enhancement, all of which run in 3D on both CPU and GPU. Specific tools for micro-CT and FIB-SEM scans are also available, such as ring-artifact removal and slice alignment. GeoDict provides several tools for image segmentation, including user-defined thresholds, threshold filters like the Phansalkar filter, and automated segmentation methods such as kmeans and Otsu clustering algorithms, as well as Artificial Intelligence-based methods.



CT-Scan of short fiber reinforced polymer.

FiberFind AI

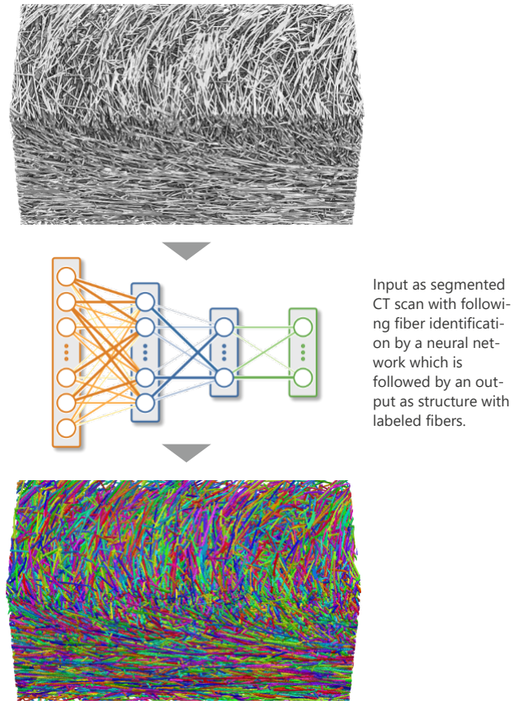
The FiberFind AI module enhances object recognition in µCT images by combining fast parameter prediction and neural networks for accurate fiber and binder detection. It focuses on understanding 3D scans of fibrous materials such as nonwovens and fibrous composites.

FiberFind employs three approaches:

- Classical image processing methods for identifying individual fibers.
- FiberFind-AI, which utilizes Artificial Intelligence (AI) to identify individual fibers.
- Analysis of statistical properties of fibers, including diameter distribution, orientation distribution, and curvature distribution.

FiberFind-AI relies on neural networks trained with ground truth data generated by the FiberGeo module in GeoDict.

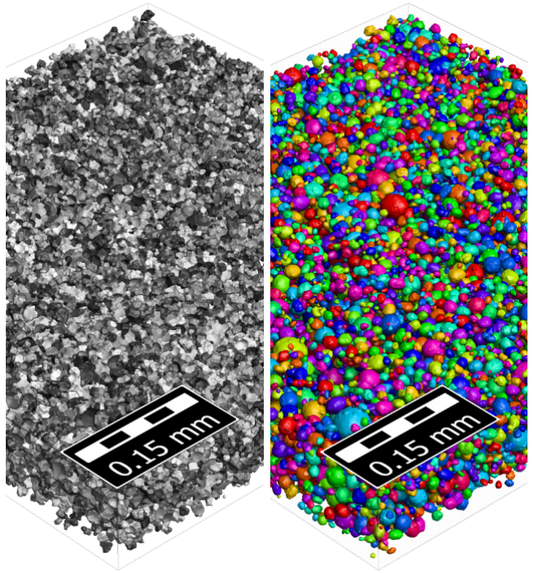
This module finds applications in various areas, such as creating structure models matching physical samples, analyzing binder content, optimizing materials, and ensuring material quality control.



Input as segmented CT scan with following fiber identification by a neural network which is followed by an output as structure with labeled fibers.

GrainFind

GeoDict's GrainFind module enables precise grain detection in µCT images by identifying individual grains and determining their best-fit shape and orientation. This information is valuable for simulations of properties dependent on grain orientation and modeling the microstructure's Digital Twin using the GrainGeo module. GrainFind analyzes individual grains, including their volume, surface area, orientation, shape, and estimates grain diameter distribution. It utilizes a specialized Watershed algorithm based on the Euclidean Distance Transform (EDT) for grain identification.



Identified grains are displayed as an index image on the 3D model.

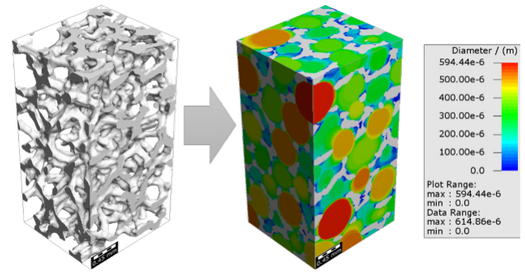
GeoDict Modules

PoroDict + MatDict

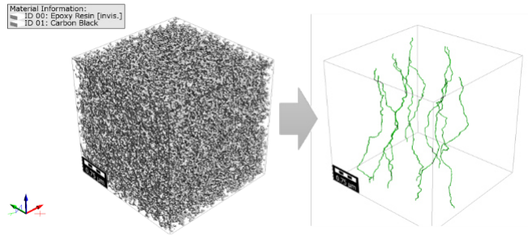
Geometrical characterization of the pore-space is carried out in GeoDict within the PoroDict module. The PoroDict module determines total porosity, connected and isolated porosity, pore size and pore throat size distributions, the surface area, and computes percolation paths (connectivity) through the pore space. When determining the pore characteristics of 3D functions, other CT, µCT or FIB / SEM image data as well as model functions generated with PoroDict can be used.

Furthermore, PoroDict can identify individual pores by a specialized watershed algorithm, to perform shape characterization (e.g. sphericity), and determine pore volume, orientation, coordination number, pore cluster sizes, Minkowski parameters, etc.

The MatDict module examines the solid material distribution in segmented 3D images or models. It determines the spatial heterogeneity, density, structure information, connected components, percolation paths (connectivity), etc.



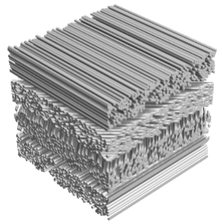
Pore size distribution determined by Granulometry (ProrDict).



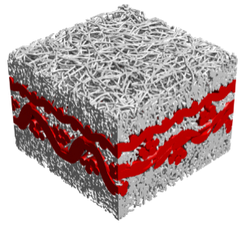
Paths of electrical percolation in an epoxy resin filled with carbon black (MatDict).

FiberGeo

The FiberGeo module generates detailed 3D microstructure digital models of nonwovens and composites based on statistical properties such as fiber parameters and orientation distribution. These models allow for close analysis akin to µCT scans and enable the design of new materials with computed material properties. The module can create various structures, including dense fiber networks, fiber lay-down processes, gradient media, and binder distribution. It supports straight or curved fibers with different profile shapes and allows specification of fiber orientation and parameter distribution. Examples of applications include modeling composites, rovings, laminates, and technical textiles like nonwovens and weaves.



Model of a laminate.



Model of a dewatering press felt

Dry carbon fiber roving with waviness.

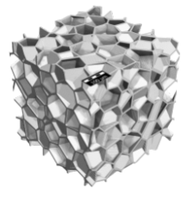
FoamGeo

FoamGeo is a powerful module for creating detailed 3D digital models of various foam types. It supports regular and random foam structures with different cell sizes, shapes, and orientations. These models provide a close analysis similar to µCT scans, revealing the intricate microstructure of foams.

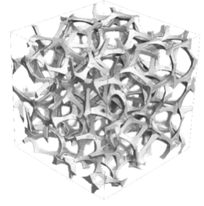
One of FoamGeo's key benefits is its ability to design new foams by adjusting statistical descriptions. Users can manipulate parameters like cell sizes, shapes, and orientations to simulate material properties such as stiffness and thermal conductivity. This enables the prediction and evaluation of foam performance through computational simulations.

FoamGeo is also valuable for comparing and optimizing foam properties. Users can assess the material properties of newly designed foams against existing products, facilitating informed decision-making and performance enhancements. The module finds applications in various industries, including metal foams, acoustic foams, and insulation materials like closed cell polyethylene foam.

With FoamGeo, researchers and engineers have a versatile tool for exploring, designing, and analyzing foam structures. Its comprehensive modeling capabilities support foam-related research, development, and optimization efforts.



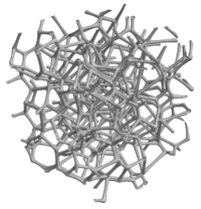
Closed cell random foam



Open cell random with triangular struts foam

Particle foam beads

Logarithmic foam structure



Mesh of the foam structure

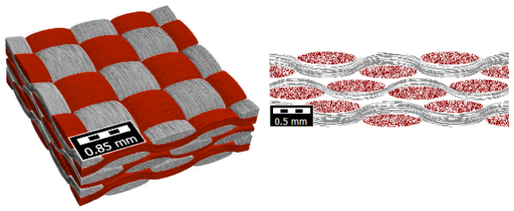
WeaveGeo

The WeaveGeo module swiftly designs and generates 3D models of regular woven structures like textiles, carbon fiber reinforced plastics, and wire meshes. Within minutes, users can create models that simulate material properties using GeoDict's Digital Material Analysis modules. The results allow for optimization of design parameters in just a few days.

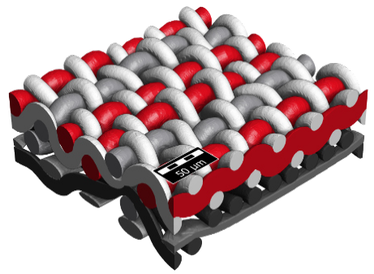
WeaveGeo supports both mono- and multifilament yarns, including ropes and random fiber bundles. Control over the mutual deformation of weft and warp yarns can be achieved by assigning stiffness to materials.

This module consists of sub-modules for designing various weave types. Simplified user interfaces are available for common weave patterns like Plain, Twill, and Satin. For more complex designs, including multi-layer structures, the FreeWeave sub-module allows custom bindings through weave diagrams. The generated material properties can be further analyzed using other GeoDict modules, such as FlowDict for CFD, FilterDict for filtration efficiency/capacity, and ConductoDict for thermal/electrical conductivity.

WeaveGeo finds applications in diverse fields, such as textiles for composites, wire meshes in architecture, protective clothing, and the paper industry.



Weave structure, all fibers resolved.



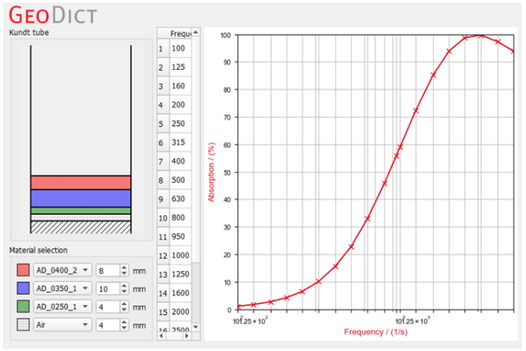
Complex weave designed in WeaveGeo

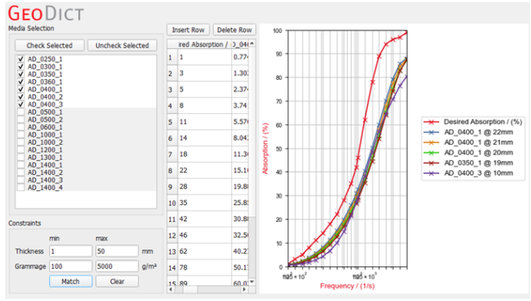
GeoDict Modules

AcoustoDict

AcoustoDict serves as a digital impedance tube, enabling the simulation of acoustic properties in porous microstructures. By utilizing a digital model or CT scan, AcoustoDict computes a set of parameters that describe the material's acoustic behavior. These parameters can then be employed as inputs for the empirical Delany-Bazley model. Through this model, AcoustoDict predicts the frequency-dependent acoustic absorption curve.

In addition to the Delany-Bazley model, AcoustoDict also supports the Johnson-Champoux-Allard (JCA) model. The JCA model provides a more comprehensive approach to acoustic characterization, accounting for the effects of viscous and thermal dissipations in the material. By incorporating the JCA model into AcoustoDict, users gain an enhanced capability to analyze and predict the acoustic behavior of porous microstructures across a range of frequencies.





Analysis of absorption and frequency of an 3D model including Oil and Polyamid 66 (with match-function in AcoustoDict).

Stack-function in AcoustoDict.

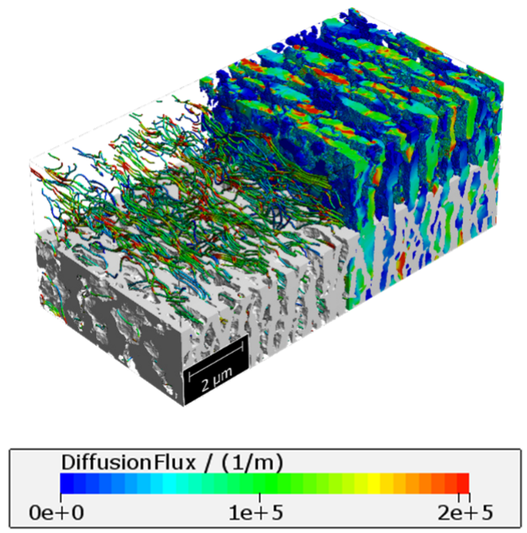
DiffuDict

DiffuDict computes the tortuosity factor and effective diffusivity of porous media. Depending on the pore size, the diffusing fluid is treated as a continuum or as single molecules reflecting off pore walls. The dominant model is determined by the Knudsen number (Kn), which compares the pore diameter to the mean path length of fluid molecules.

For small Knudsen numbers, the fluid is treated as a continuum, and the concentration distribution follows Laplace's equation. Effective diffusivity is determined from the resulting concentration flux using Fick's first law. The relative diffusivity and tortuosity factor are obtained by comparing the effective diffusivity with the bulk diffusivity of the fluid.

For large Knudsen numbers, the simulation includes the reflection of single molecules at the pore walls, calculating their mean squared displacement over time. The effective diffusivity is computed based on this value.

For intermediate Knudsen numbers, Bosanquet's approximation is employed to find the effective diffusivity by averaging between the two cases.

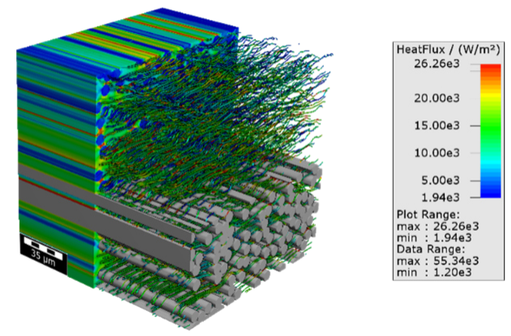


Determination of thermal conductivity of fiber reinforced polypropylene.

ConductoDict

ConductoDict is dedicated to simulating electrical and thermal properties of materials. Within ConductoDict, effective conductivity computations are performed for porous and composite materials. This module encompasses two solvers: EJ (Explicit Jump) and LIR, which facilitate the calculation of electrical and thermal conductivity tensors, formation factor, as well as potential, temperature, current density, electric field, and heat flux fields.

ConductoDict offers flexibility in assigning different conductivity values to segmented phases and varying contact resistivity between different phases. Additionally, it supports the assignment of non-isotropic material properties, such as transverse-isotropic or orthotropic properties. This capability allows for accurate modeling of materials with varied conductivity and complex structural configurations, providing insights into their electrical and thermal behavior.



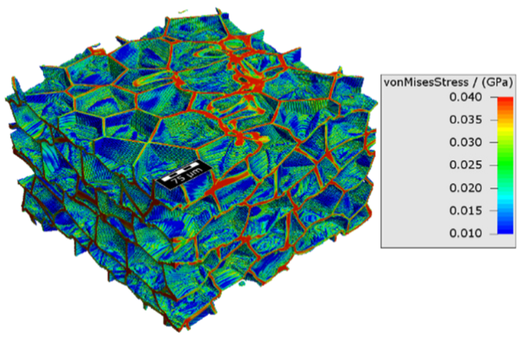
Determination of thermal conductivity of fiber reinforced polypropylene.

ElastoDict

ElastoDict in GeoDict revolutionizes the characterization of complex materials by enabling direct calculations on segmented CT scans, eliminating the need for meshing. With ElastoDict, you can analyze anisotropic stiffness, elastoplastic deformation, damage, and material failure directly on the 3D microstructure, even visualizing these properties on CT images. It offers three powerful options:

- **ElastoDict-AF**: This option provides fast analytic approximations and bounds for the linear elastic properties of complex microstructures. It efficiently computes a first approximation of the material behavior without solving partial differential equations, making it ideal for quick assessments.
- **ElastoDict-VOX**: This option accurately computes the linear elastic properties of complex microstructures by solving the corresponding partial differential equation on the 3D image or model. It provides detailed results, including the local von Mises stress, the complete stiffness tensor, and information about the material's orthotropic, transversal isotropic, or isotropic character, which indicates directionally dependent properties. Additionally, extensive post-processing steps can be performed on the VOX results.
- **ElastoDict-LD**: This option enables the simulation of nonlinear large deformations. It allows you to set up standard tensile experiments in arbitrary directions of the 3D microstructure. By incorporating advanced material models, such as damage, failure, plastic deformation, and viscous effects, it provides comprehensive insights. With ElastoDict-LD, you can obtain strain-stress curves, identify regions where damage occurs and the material fails, and conduct cyclic load experiments, bending tests, and shear experiments. Furthermore, the LD simulation generates deformed 3D structures from each computed deformation step, facilitating visualization and further analysis.

By leveraging the microstructure scale, ElastoDict empowers engineers and researchers to improve component simulations and optimize material designs, all while directly utilizing segmented CT scans without the need for meshing. It represents a significant advancement in accurately characterizing and understanding the mechanical properties of complex materials.



Complex weave designed in WeaveGeo

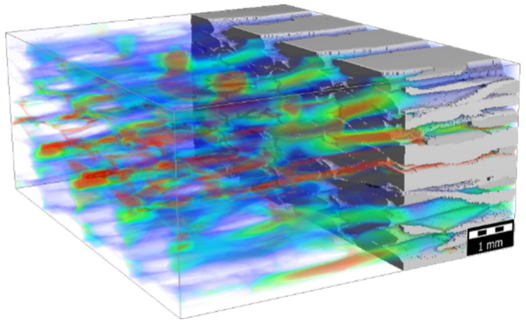
GeoDict Modules

FlowDict

FlowDict in GeoDict enables simulation of single-phase flow, offering three solvers (SimpleFFT, LIR, Explicit Jump) to compute permeability and fluid flow fields by solving the (Navier-)Stokes(-Brinkman) equations using finite volume approaches. Its capabilities encompass predicting mean flow velocity for a given pressure drop, estimating pressure drop for a given mean flow velocity, and determining the full or partial permeability tensor.

LIP and SimpleFFT have been demonstrated to handle geometries with 109 cells and more, as documented in Saxena et al., 2017, and Menke et al., 2018. The LIR solver's methodology, published by Linden et al., 2015, has also been cited in these studies.

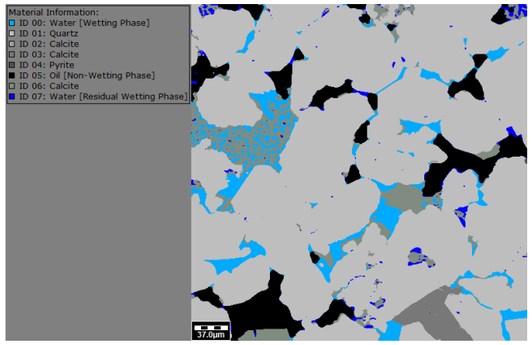
GeoDict provides visualizations and exports of pressure and velocity fields in *.raw file format. Additionally, it reports key values such as absolute permeability, pressure drop, mean velocity, and the complete permeability tensor.



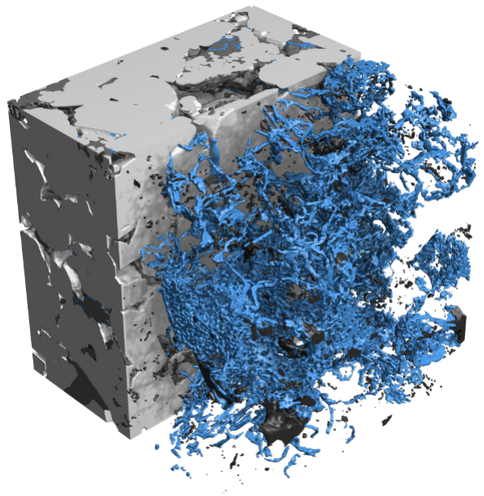
Flow of epoxy resin through a non- crimp fabric.

SatuDict

SatuDict in GeoDict analyzes the distribution of two fluid phases (gas or liquid) within porous materials, affecting properties like permeability, diffusivity, thermal conductivity, and electrical conductivity. It computes capillary pressure curves using the pore morphology (PM) method, enabling calculation for imbibition and drainage. Schulz et al. (2015) extended the PM method to accommodate different wettability conditions. The PM method considers fluid properties by adjusting interfacial tension and derives actual fluid distributions in the pore space. Berg et al. (2016) compared PM-generated distributions with computed tomography measurements. Combining with FlowDict determines effective and relative permeability, while combining with ConductoDict computes resistivity index, saturation exponent, cementation exponent, and relative diffusivity as in DiffuDict.



2D view of drainage simulation (simulated with SatuDict)



Simulation of imbibition in a Berea sandstone: a non-wetting liquid (oil) is displaced by a wetting liquid (brine).

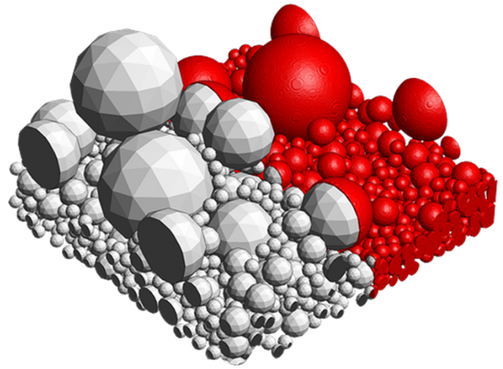
ExportGeo-CAD

ExportGeo-CAD exports structures from GeoDict formats to generic surface representation formats or generic CAD formats, enabling the integration of GeoDict-modelled structures into pre-established workflows.

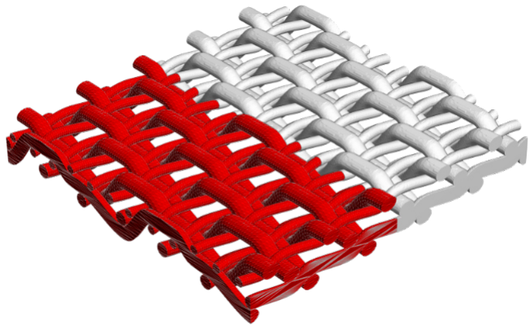
ExportGeo supports a variety of surface description formats like *.stl, *.wrl, *.obj.

It also can be used in combination with CADlook (only available on Windows) to export CAD formats e.g. *.x_t, *.stp, *.igs, *.sat.

ExportGeo-CAD enables e.g. 3D printing, visualization using an external render software and integration into a simulation workflow.



Preview of the surface triangulation of a sphere cluster



A mesh of a forming fabric created with the WeaveGeo module and triangulated with ExportGeo-CAD

Customer Service & Support

An intensive exchange of information, trainings, workshops and our annual User Meeting ensure for our customers and partners the transfer of know-how and the same high-service standard for all GeoDict users.

For complex projects and applications, Math2Market offers consulting and carries out project work for our customers.

GeoDict User Guide

A comprehensive User Guide is available to all GeoDict users. The User Guide handbooks, for all GeoDict modules, describe all parameters in the Graphical User Interface for the modules, with images and explanations of their options.

The User Guide handbooks are reachable with 1-click directly from the GeoDict GUI and available as PDFs from the Math2Market website.

Training offers

Online or in person, our application specialists use practical examples to show the functionality and the possibilities of GeoDict simulations.

The content is oriented towards your level of experience with GeoDict and tailored to your application area.

Self Learning 24/7

Our written and short video tutorials provide a step-by-step introduction, followed by advanced knowledge in the functionality and possibilities of GeoDict. All are advantages: decide when and where, and learn at your own pace.

The range of topics is regularly revised and expanded.

Digital Material R&D team
Individual trainings onsite and online, individual consulting, and industry-specific support

GeoDict Consulting and Projects team
Individual automation, app engineering, validation projects, and customization projects

GeoDict Development team
Annual software releases, regular Service Pack updates, and individual software development projects

Customer Support team
Professional support on technical and scientific questions related to GeoDict

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GeoDict - Licensing flexibility

For the versatile fields of application of GeoDict, we offer a flexible range of licenses to provide an attractive price-performance ratio to our customers.

GeoDict is the complete solution for multi-scale digital research and development of materials in academic and industrial settings. GeoDict's modular structure makes possible to adapt the software package to the customer requirements at any time and to find a customized solution for every application. All modules are completely integrated into GeoDict and, thus, guarantee a smooth simulation workflow.

Purchase of a GeoDict license

When purchasing a GeoDict license, a license package is built according to the requirements of the application. The license price depends on the selected license model, the modules included in the package, and the required computing speed.

We help in selecting a license package fitting your application and your working situation by choosing the most useful customizable combination of GeoDict modules. An overview of the available modules is found in pages 8-9. Individual modules may be varied in a package at any time.

License Type	Description	Maintenance (Updates and Support)
Purchase	unlimited time license	1 year included, afterwards cost-effective renewal
or		
Lease	limited time license	defined by lease period

Start with a validation project!

Want to see convincing results and customer-fitted simulation requirements before (or instead of) ordering?

Choose a pay-for validation project run by Math2Market for your specific application. The validation project brings solution-oriented information on a GeoDict configuration that works for you.

Furthermore, we train you specifically for your application case with GeoDict.

The simulation requirements for the application of the customer are analyzed in a pay-for validation project that provides solution-oriented information on the best GeoDict configuration for you. Contact us about your particular material development or analysis needs!

License Options

Node Locked
One on-site computer, one user at a time

- **One Site**: All employees employed at **one** designated site
  - **No Cloud**: Physical machines

Floating
Any computer, one user at a time per license

- **One Site**: All employees employed at **one** designated site
  - **Local**: Physical machines, Virtual machines
- **Two Sites**: All employees employed at **two** designated sites
  - **Customer Cloud**: On-premise clouds or HPC solutions
- **All Sites**: All employees employed at **all** sites
  - **Premium Cloud**: GeoDict pay-per-use clouds, all other clouds

GeoDict: Q&A

What is GeoDict ?

GeoDict is a comprehensive simulation software suite developed by Math2-Market for digital material analysis, research, and development. It allows users to generate, edit, and visualize complex material models and prepare results for presentations.

Who typically uses GeoDict?

GeoDict is typically used by researchers, scientists, and developers in the field of Materials Science, including those working in academia, industry, and research institutions.

How does GeoDict help with material analysis and research?

GeoDict offers a range of tools and features that assist in digital material analysis and research. These include modules for image processing, material modeling, property computation, and prediction. It also provides advanced options to import and export data in various formats.

How does GeoDict integrate with existing workflows?

GeoDict seamlessly integrates with established workflows through its interfaces to Python, MATLAB®, and Microsoft Excel®. This allows for efficient automation and deep analysis of results within these well-known environments.

What are the key features of GeoDict?

Key features of GeoDict include a highly user-friendly graphical interface, fast 3D visualization of material models and simulation results, voxel and analytic object-editing tools, image and video capturing and processing tools, and scripting interfaces to Python and MATLAB®.

How do I customize GeoDict to meet my specific needs?

GeoDict is designed with a focus on flexibility and adjustment to your precise requirements. This can be optimally achieved by selecting from its dedicated modules designed for various tasks, including image processing, material analysis, material modeling, and property prediction. Refer to pages 10 - 19 for an in-depth overview of the modules that are particularly relevant for digital Research & Development in Material Sciences.

What data types may I import into and export from GeoDict?

GeoDict supports import and export of data in various formats. It imports files in GeoDict formats and exports to both GeoDict and non-Geo-Dict formats, including RAW Data, VOL Data, Avizo Binary Files, and 2D Image Stack. See details in page 12.

How does GeoDict handle 3D material models?

GeoDict includes tools to construct any geometry from analytic objects and modify 3D material models. These features allow detailed exploration and analysis of the data.

How does the post-processing and analysis in GeoDict work?

GeoDict provides detailed post-processing and analysis capabilities through its GeoDexcel module. GeoDict result files are automatically loaded into Microsoft Excel® spreadsheets for further analysis and comparison.

How does GeoDict benefit my work in materials science or material development?

GeoDict serves as an innovation catalyst, fostering a space where creativity thrives. Its flexible environment allows experimenting with diverse scenarios regarding materials and conditions, facilitating rapid iteration and exploration of new ideas. With GeoDict as your ally, be ready to push the boundaries of possibility, bringing novel materials to market faster and staying ahead of the competition.

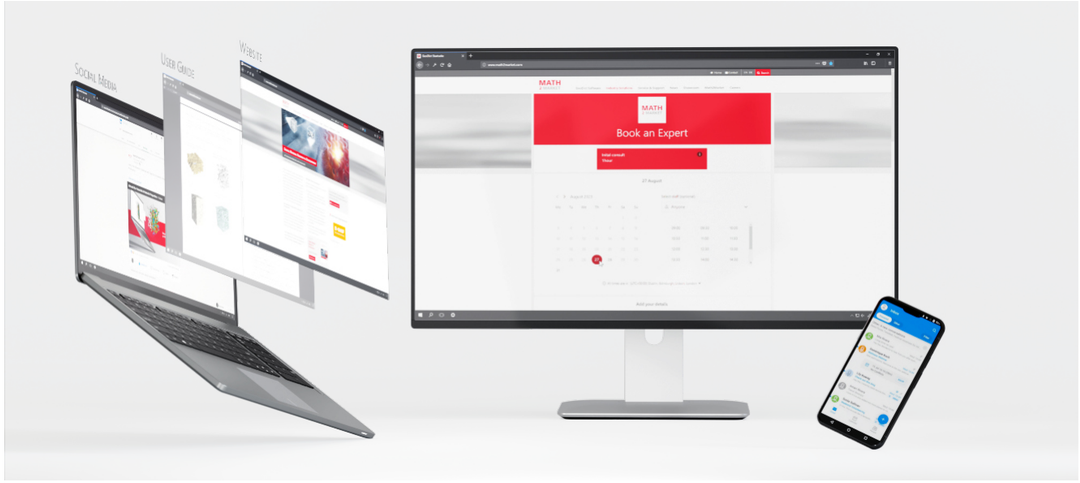
What kind of support and resources are available to learn how to use GeoDict?

Math2Market offers various resources to quickly learn how to use GeoDict, including tutorials, user guides, and a highly skilled support team that assists if technical issues or queries arise.

How is GeoDict licensed and what are the costs associated with using it?

Specific licensing information and costs associated with GeoDict may be obtained by contacting Math2Market directly as these details might vary based on the intended use, number of users, and the specific modules needed.

Empowering Your Vision: Your Success, Our Priority



Online Scheduling

We understand that your time is precious, and we are committed to making your communication with us as convenient as possible. We offer a hassle-free online booking system to streamline the scheduling process.

The journey towards innovation, collaboration, and success starts with a single step. Use our online system to schedule a query or consultation, and let us guide you on this exciting path. We are ready to provide insights, offer solutions, and work alongside you to achieve your goals. Don't miss out on the opportunity to connect with our experts at your convenience. Book your consultation today and take the first step towards unlocking digital innovation.

Make an apointment with our **Digital Material R&D** team

Website

Explore our comprehensive website. Find detailed information about our services, case studies highlighting success stories, and a contact form to reach us conveniently.

www.math2market.com

Email

Prefer to communicate via email? Drop us a message. We direct your inquiry to the right team and promptly address your needs.

digital-materials@math2market.de

Stay Connected

We are dedicated to sharing valuable insights, thoughts, and inspiring content with the simulation community. Connect with us and do not miss out on the latest updates and engaging discussions.

Linkedin.com

YouTube.com

Math2Market - The Company

GeoDict combines cutting-edge scientific advances and powerful software development into a user-friendly solution for innovative digital material analysis, research, and development in industrial and academic settings.

Math2Market GmbH was founded in September 2011 by three members of the GeoDict software development team as a spin-off from the Fraunhofer Institute for Industrial Mathematics (ITWM, Institute für Techno- und Wirtschaftsmathematik) in Kaiserslautern, Germany. Some of the founders had been working on the software since its inception in 2001. Today, Math2Market has a workforce of over 60 employees at its Kaiserslautern site and, with GeoDict, is one of the worldwide leading providers of digital solutions in the field of material analysis, research, and development.

„With GeoDict, complex fiber and foam microstructures are modeled with just a few clicks, without the hassle of meshing. Previously unimaginable insights into the microstructure of materials are now within reach and at your disposal to develop the materials of tomorrow."

Dr.-Ing. Oliver Rimmel
Business Manager Digital Material R&D / Math2Market GmbH

Over 400 universities, research institutes, and large companies from various industries worldwide use GeoDict to develop innovative materials and optimize their material analysis and development processes. With our unique pool of top mathematicians, physicists, geologists, chemists, biologists, engineers, and computer scientists, we believe in making available the benefits of cutting-edge, university-level research to our clients, to be applied by non-experts using our software GeoDict.

Our customers also benefit from the comprehensive services of Math2Market, including regular updates of GeoDict, intensive customer assistance and consulting, as well as training and reliable support by our experts in their respective fields.

Math2Market cooperates in diverse ways with international partners from industry and academia and participates regularly in scientific congresses and technical trade fairs with innovative scientific contributions.

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