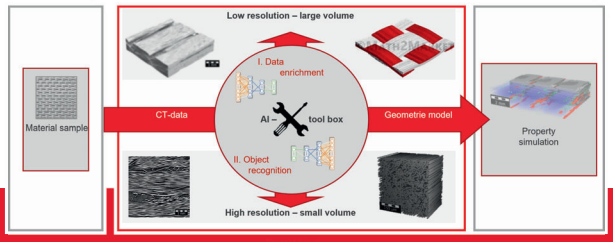
# GeoDict

The Digital Material Laboratory

KI4 MATERIAL MODELING




## Development of an AI-based workflow for object recognition in computed tomography data using the example of fiber-plastic composites

Development of an AI-based workflow for generation of structure models from CT-Data by using object detection on gray-scale data and the prediction of composite properties

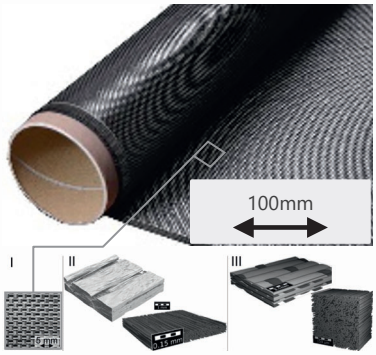
- Close the gap between CT-Data and geometry model
- Improve the Object detection based on unsegmented CT-images
- Create large high-resolution geometry models for the prediction of processing properties based on prior known structure and scan information


**Authors:**
**Dominik Michel**[1,*], Lilli Burger[1], Dennis Mosbach[1], Andreas Grießer[1], Rolf Westerteiger[1], Erik Glatt[1], Oliver Rimmel[1]

[1] Math2Market GmbH, Richard-Wagner-Straße 1, 67655 Kaiserslautern, Germany
[*] Corresponding author: dominik.michel@math2market.de


Our project partners:

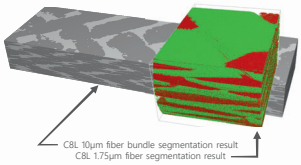
Leibniz-Institut für Verbundwerkstoffe



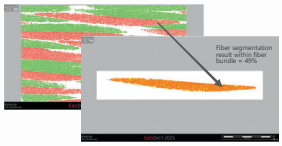

Typical carbon fiber fabrics for FRP production **(I)**, µCT-generated images of a fiber structure **(II, top)** & a fiber bundle section **(II, bottom)**, computer-generated „replicas" **(III)**

### Challenges by Segmentation of 3D-datasets (CT-data)

- Low contrast between fibers and matrix material, intensified issue by additional image artifacts
- Accuracy of the segmentation with almost indistinguishable gray-values
- Detection on different scales, between individual fibers and full fiber bundles
- Artifacts and limited resolution lead to deviations in the model and the prediction
- Using easy-to-use AI-segmentation tools currently available in GeoDict
- Relevant device- and material-specific artifacts
  - Direction-dependent noise in scans
  - Direction-dependent contrast of the fibers
  - Low contrast of the fibers to the matrix
  - Displacement of and contacts between rovings
  - Resin-rich zones and locally variable fiber volume content



C8L 10µm fiber bundle segmentation result
C8L 1.75µm fiber segmentation result



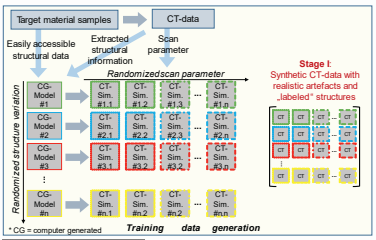

C8L 1.75µm fiber segmentation result slice with fiber segmentation result within fiber bundle

## Choice of material

A carbon fiber fabric and a glass fiber fabric were selected. This allows development and validation to be carried out on both different fiber materials and semi-finished product architectures. On the one hand, the mesoscopic structure (i.e. the shape in which the fiber bundles were interlaced / sewn) is of interest in a CF fabric or a GF fabric. On the other hand, the microscopic structures, in which the individual fibers within the fiber bundles are analyzed, are also of interest.

Example shown here:

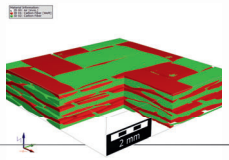
- Sample thickness 2.04mm
- Carbon fibers in epoxy resin matrix
- 8 layers of G-weave woven bundles
- Full fiber bundle contains 3000 fibers with 7µm diameter
- Fiber Volume Content 44.1 vol.-%




### Generation of synthetic CT-data with added artifacts

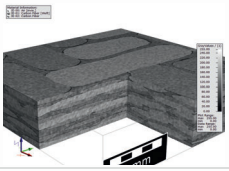
- Investigation of µCT-scans to classify artifacts based on the µCT-parameters
- Parameter space definition for generation of synthetic µCT datasets
- Randomization of structure and scan-parameters for different synthetic µCT-datasets
- Development of a simulation environment for the generation of synthetic CT data
- Generation of µCT-datasets with GeoDict using GeoApp "Generate Artificial CT"
- Simulative generation of a large number of synthetic training datasets
- Parameter space variation for training of different neural networks
- Addition of realistic device- and method-specific imaging artefacts
- Synthetic CT data can be generated in sufficient quality (fiber volume content difference between real and synthetic CT data is less than 5 percentage points according to the defined segmentation method)

User interface of macro used for this work




Synthetic C8L 10µm structure

Synthetic C8L 10µm artificial µCT image



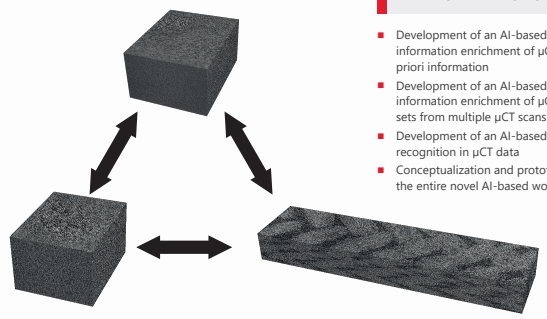

## GeoApps in this workflow

GeoApps are script-based application workflows included in GeoDict, using tools and modules available in GeoDict in combination with the possibilities of a script-based programming language to enable complex workflows, include new ideas and utilizing Python plug-ins for applied mathematical modeling.

The **Generate Artificial CT** app available in GeoDict creates a multi-material artificial CT based on the voxel geometry loaded in GeoDict.

The project-specific **Fiber Bundle Structure Generator** app creates carbon or glass fiber-plastic composites with different numbers of layers as well as fiber volume percentages.

C8L 1.75µm low-noise scan



C8L 1.75µm high-noise scan

C8L 10µm scan

Pairs of low- and high-resolution data combined with aligned overview data

### Artificial intelligence for object detection and Super-Resolution

- Development of an AI-based method for information enrichment of µCT data based on a priori information
- Development of an AI-based method for information enrichment of µCT data based on data sets from multiple µCT scans
- Development of an AI-based method for object recognition in µCT data
- Conceptualization and prototypical development of the entire novel AI-based workflow in GeoDict-AI
- Use both real and synthetic CT-data for training, testing and validation of AI for object detection
- Integrate a-priori information for identification of objects on different scales
- The a-priori-information could be used to simplify segmentation or to correct unrealistic results

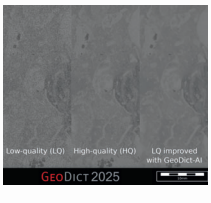
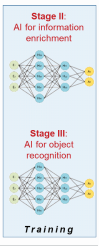



Image enhancement with GeoDict-AI




## GeoDict-AI

Functionalities in GeoDict that aim to reconstruct 3D models obtained from segmented computer tomography or FIB/SEM images of different multi-component materials, e.g. nonwovens and electrodes.

Provides the possibility of using Artificial Intelligence (AI) approaches for the separation of the different material during image segmentation.

Using the GeoDict structure generation modules to generate training data for the right parameter ranges to match the statistical properties for the considered materials.

Train and apply a custom neural network in GeoDict AI. A neural network can be trained to enhance the image quality.

## AI for the generation of simulation models for material development from CT data

In the research project, KI4MaterialModeling, funded by the German federal ministry of education and research, introduces an AI-powered workflow designed to enhance geometry model creation from µCT data, targeting both efficiency and accuracy to meet the needs of advanced material development.

The primary objective of KI4MaterialModeling is to develop a comprehensive, AI-based approach for generating precise geometry models from µCT data, with an emphasis on fiber-reinforced polymer composites as a representative case study. The methodology builds on three interconnected AI-driven components: (1) the generation of synthetic µCT data containing realistic imaging artifacts, (2) a specialized AI model for data enrichment that enhances µCT data quality, and (3) an AI-based object recognition system to identify structural features within µCT datasets. Together, these components form a cohesive workflow that advances current capabilities.

Highlights

- Fusion of synthetic geometry model generation and µCT image segmentation tools
- Object recognition on gray value images
- AI-based information enrichment
- Application of structurally complex fiber-plastic composites promises a broad transferability to other material classes


Supported by: Federal Ministry of Education and Research on the basis of a decision by the German Bundestag

**Funding:**

The project "KI4MaterialModeling" is founded by the BMBF (funding reference: 01IS23054A) and conducted in cooperation with Leibniz-Institut für Verbundwerkstoffe GmbH



**References:**

A. Grießer, R. Westerteiger, E. Glatt, H. Hagen, A. Wiegmann; Identification and analysis of fibers in ultra-large micro-CT scans of nonwoven textiles using Deep Learning; The Journal of the textile Institute (accepted 2022 with minor revisions)

GeoDict simulation software Release 2025, by Math2Market GmbH, Germany, doi.org/10.30423/release.geodict2025



Math2Market GmbH | Richard-Wagner-Str. 1 | 67655 Kaiserslautern, Germany
☎ +49 631 205 605 0 🖷 +49 631 205 605 99 ✉ digital-materials@math2market.de
WWW.MATH2MARKET.COM


MATH 2 MARKET