Deformation and the Change of Filtration Properties of Weaves - A Computational Approach

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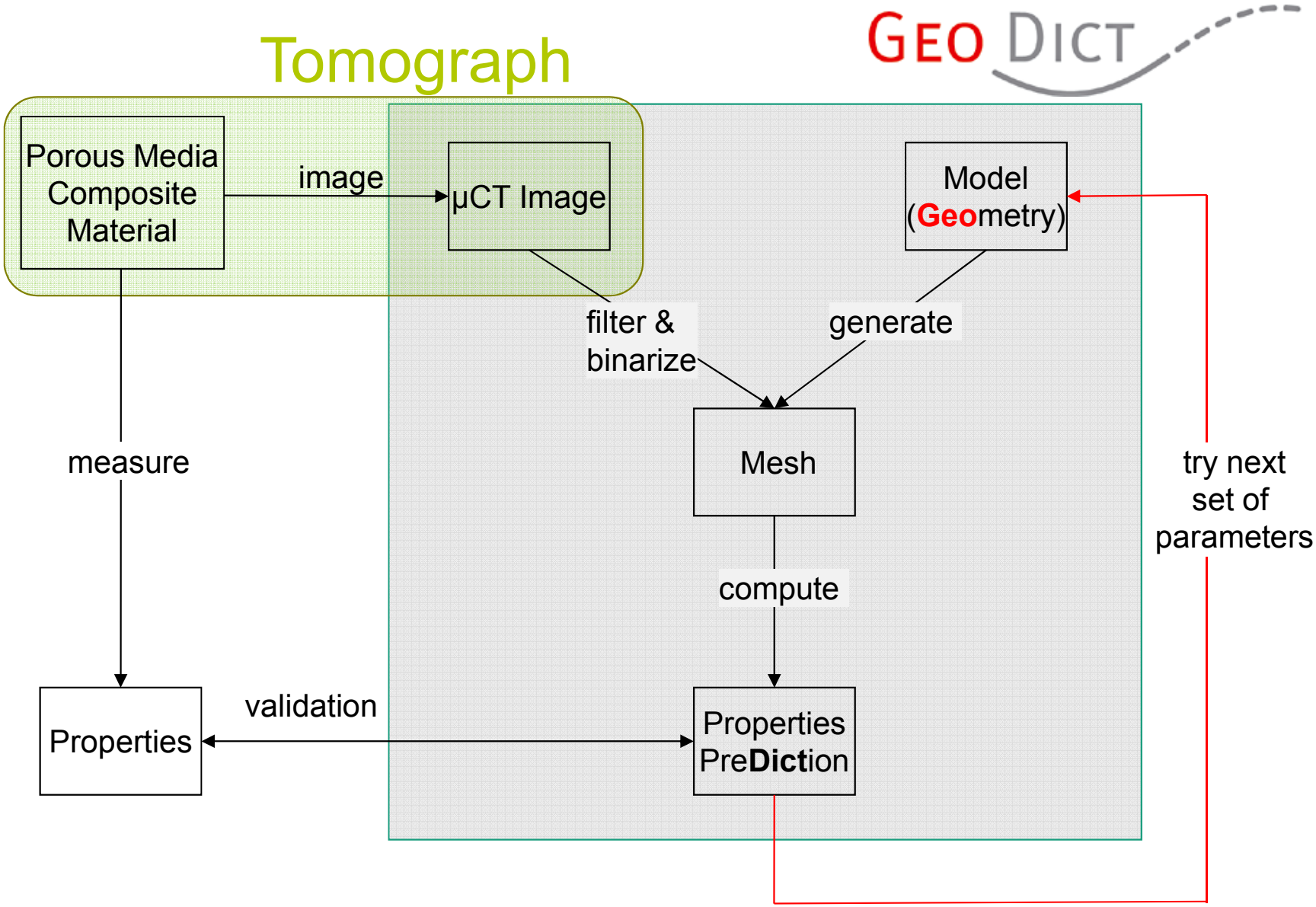
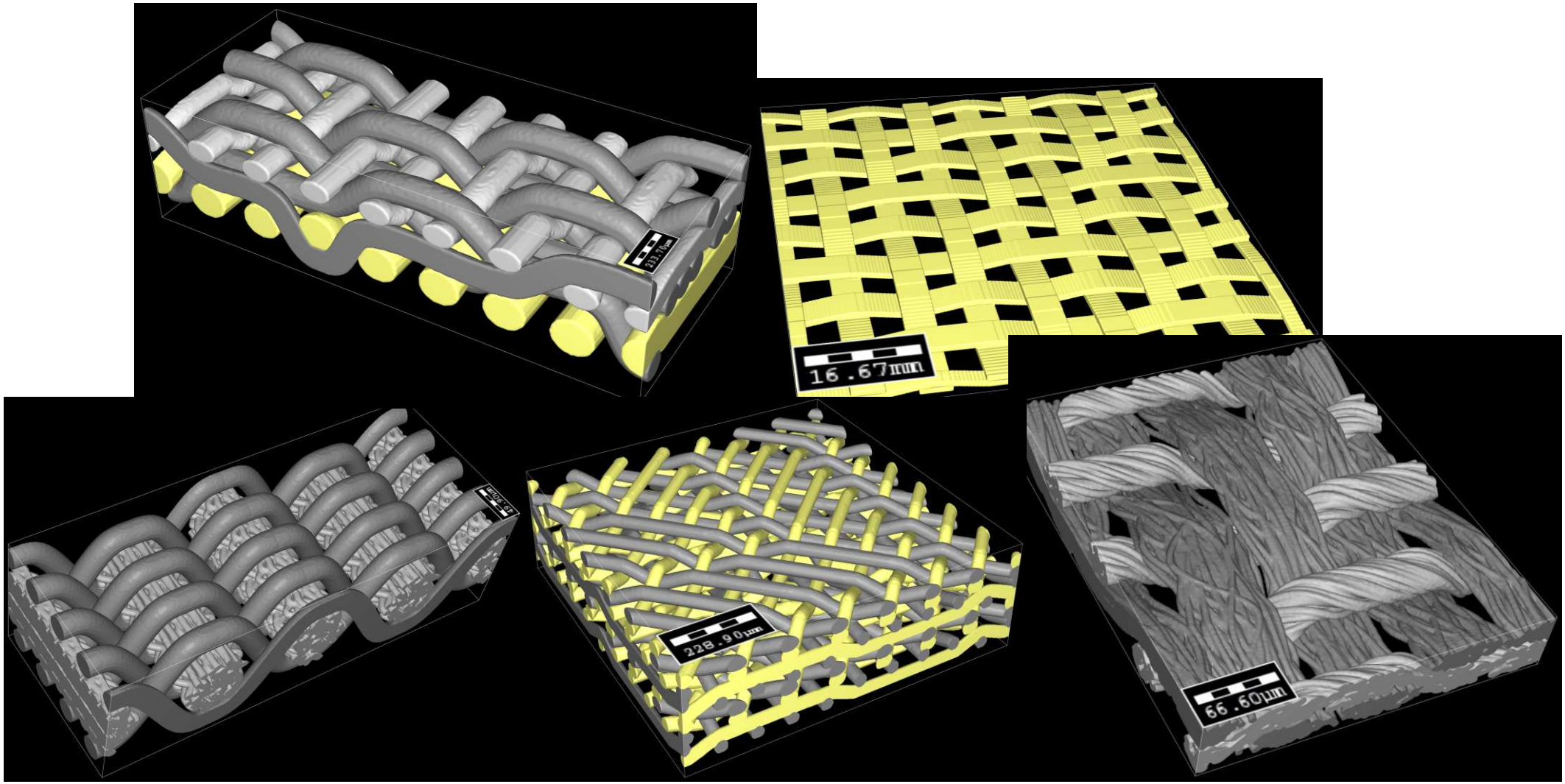
Outline

- Computing Material Properties with GEO DICT
- Structure Generation - WeaveGeo
- CFD Simulation - FlowDict
- Filtration Simulation - FilterDict
- Structural Mechanics - FeelMath
- Results
- Conclusions

Computing Material Properties with GeoDict



Structure Generation – WeaveGeo



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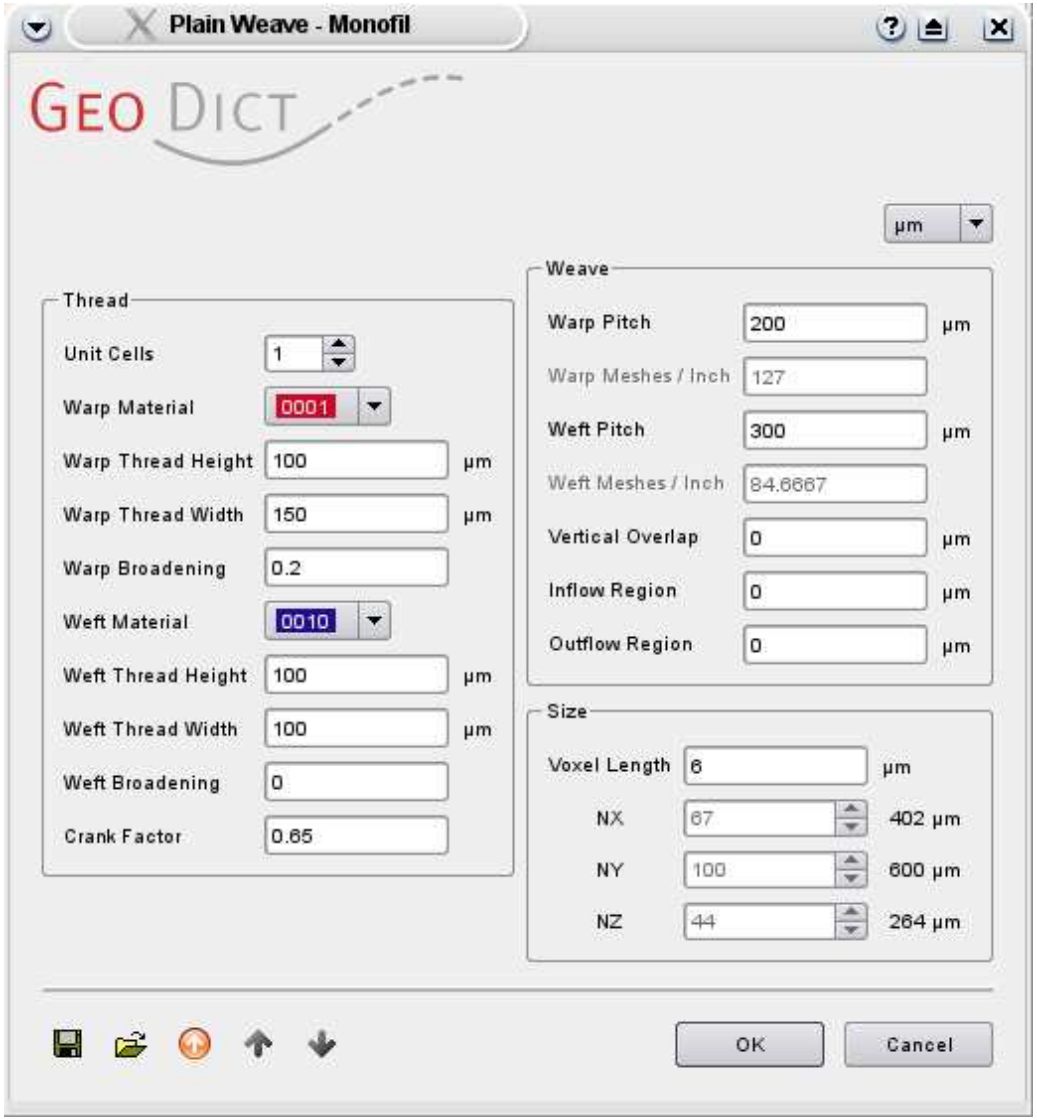
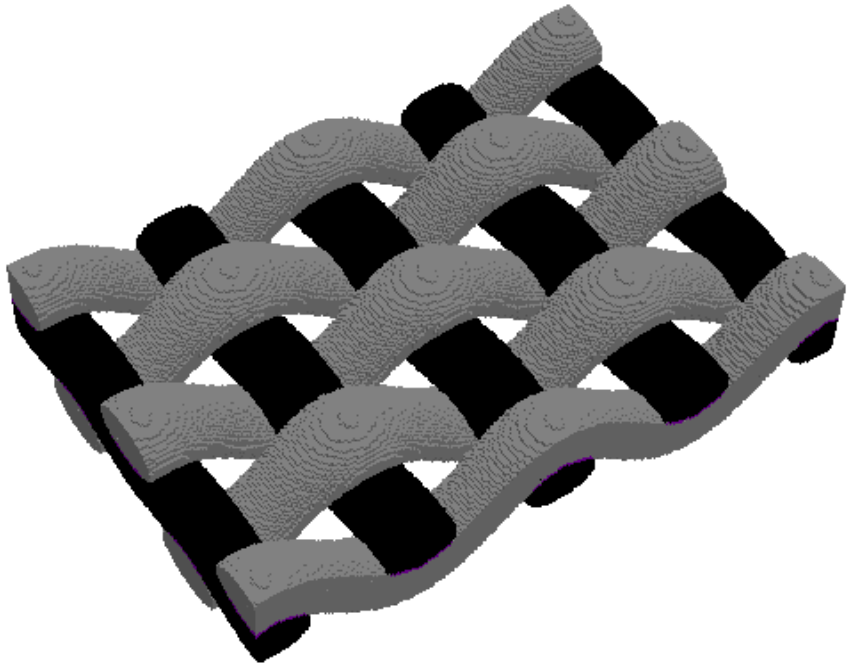
Structure Generation – WeaveGeo





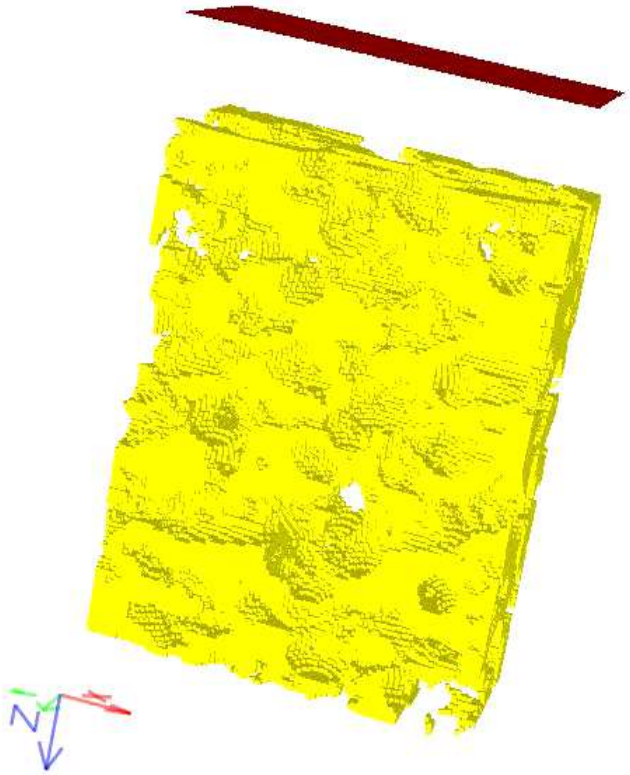
CFD Simulation - FlowDict

Navier-Stokes-Brinkman equations

$$
\begin{aligned}
-\mu\Delta\vec{u} + \nabla\vec{u}\cdot\vec{u} + \kappa^{-1}\vec{u} + \nabla p &= \vec{\mathrm{f}}, \quad \text{(momentum balance)} \\
\nabla\cdot\vec{u} &= 0, \quad \text{(continuity)}
\end{aligned}
$$

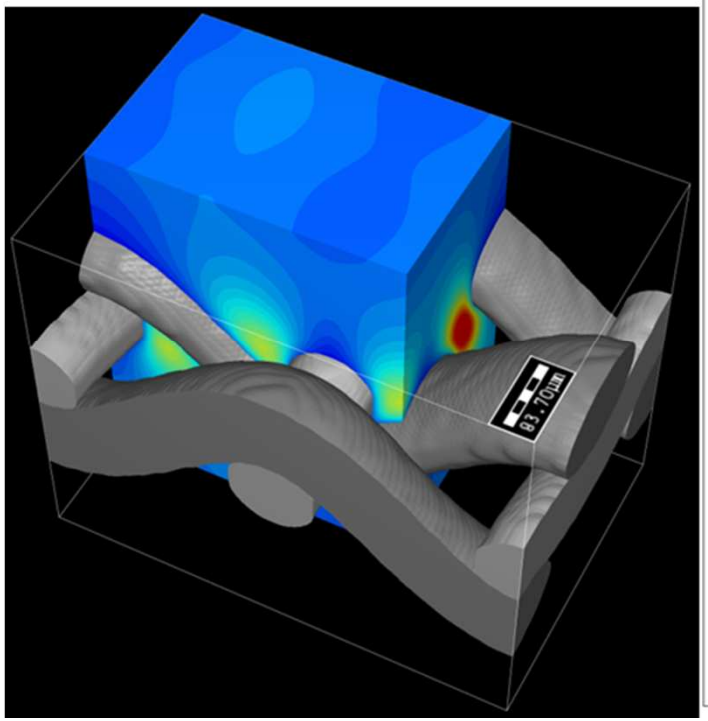
$+$ boundary conditions,

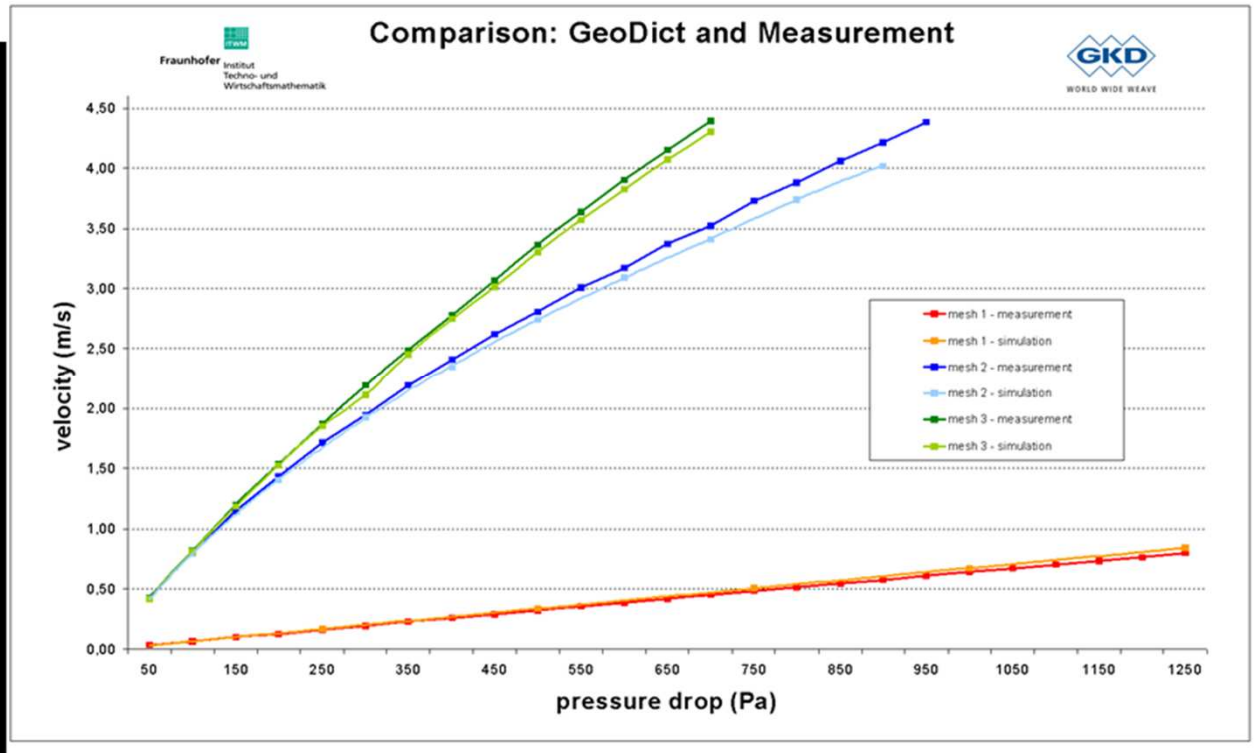
$\vec{u}$: velocity
p : pressure
$\vec{\mathrm{f}}$: force (density)
μ : fluid viscosity
κ : permeability of porous voxel



- Convective term -> optional for fast flows
- Brinkman term -> optional for porous media flows
- SIMPLE-type finite volume method optimized for huge voxel meshes

CFD Simulation - Validation





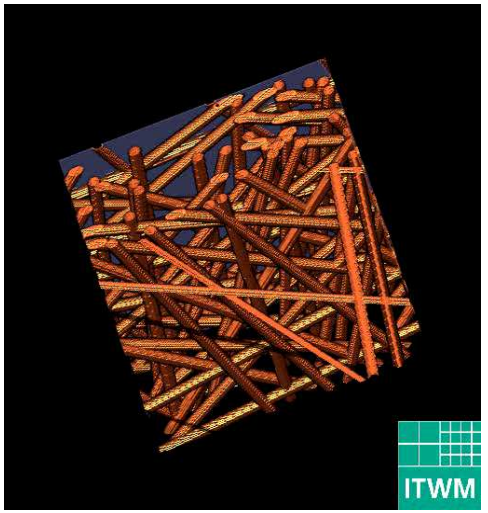
Filtration Simulation - FilterDict

OPTIMIZATION

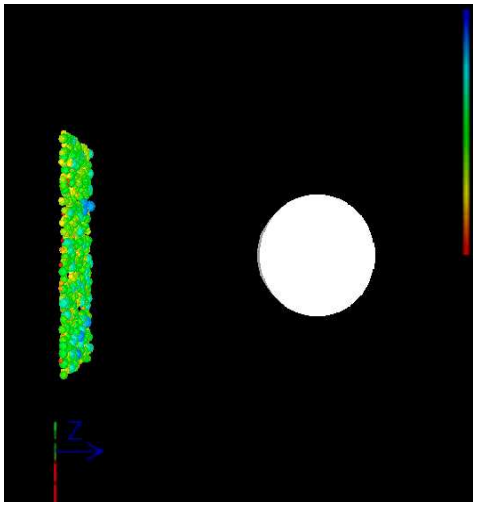
1. Choose initial structural parameters
2. Generate / modify structure
3. Solve CFD problem
4. Compute particle transport and deposition
5. Compute filtration efficiency and pressure drop
6. Choose new material parameters

LIFETIME

Flow



Single Fiber Simulation



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Filtration Simulation - FilterDict

Lagrangian Particle Transport

$$\frac{d\vec{x}}{dt} = \vec{v}$$
$$\frac{d\vec{v}}{dt} = -\gamma\left(\vec{v}(\vec{x}) - \vec{u}(\vec{x})\right) + \frac{Q\vec{E}_\circ(\vec{x})}{m} + \sigma\frac{d\vec{W}(t)}{dt}$$

Particle Deposition

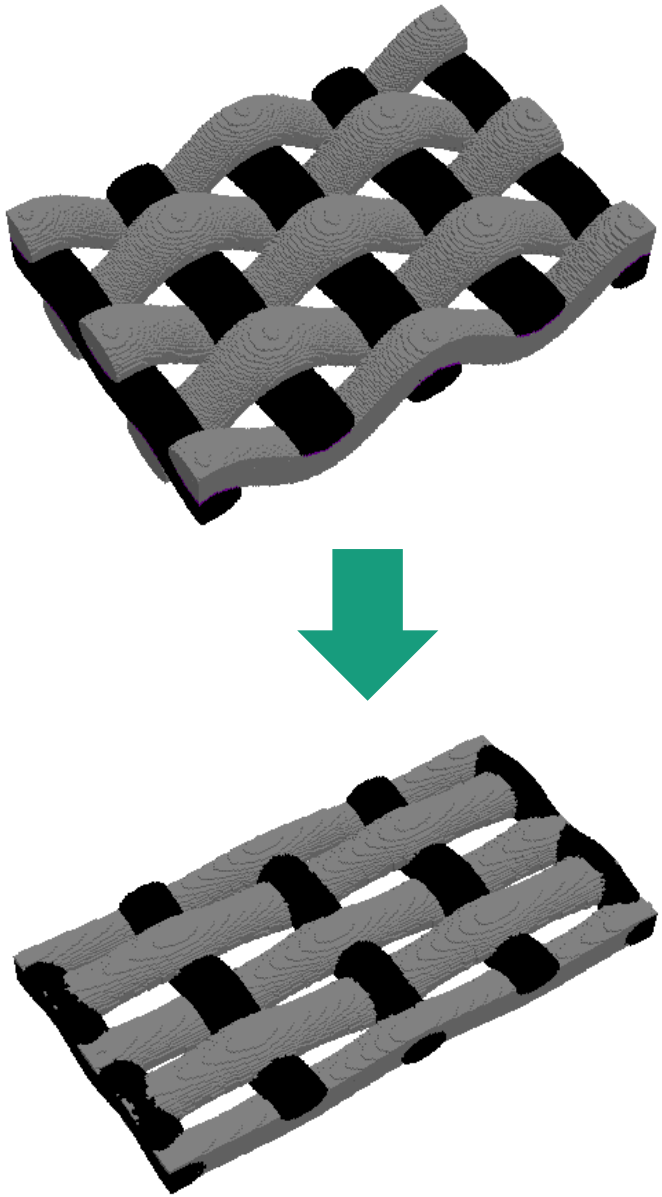
- Collision handling
- Adhesion model

Modification of Geometry

- Solid deposition model (particles resolved by voxels)
- Porous deposition model -> small particles are handled as porous media
- Porous deposition model + sub voxel collision handling

Structural Mechanics - FeelMath

- Use analytic description of fiber axis (GAD format)
- Use Simo beam theory [Simo85]
  - 6 degrees of freedom per node (3 displacements and 3 rotations)
  - Large displacements, rotations, and strains
- Introduce bond elements at crossing points as contact model
- Compute deformed structure
- Discretize to voxel mesh

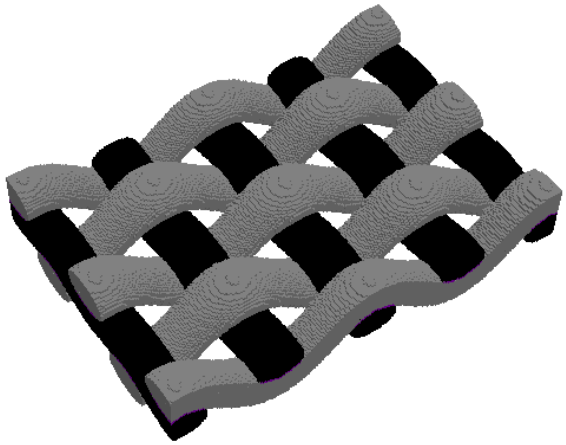


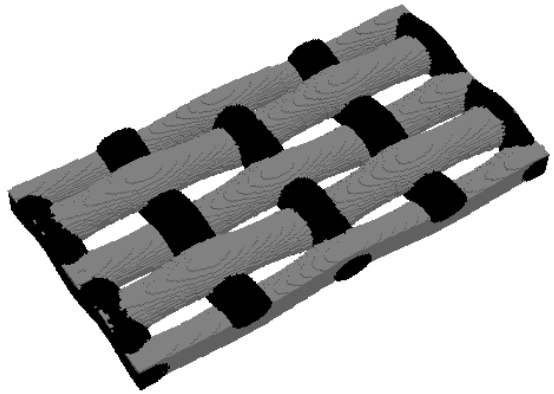
Current shortcomings

- Fibers may overlap after deformation
- Handling of cross-sections

Results - Deformation

- Use a plain weave
- Apply 30 % strain



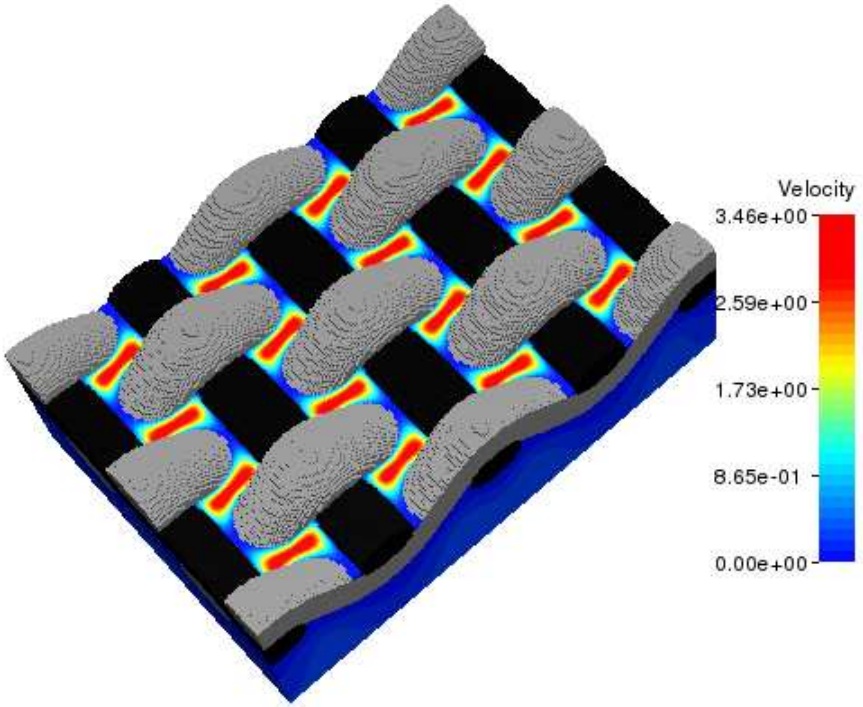


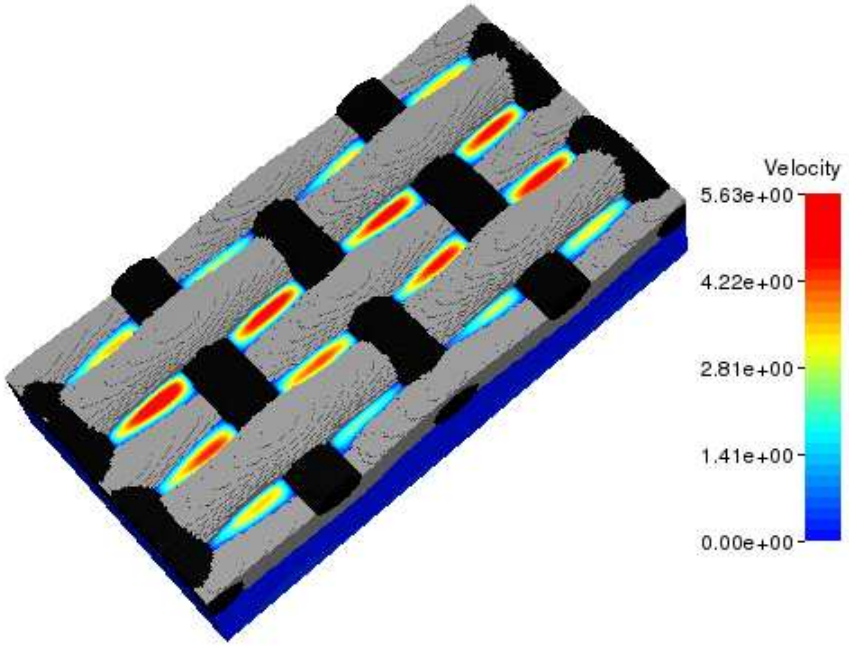
Geometrical observations

- Through pores initially being square developed a rectangular shape
- Maximum through pore diameter stays almost constant at 10 µm
- Medium is flattened

Results – CFD Simulation

- Apply pressure drop of 100 Pa across the medium
- Average velocity
  - undefomed case: 0.27 m/s
  - deformed case: 0.34 m/s





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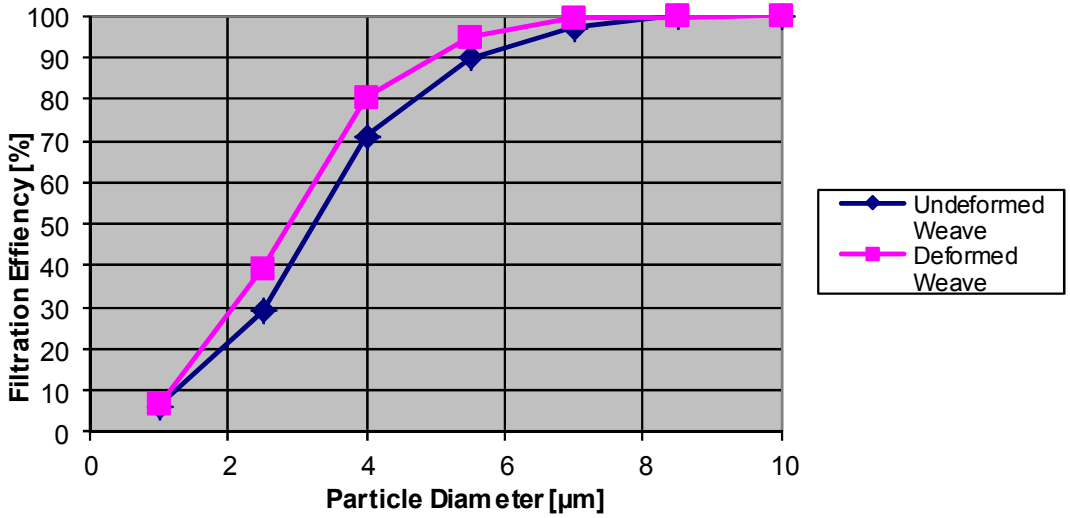
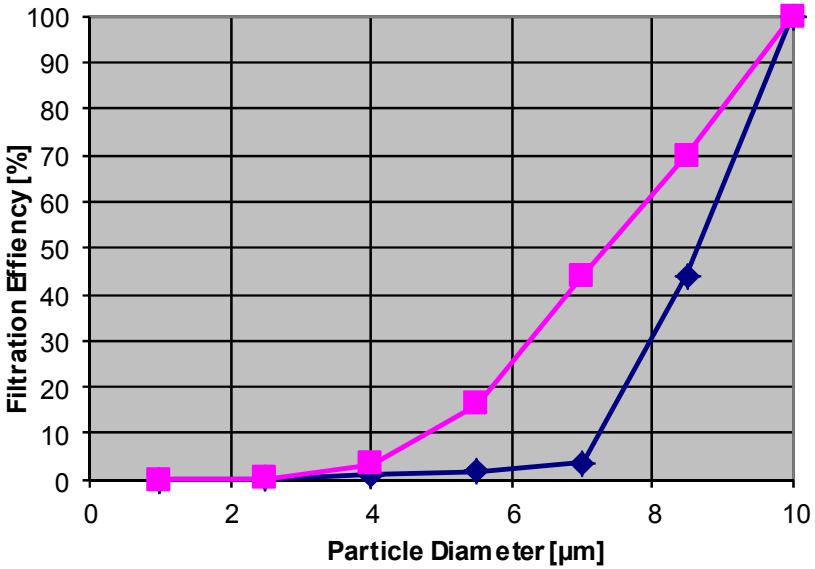
Results – Filtration Simulation

- Inflow velocity 0.1 m/s
- Compute initial filtration efficiencies



Caught On First Touch



Sieving

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Conclusions

- A simulation framework for the microstructure simulation of weaves is developed.
- The single steps are performed by the Fraunhofer software GeoDict and the modules WeaveGeo, FlowDict, FilterDict and FeelMath.
- The simulation chain starts from a fully resolved woven. Deformation, fluid flow and particle filtration is then computed.
- The innovation of this work consists in the presentation of the new elasticity solver and its application to woven filter media.
- The results can be interpreted consistently within the model.
- Our future work will focus on
  - quantitative validation of the models
  - model refinements (overlap, cross-section handling)
  - transfer the methods to other fields of application

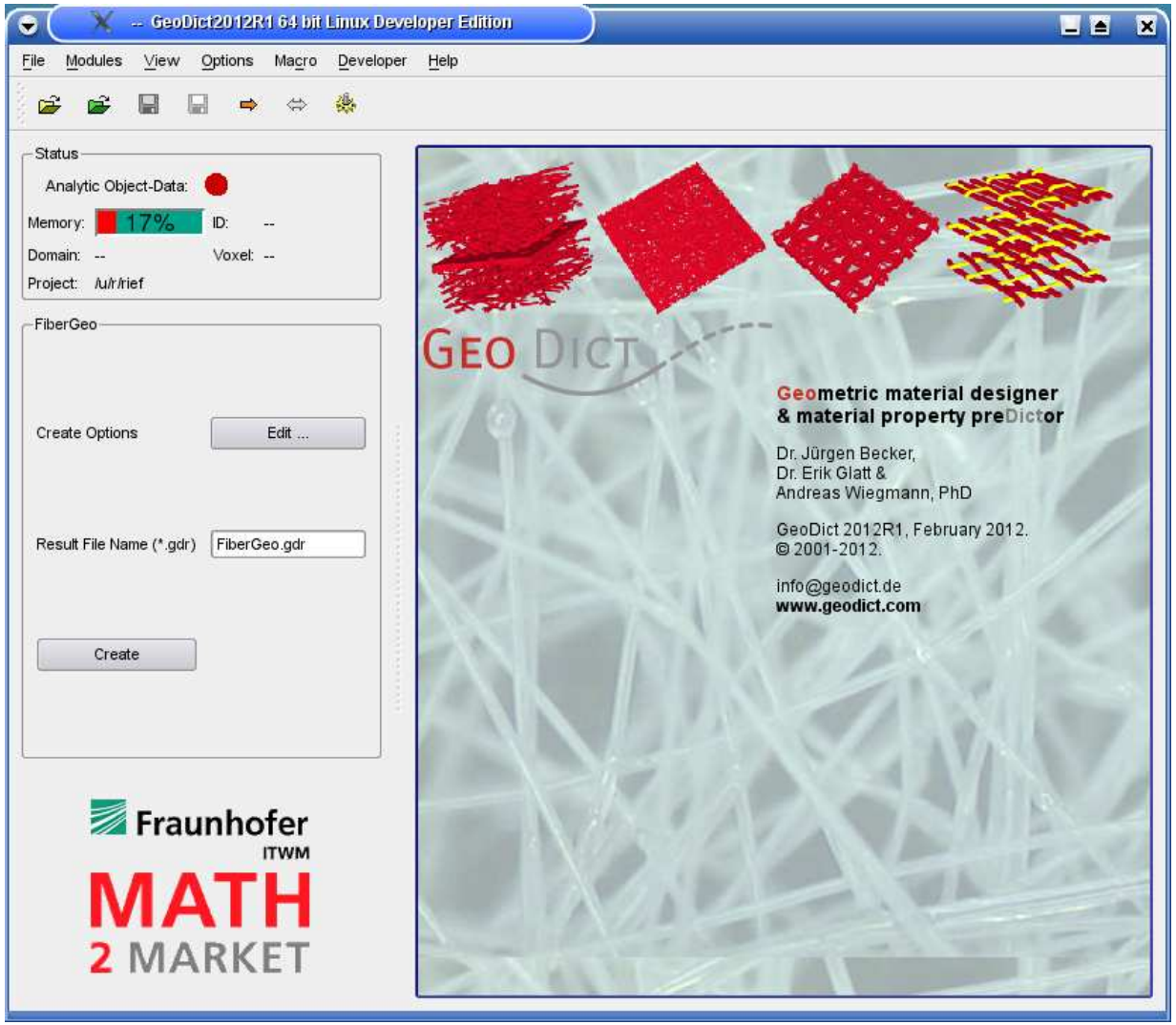
Thank You!

GEO DICT

Geometry generator, property predictor and virtual material designer

www.geodict.com

MATH 2 MARKET



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