Modeling Life Time and Dust Holding Capacity of Nonwoven Filter Media with GeoDict

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12. Symposium Textile Filter Chemnitz

MATH 2 MARKET

Math2Market GmbH

- Founded September 21 2011 in Kaiserslautern.
- Spin-off of Fraunhofer Institute for Industrial Mathematics ITWM.
  Located in the Business and Innovation Center in Kaiserslautern.
- Business based on GeoDict software formerly developed by ITWM.
  Continued close cooperation with ITWM on algorithms.

GEO DICT

- GeoDict® exists since 2001,
  first sales in 2003, first sales for filtration (FilterDict® module) in 2005.
- The intellectual property rights to the GeoDict software belong to
  Math2Market GmbH since January 1, 2013.

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Outline

1. General approach: the virtual material lab
2. Import of CT data
3. Creating realistic 3D structure models
4. Simulation of filter life time and dust holding capacity

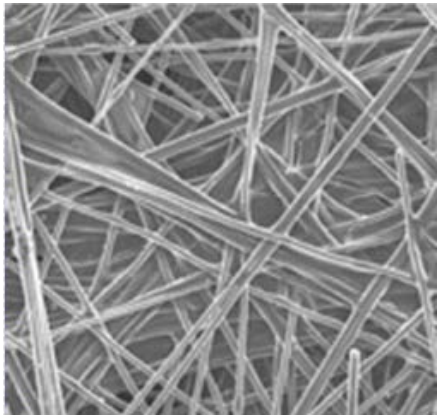
1. General Approach: The Virtual Material Lab

The Virtual Material Lab Approach:

The Virtual Material Lab Approach:

Experiment / Lab

Filter Material



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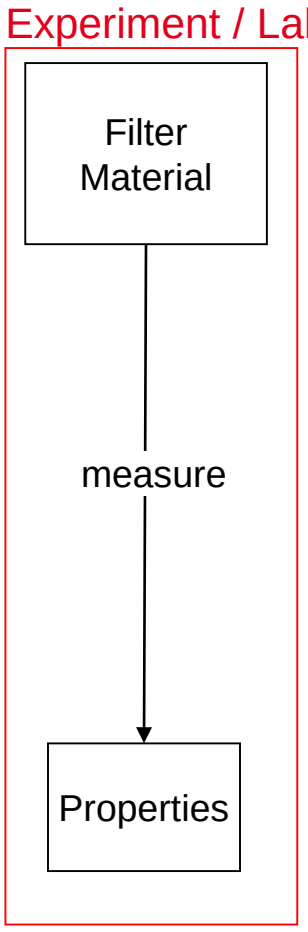

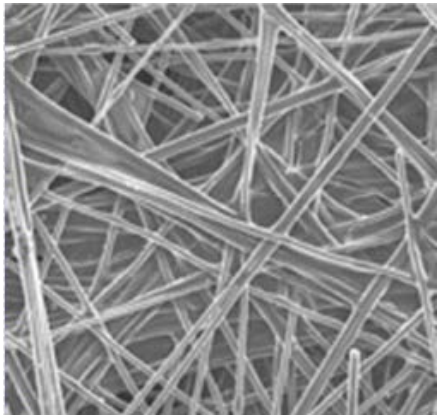

Properties are:
- pore size distribution
- filter efficiency
- filter capacity
- effective stiffness
- …

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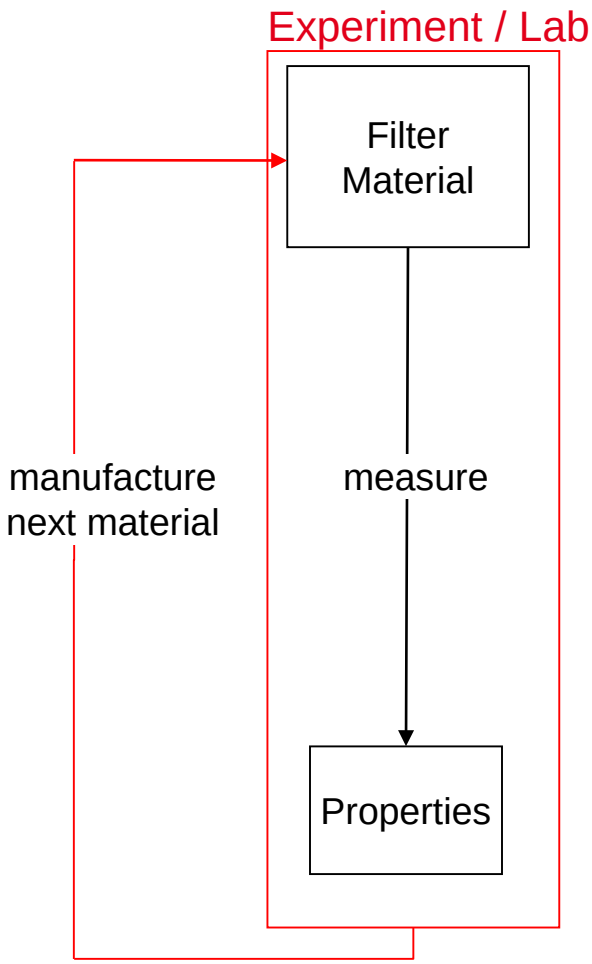

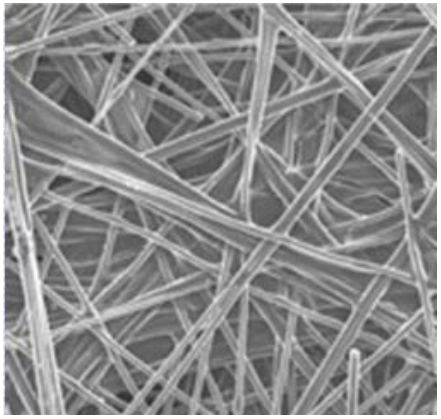

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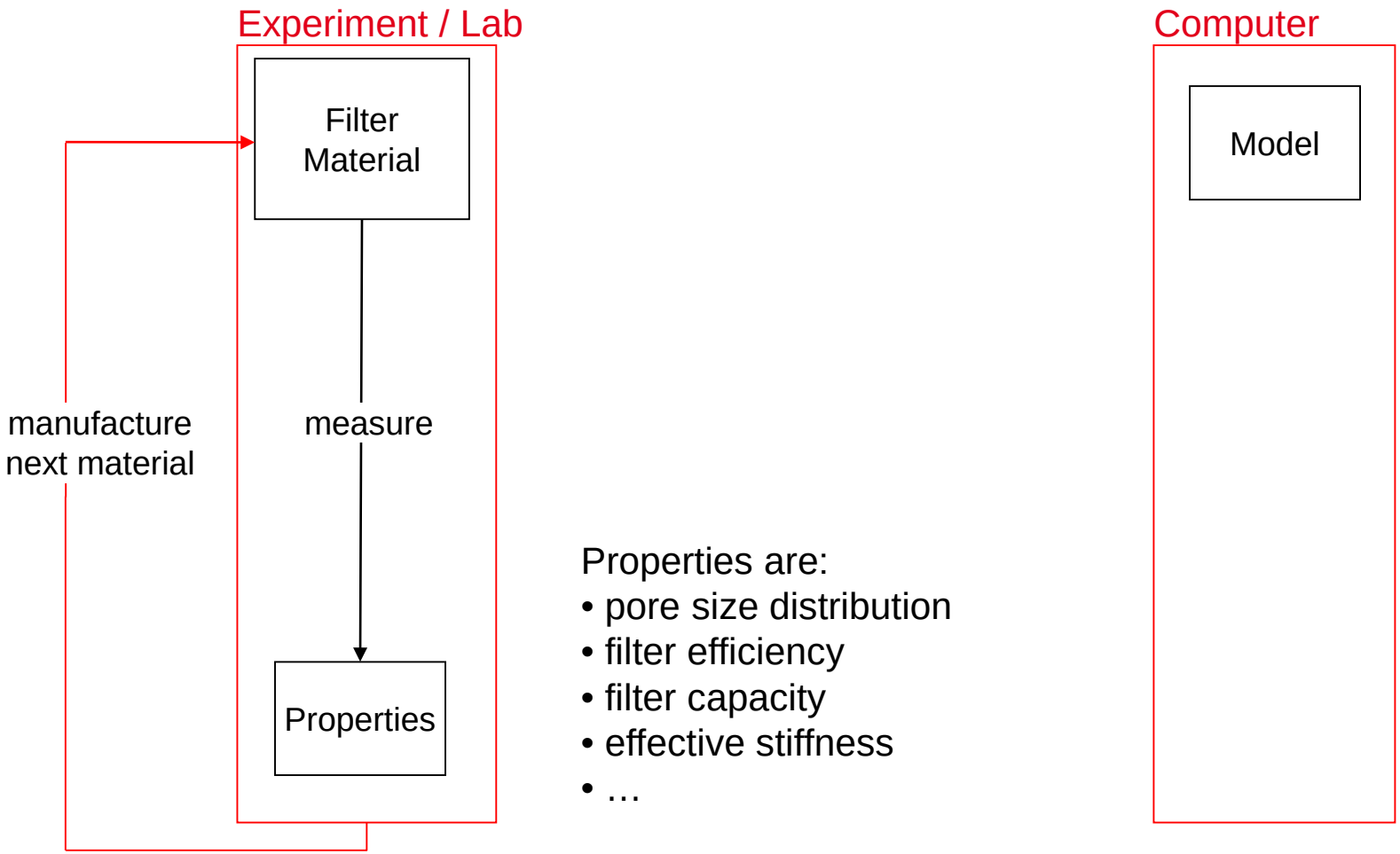

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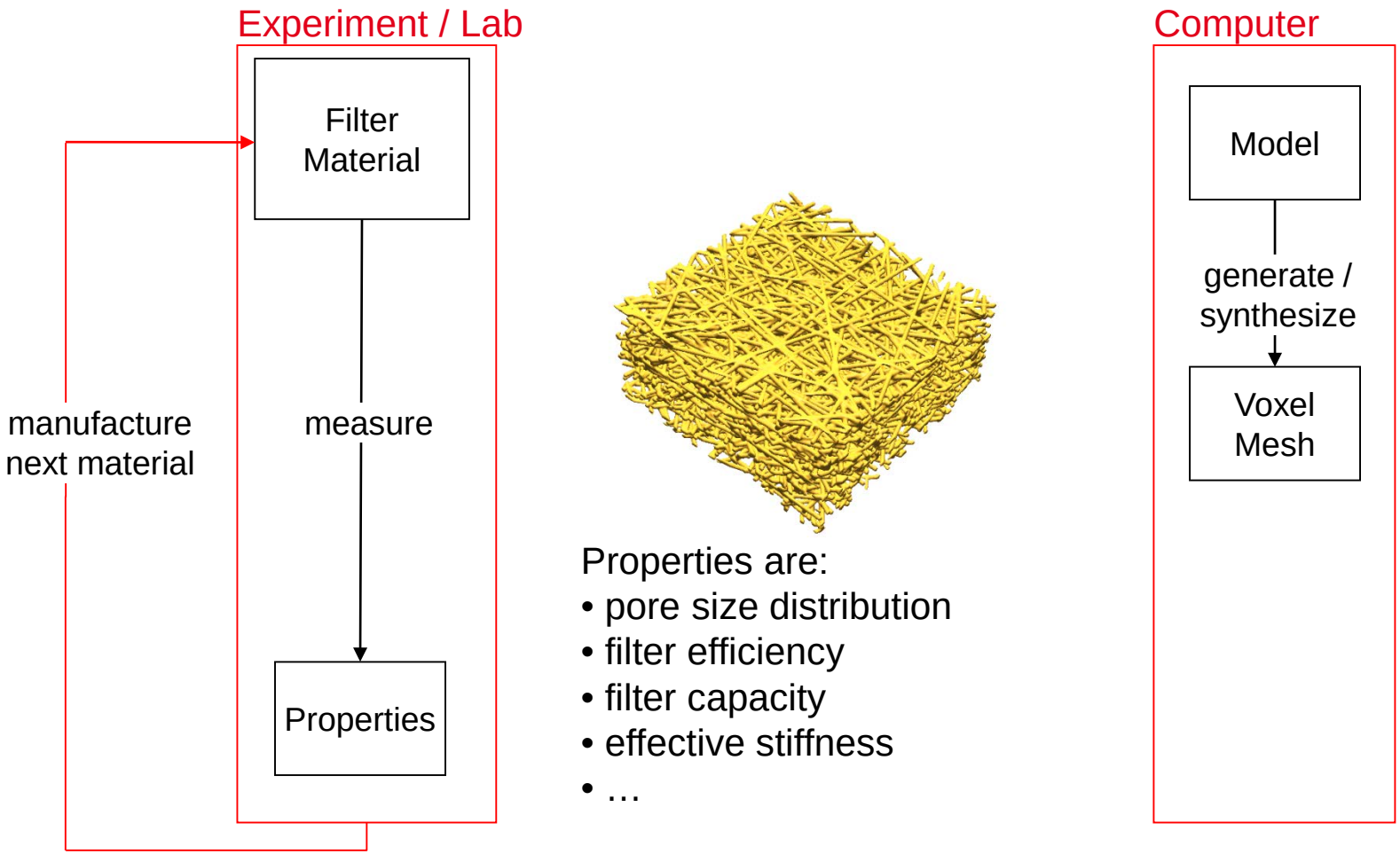

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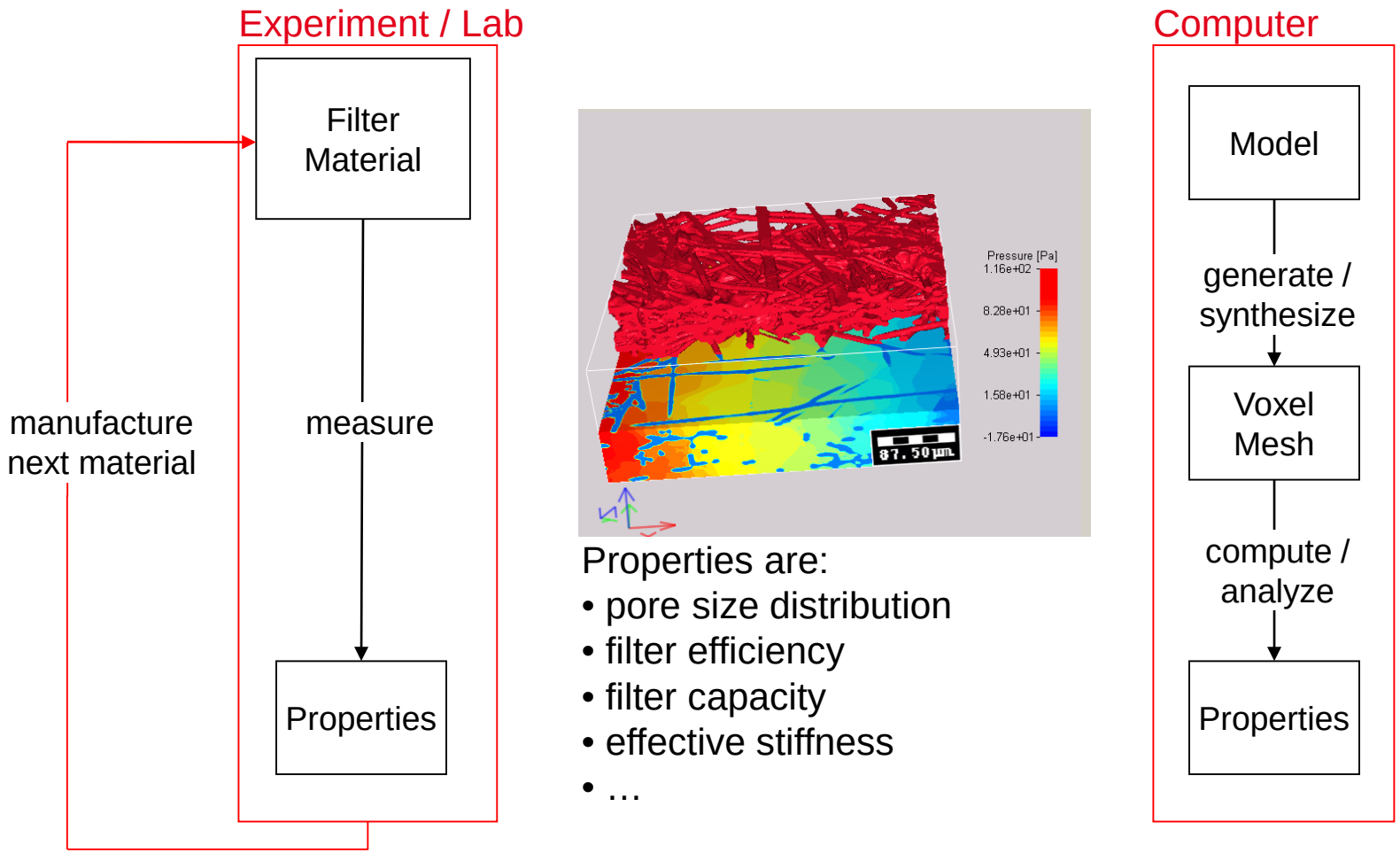

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The Virtual Material Lab Approach:

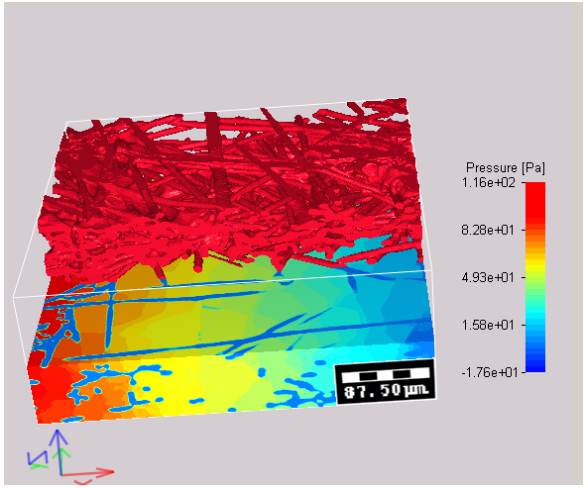
Experiment / Lab

Filter Material

measure

Properties

manufacture next material



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Computer

Model

generate / synthesize

Voxel Mesh

compute / analyze

Properties

try next set of parameters

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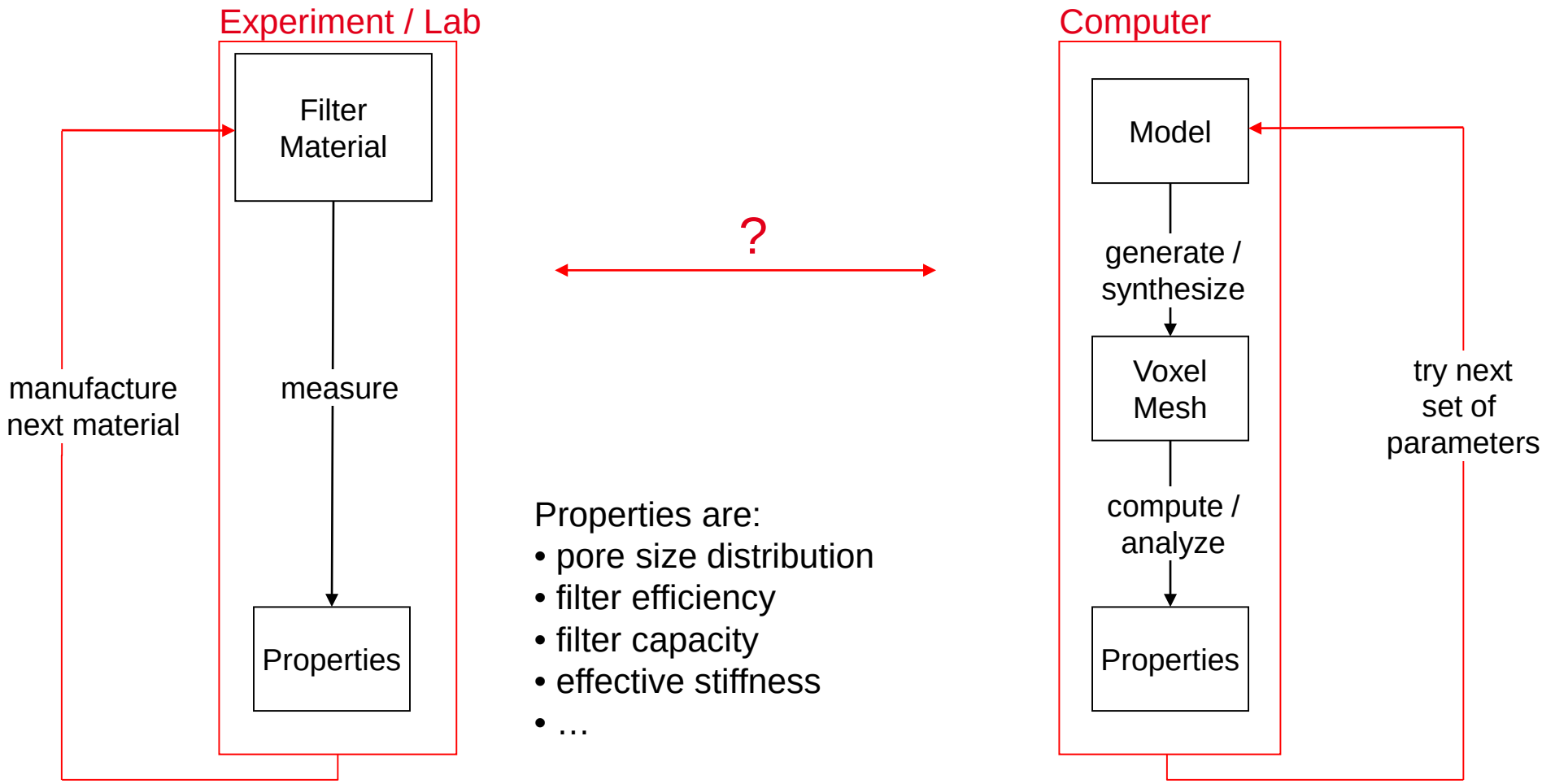

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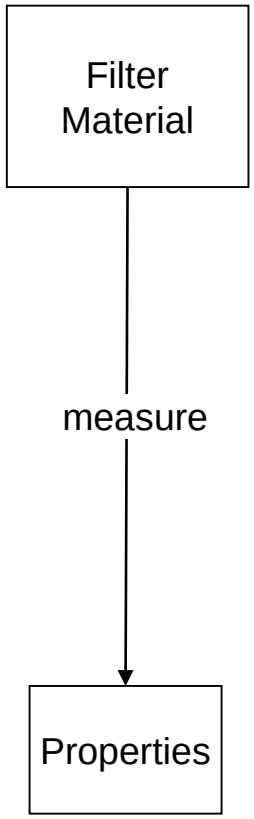
Analysis or Property Computations



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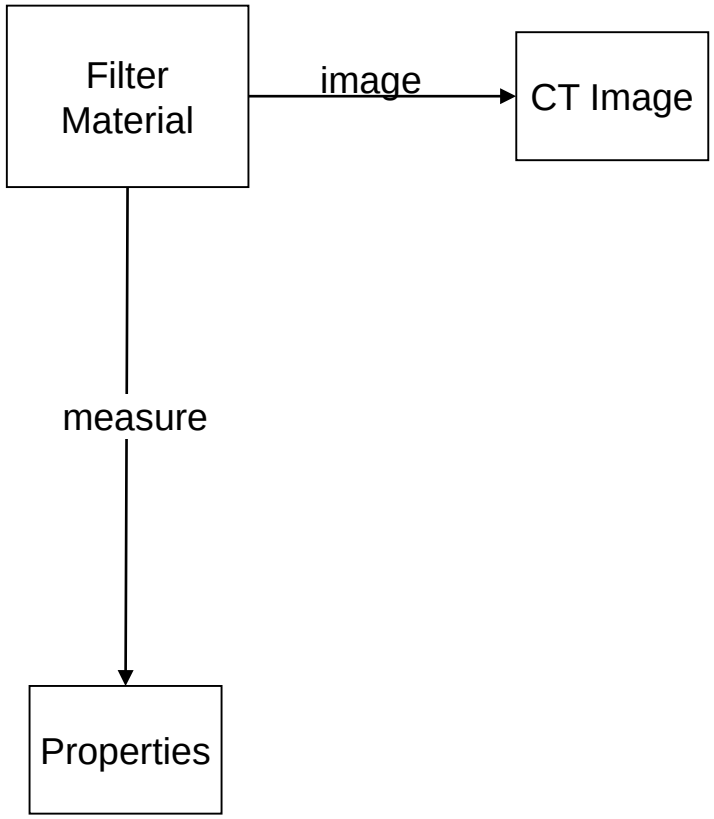

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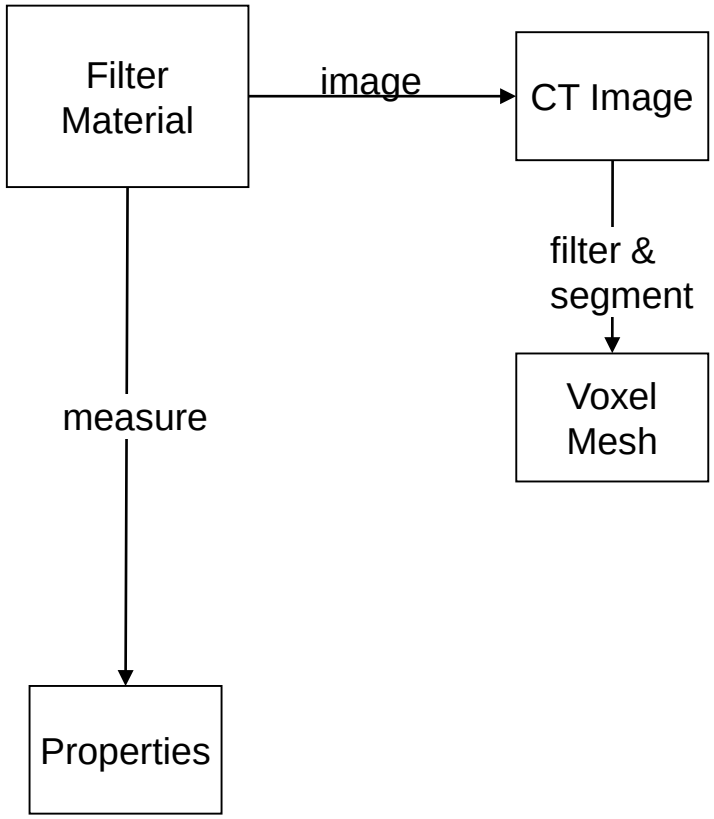

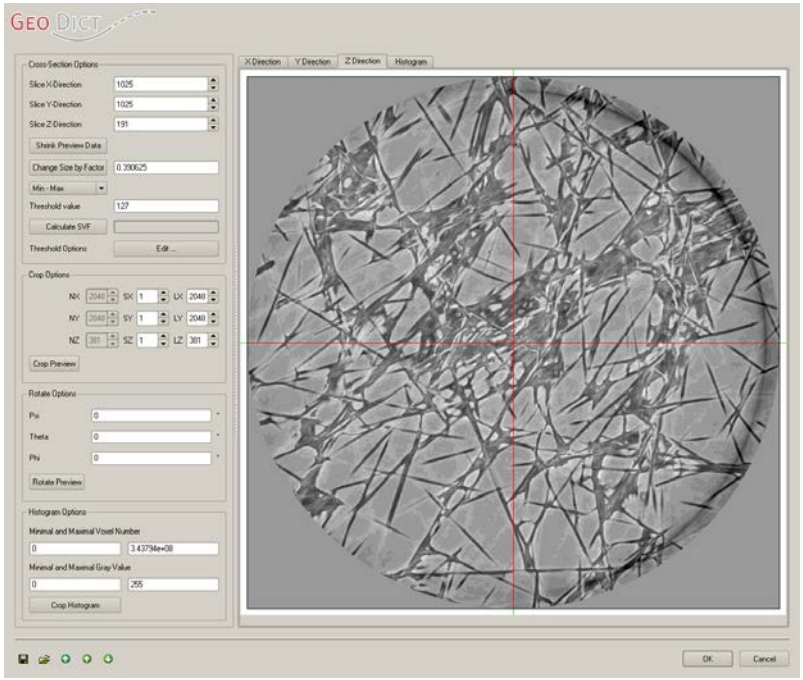

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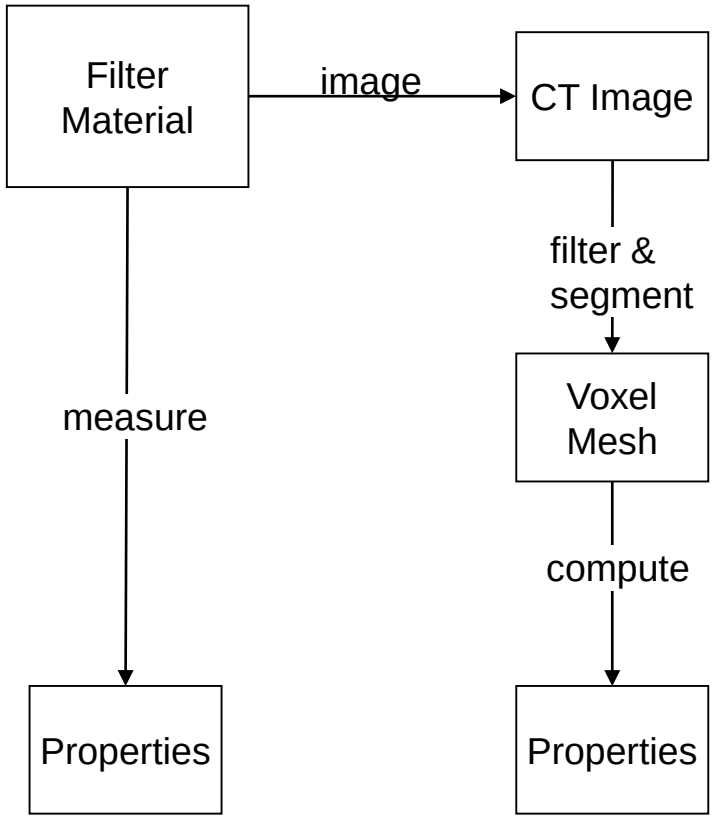

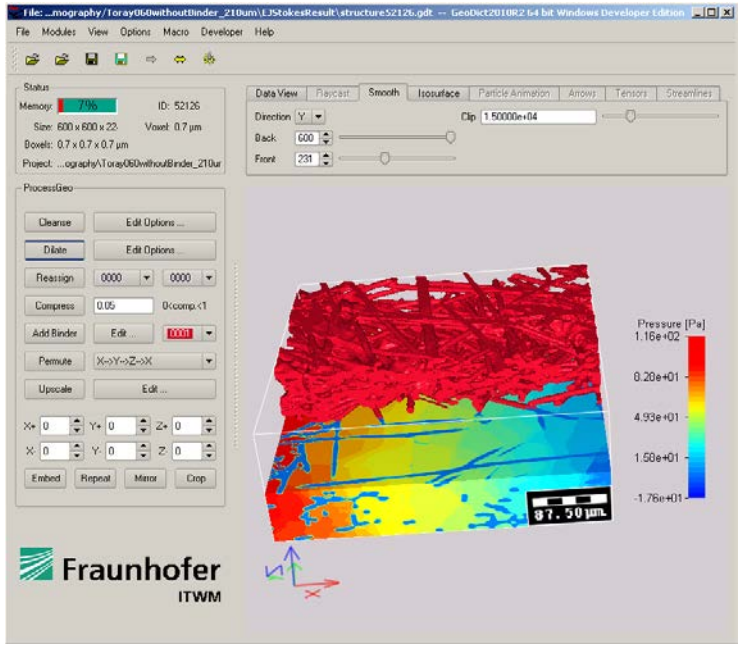

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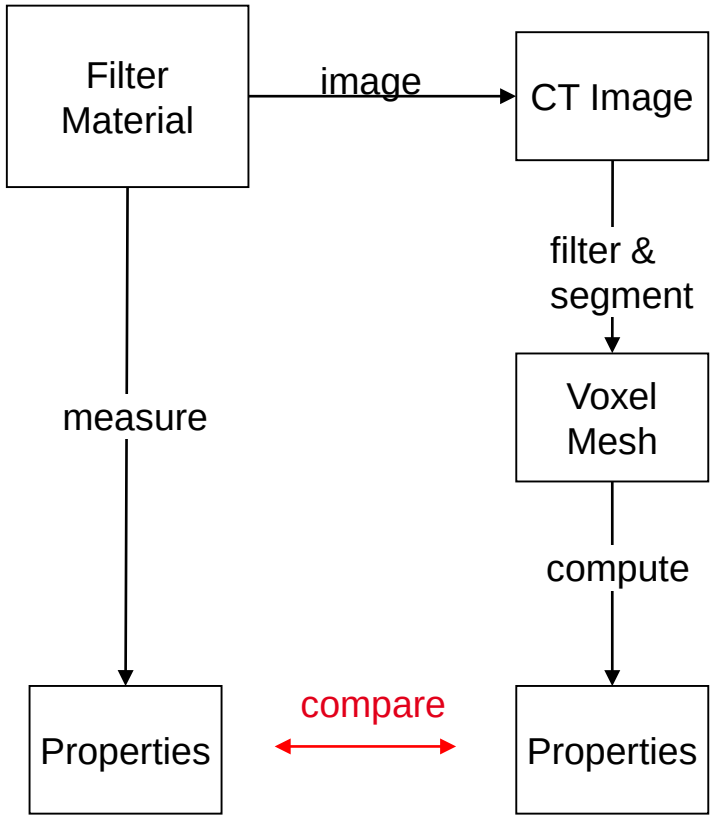

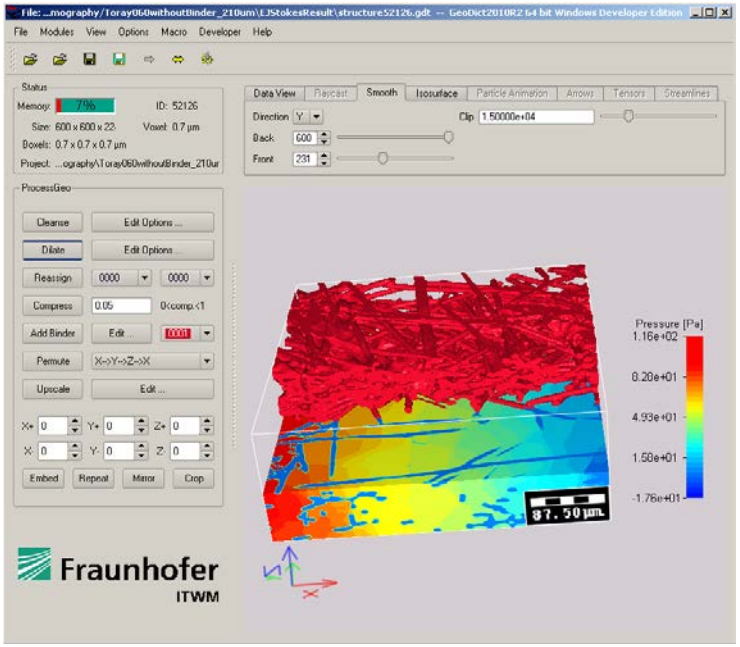

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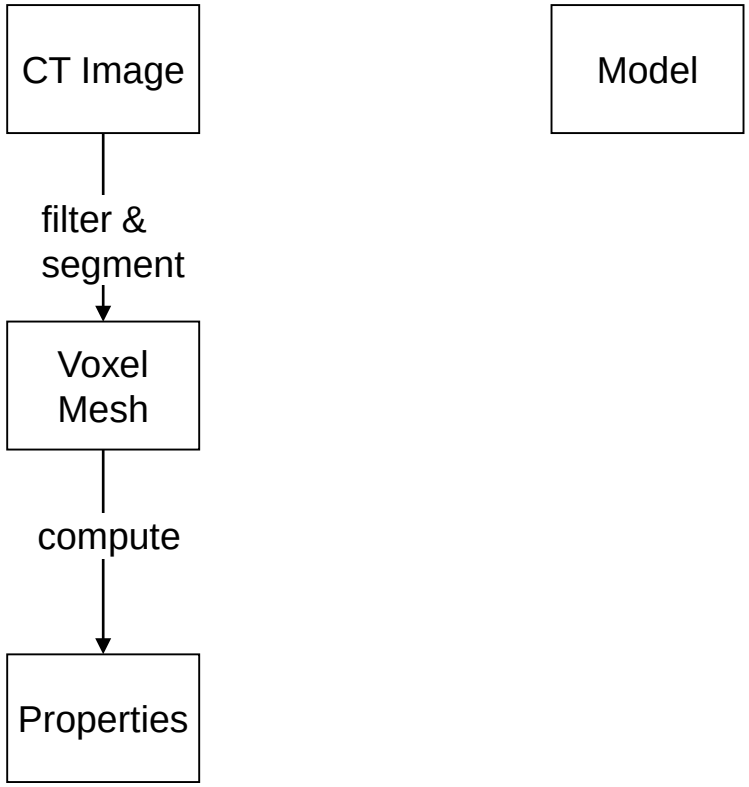

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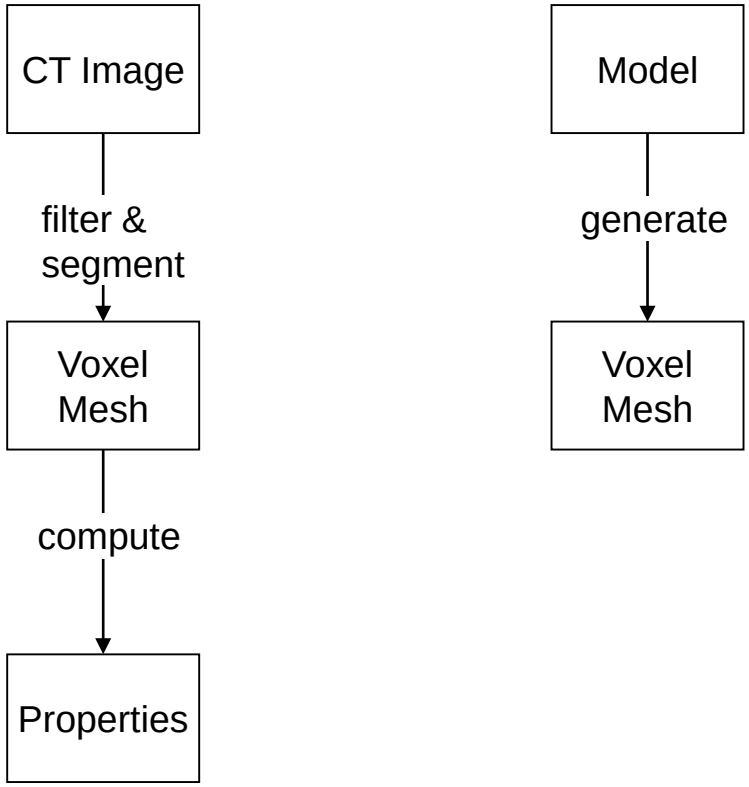

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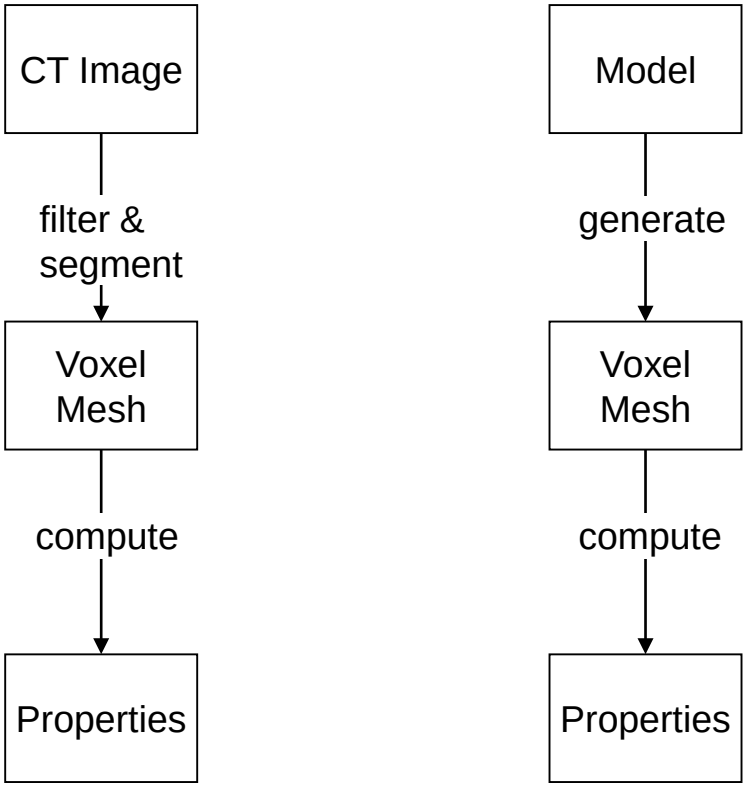

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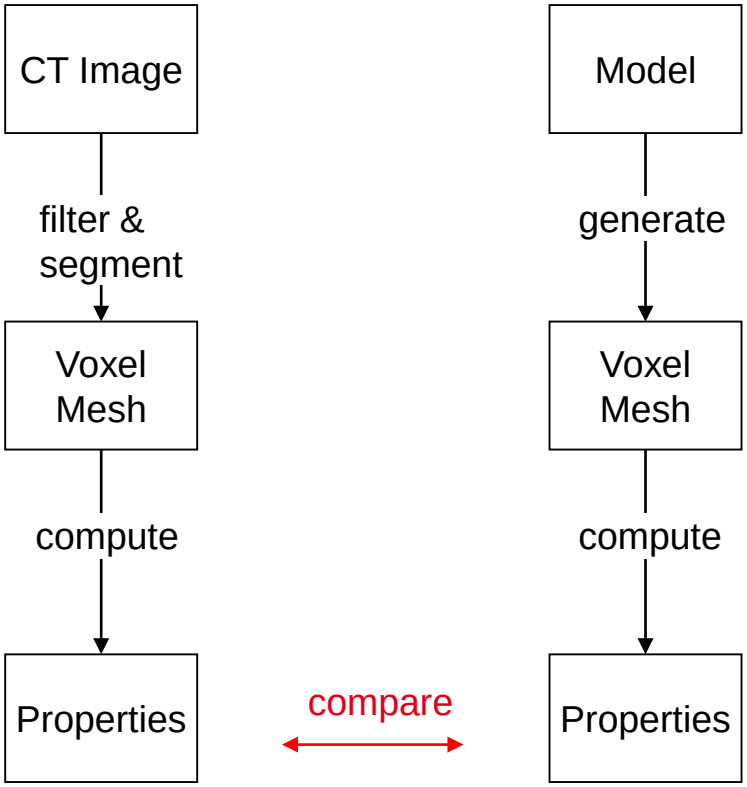

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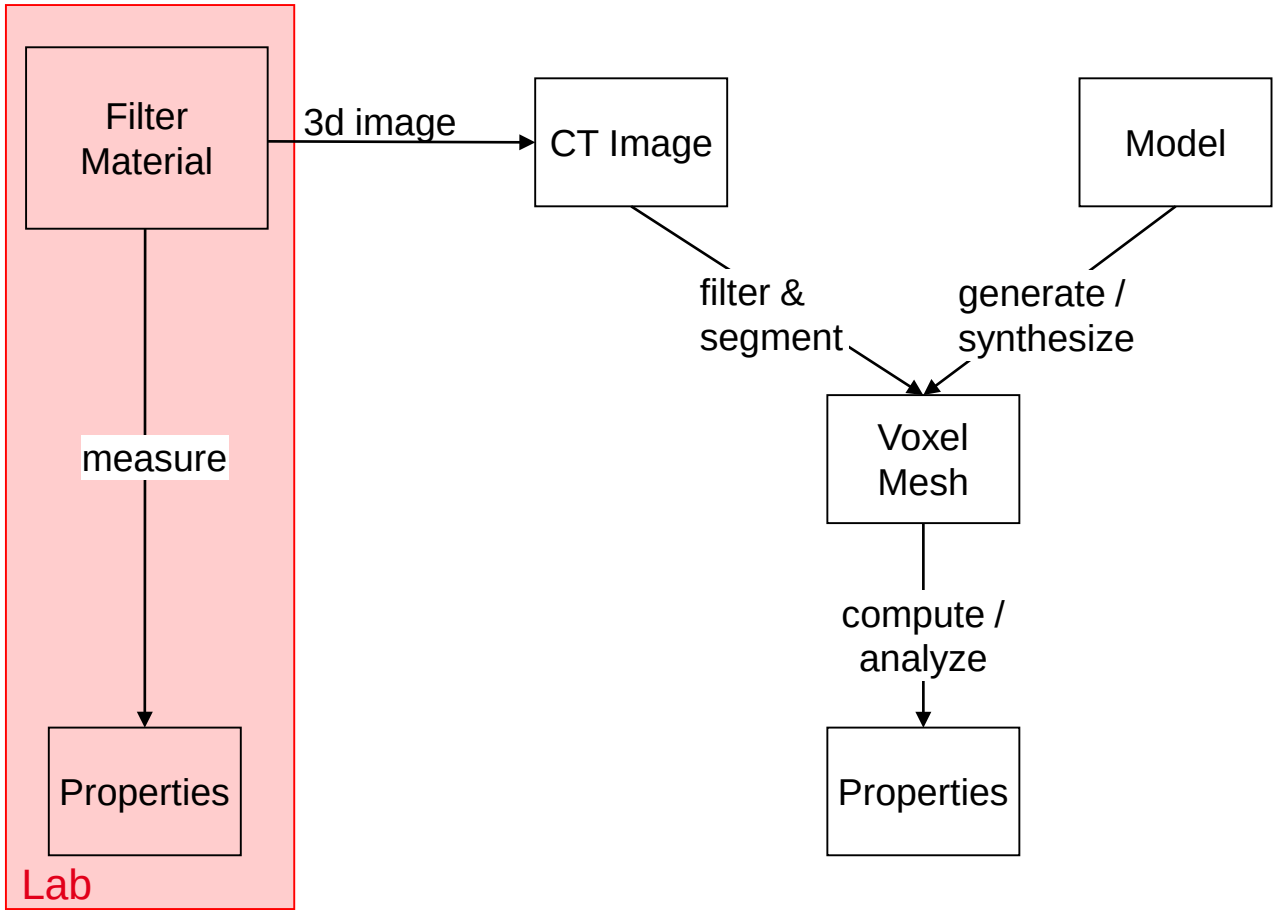

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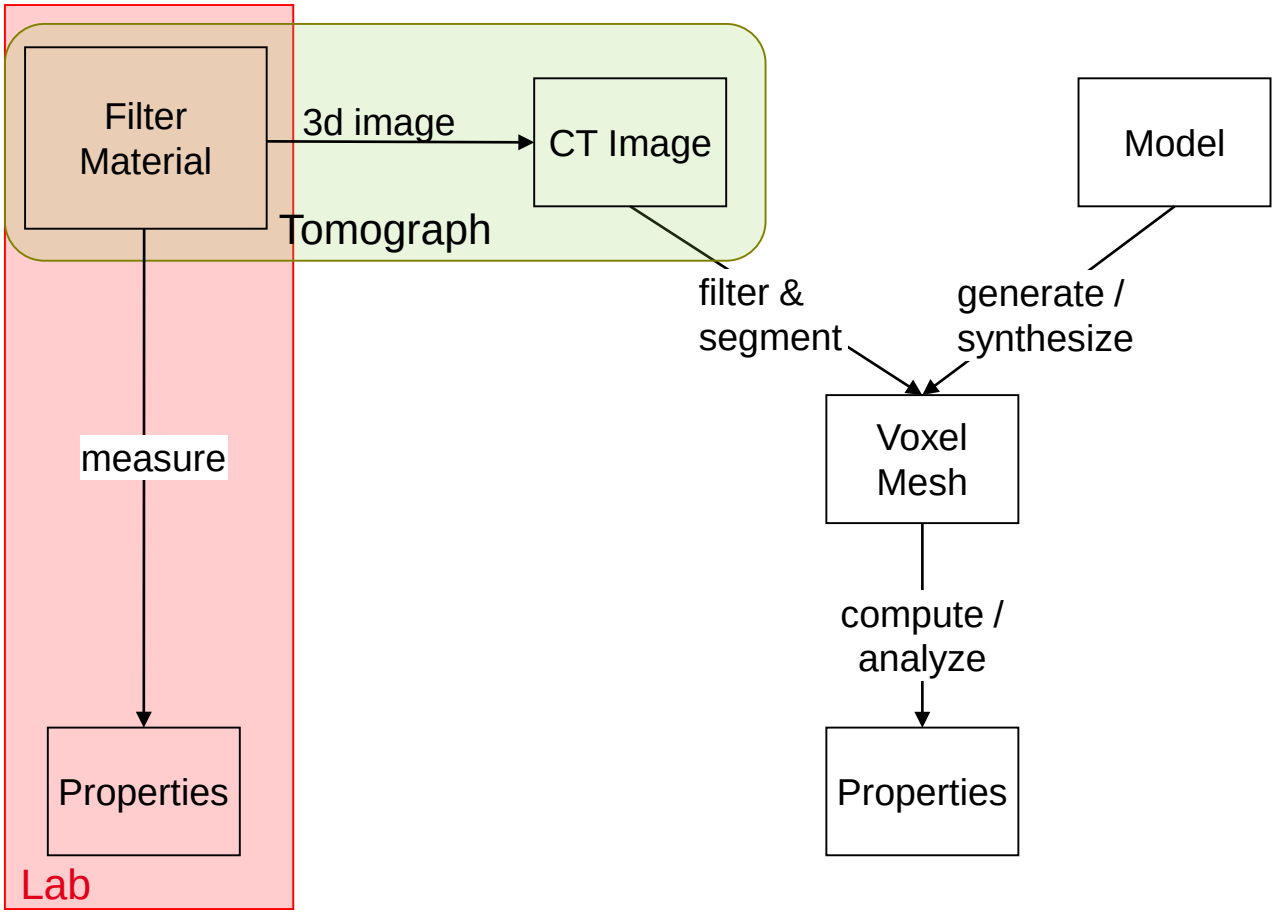

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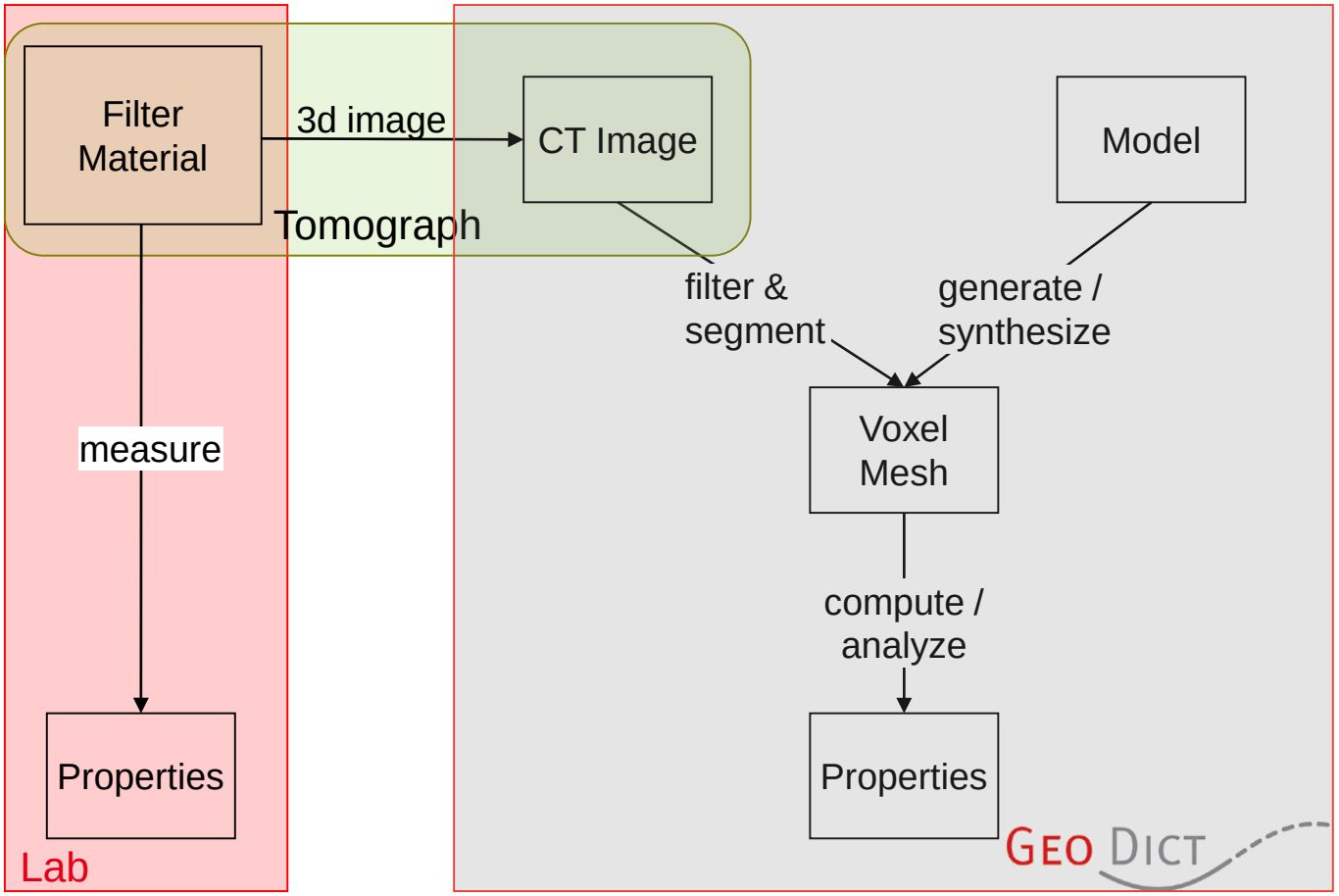

2. Import of CT Data

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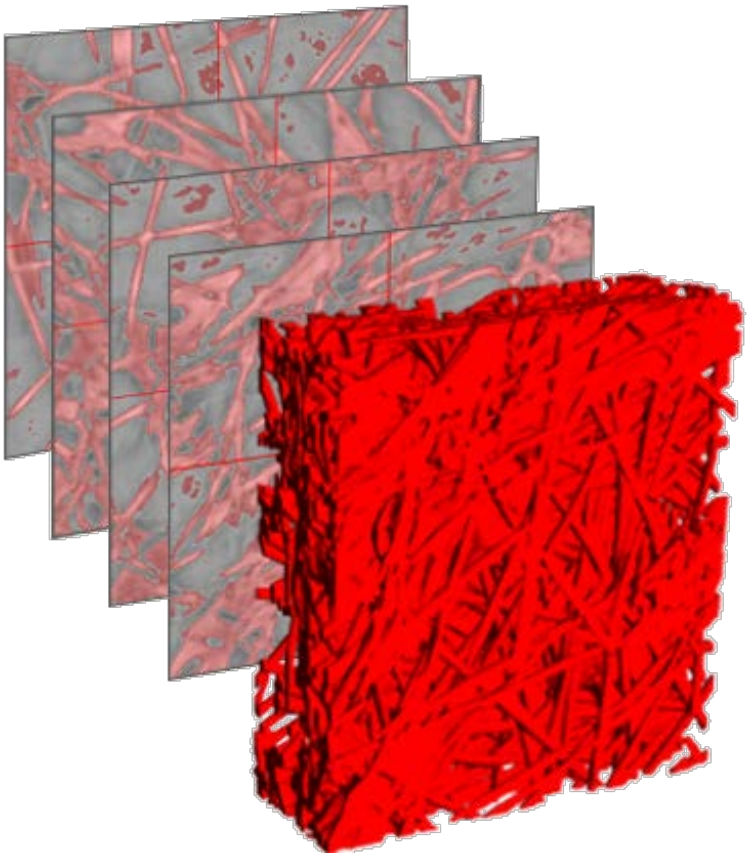
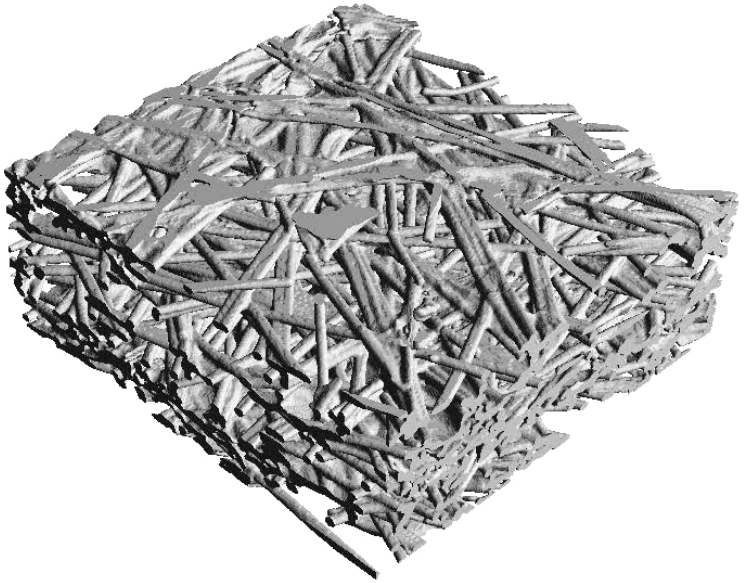




Simulation on CT Images

(+) Allow simulations on real filter structures

(-) Modifications of the filter structure are not possible

Aim: create a model that mimics the tomography first,
then modify it to find structures with enhanced properties!

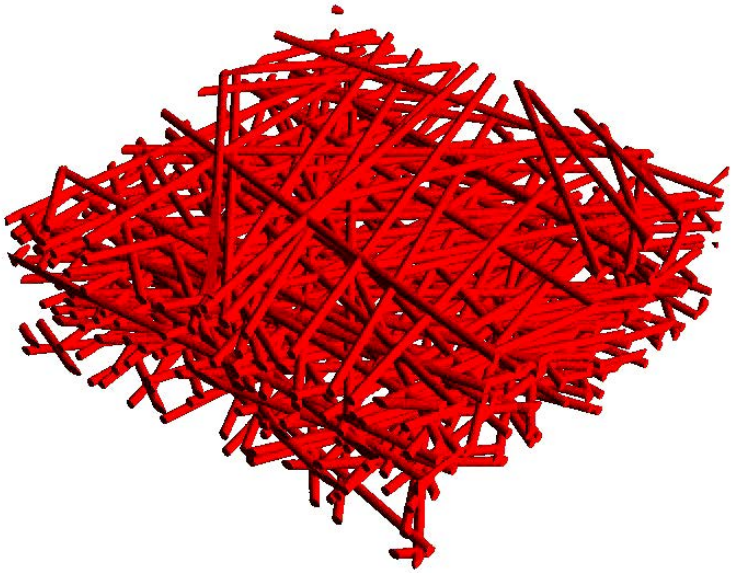
In this presentation: because of confidentiality, the filter structure used for the simulations does not mimic a specific filter media.

3. Creating Realistic 3D Models

Creating 3D Structure Models

Input parameters needed (straight fibers):

- Porosity
- Fiber type: cross sectional shape, diameter, length
- Fiber orientation tensor
- Thickness (height) of the filter media



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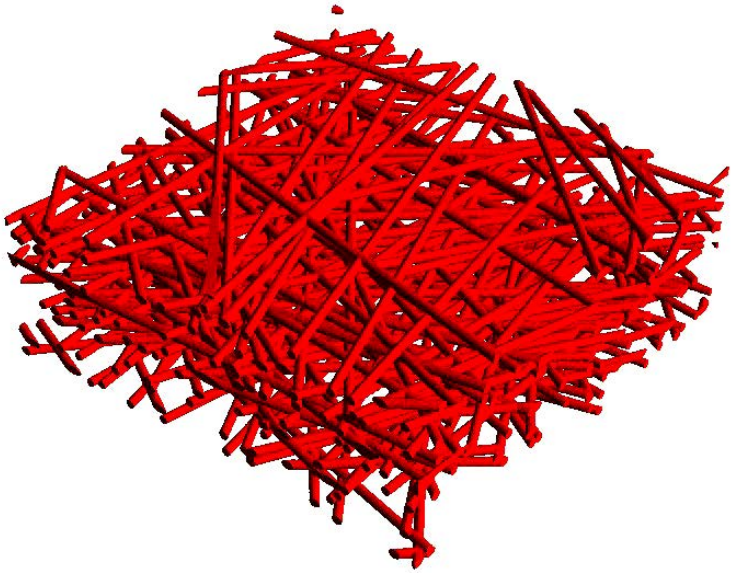


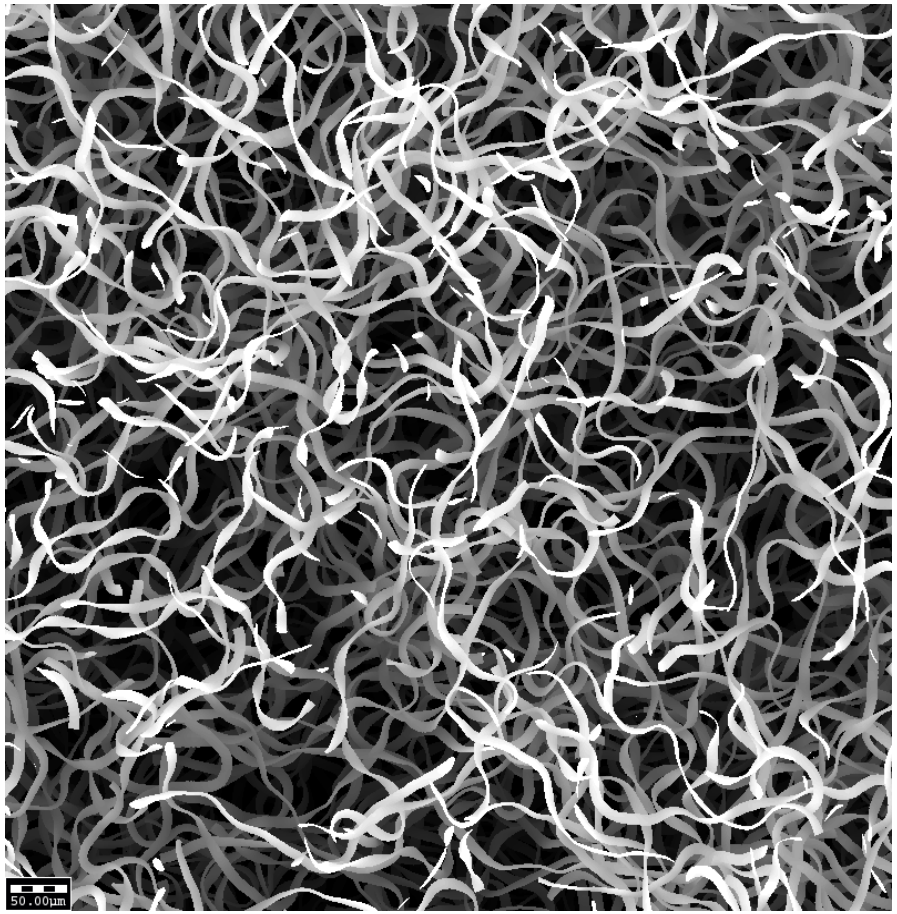
Parameters might be

- known from manufacturing process
- measured experimentally
- measured from CT image

Curved Fibers

Additional input for curved fibers:

- Local straightness
- Global straightness
- Torsion



Filter Model

- Ellipsoidal cross section, diameter distribution
- Curved fibers
- Fibers oriented in xy-plane
- 500 x 500 x 650 grid cells, 1 µm voxel length

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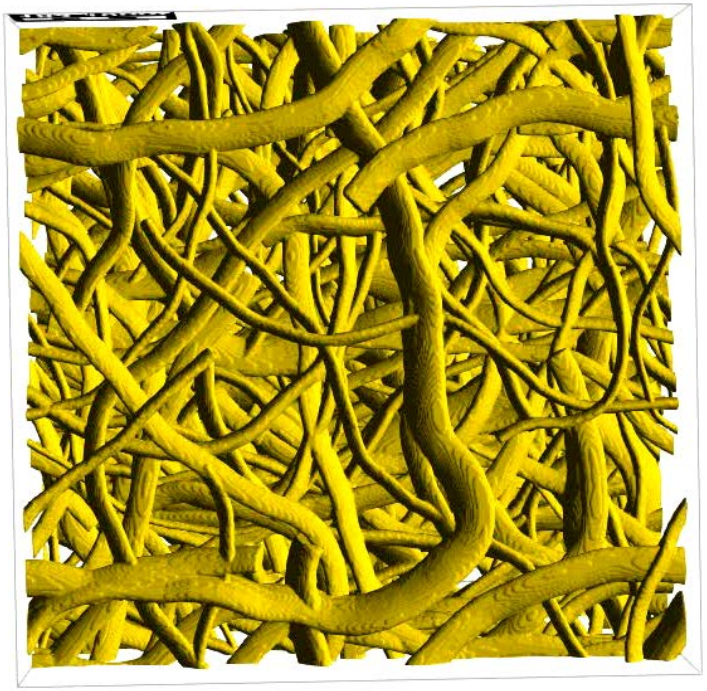

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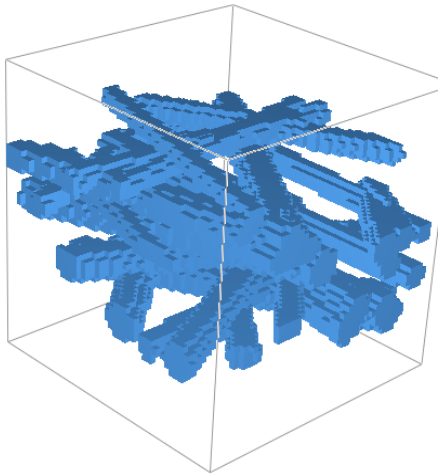
4. Simulation of Filter Life Time and Dust Holding Capacity

Approach to Efficiency Simulations

Basic idea:

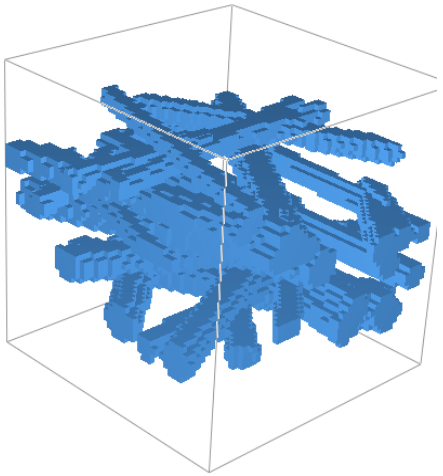
1. Filter media model

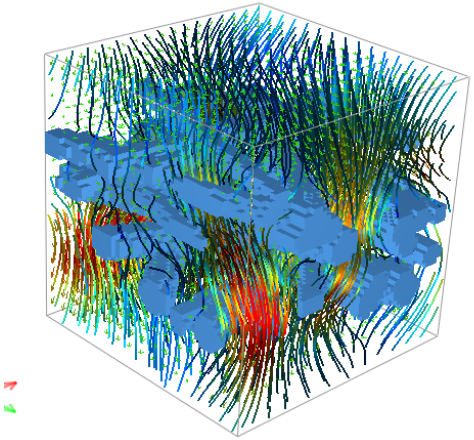


Approach to Efficiency Simulations

Basic idea:

1. Filter media model
2. Determine flow field





Approach to Efficiency Simulations

Basic idea:

1. Filter media model
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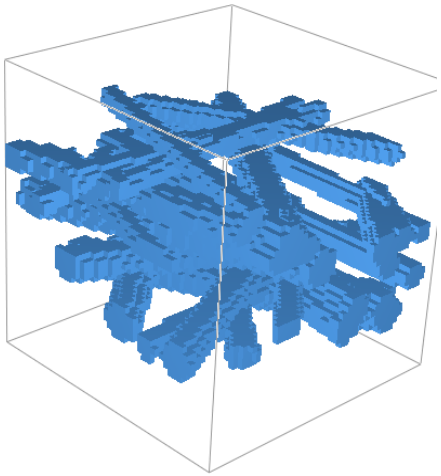
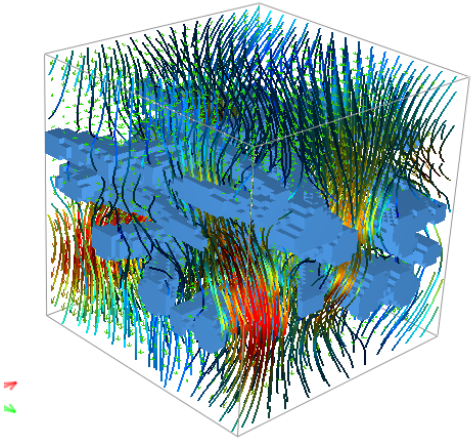
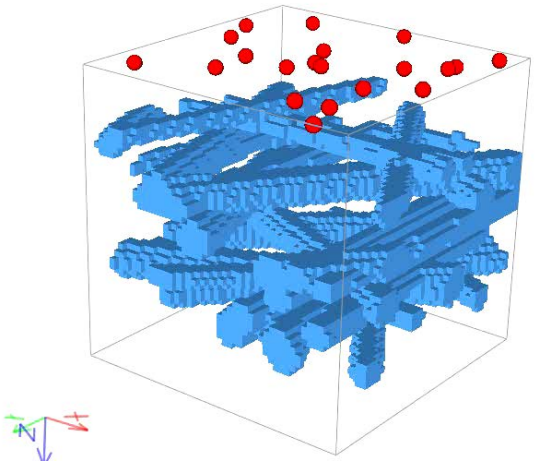
3. Track particles (filtered or not?)







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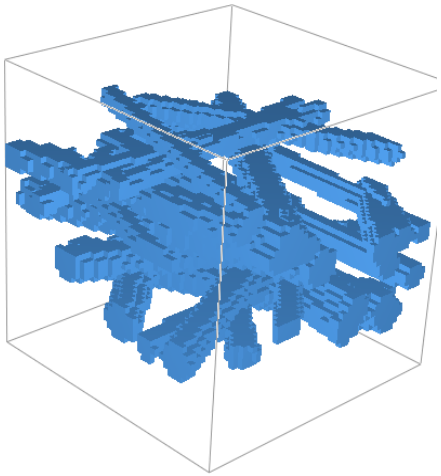
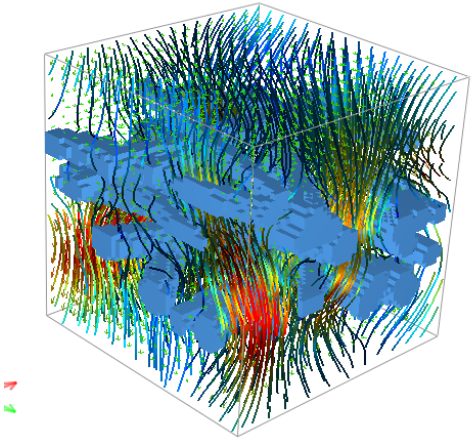
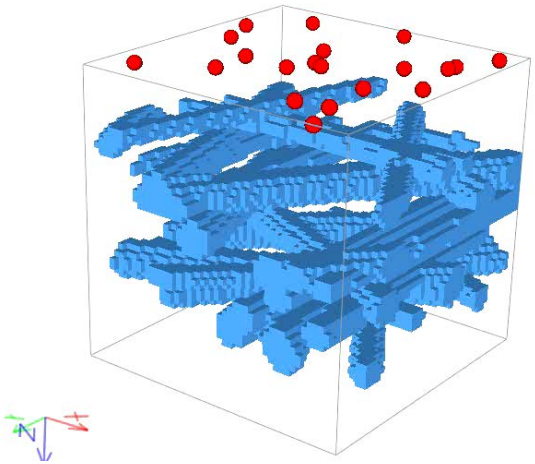
- Starting positions
- Brownian motion







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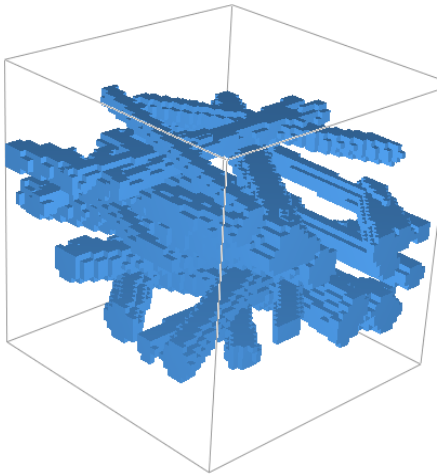
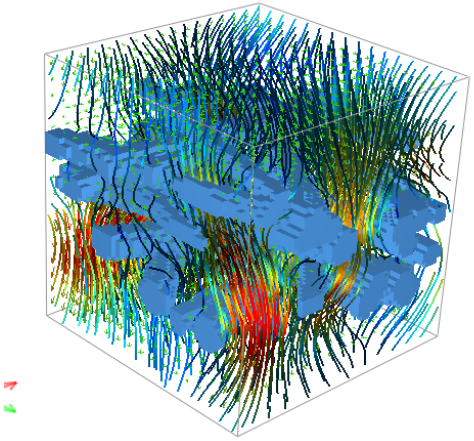
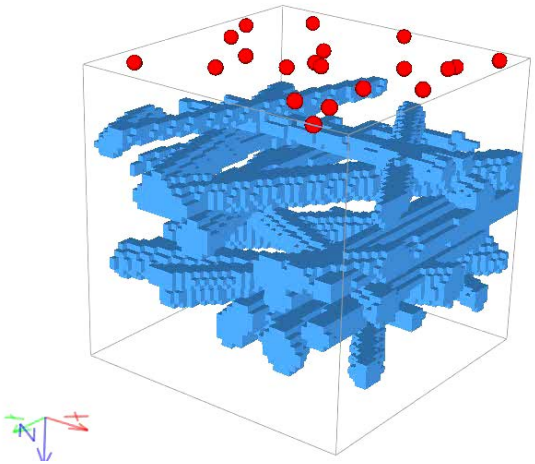
Result:

- Percentage of filtered particles







Particle Tracking and Adhesion

Particle tracking:

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- Moving particles do not change flow field
- Modeled effects: Inertia, Brownian motion, electrostatic attraction

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Particle Tracking and Adhesion

Particle tracking:

- Particles of the same batch move independently from each other
- Moving particles do not change flow field
- Modeled effects: Inertia, Brownian motion, electrostatic attraction

Adhesion Model: What happens when a particle touches the filter material?

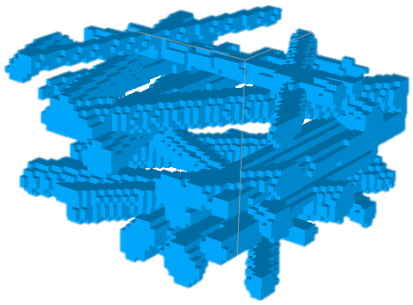
Particles always stick => ***Caught on first touch***

Particles stick if kinetic energy cannot overcome adhesive forces => ***Hamaker***

Particles do not stick => ***Sieving***

(Particles loose energy when touching => ***Restitution*** factor)

Approach to Life Time Simulations



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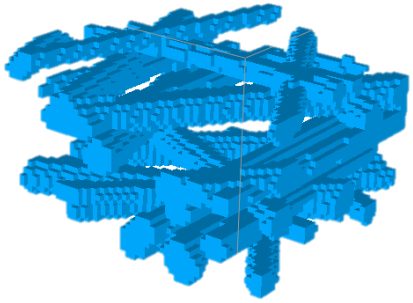
Approach to Life Time Simulations



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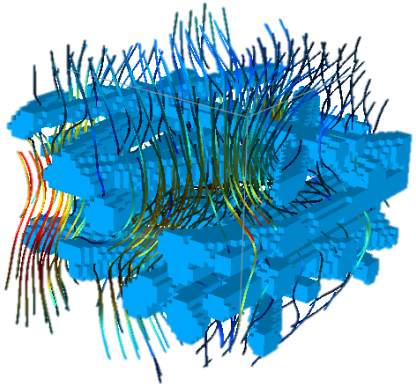
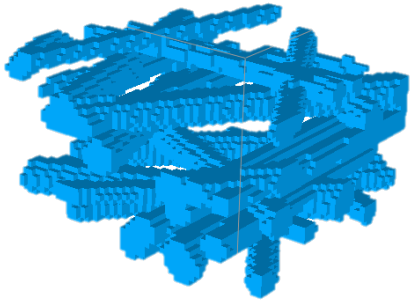


2. Flow Field

Approach to Life Time Simulations



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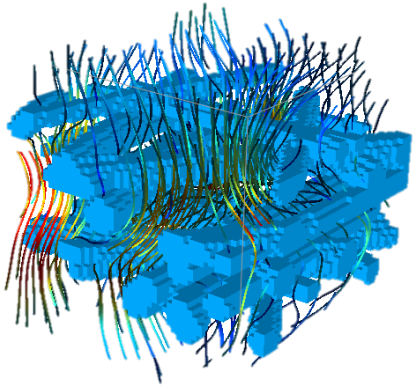

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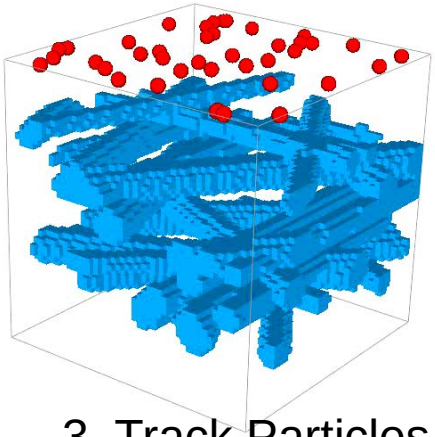
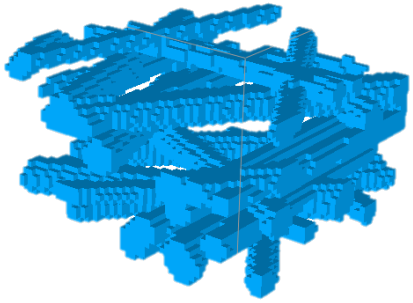


3. Track Particles

Approach to Life Time Simulations



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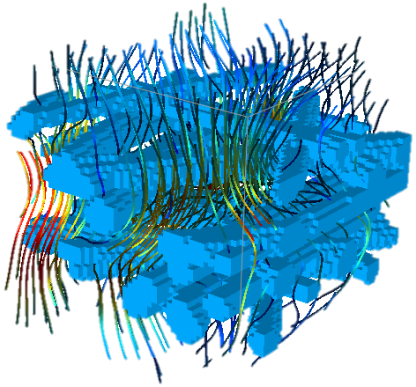

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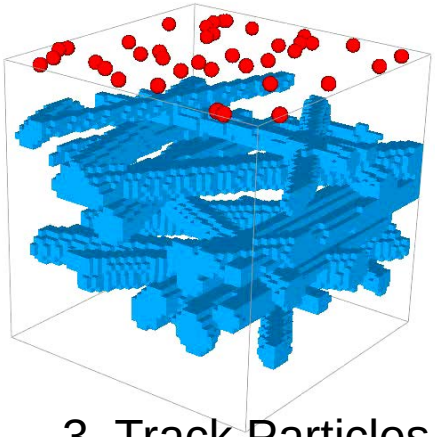
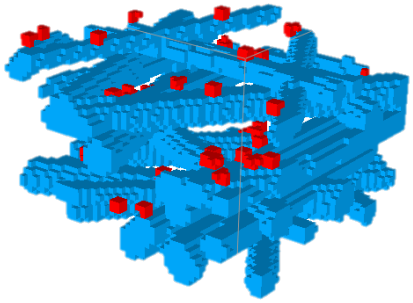
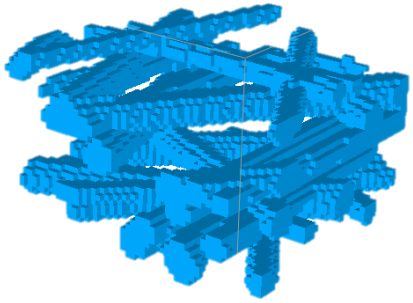


3. Track Particles

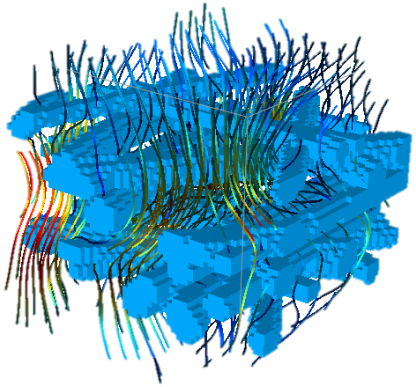


4. Deposit Particles

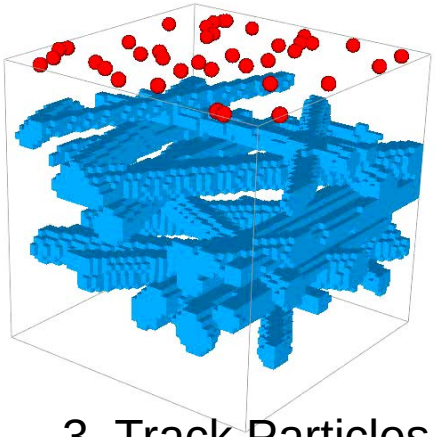
Approach to Life Time Simulations



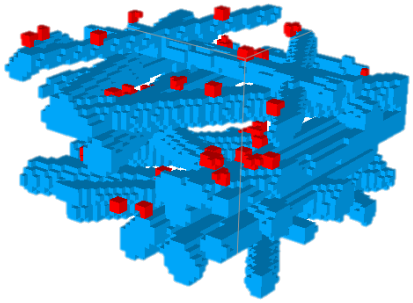
1. Filter Model



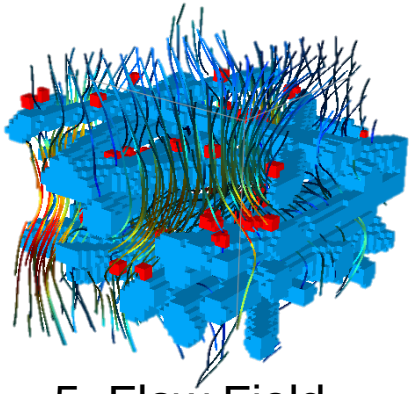
2. Flow Field



3. Track Particles

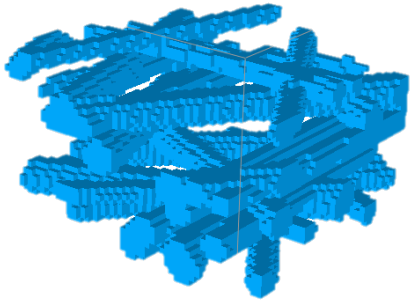


4. Deposit Particles

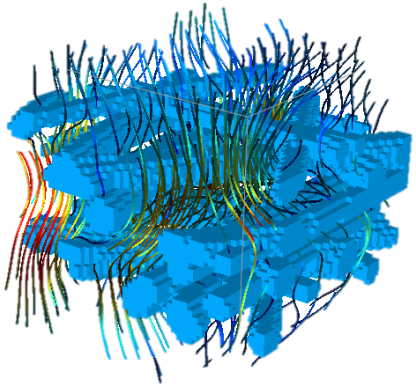


5. Flow Field

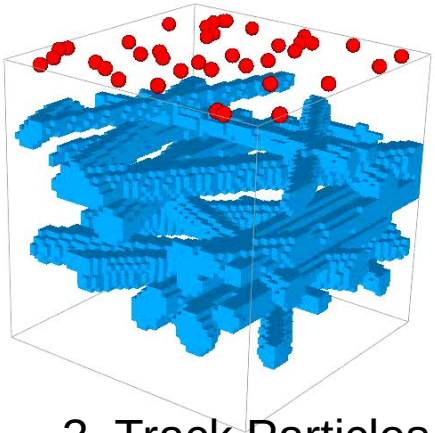
Approach to Life Time Simulations



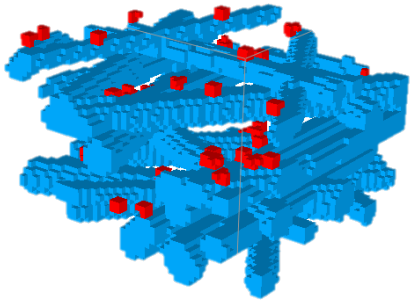
1. Filter Model



2. Flow Field



3. Track Particles



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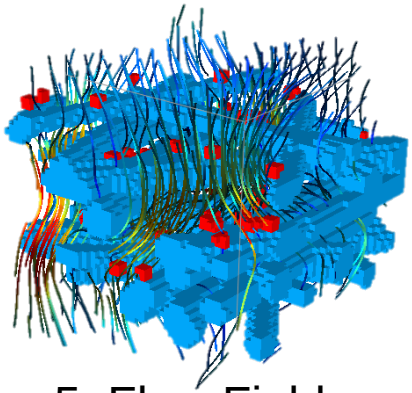
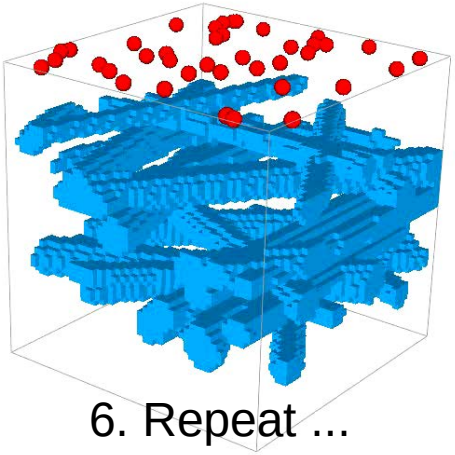


5. Flow Field



6. Repeat ...

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Particle Deposition

- Fluid: oil
- Multi pass test
- Sieving model
- Particles diameters: 2 – 40 µm

Particle Deposition

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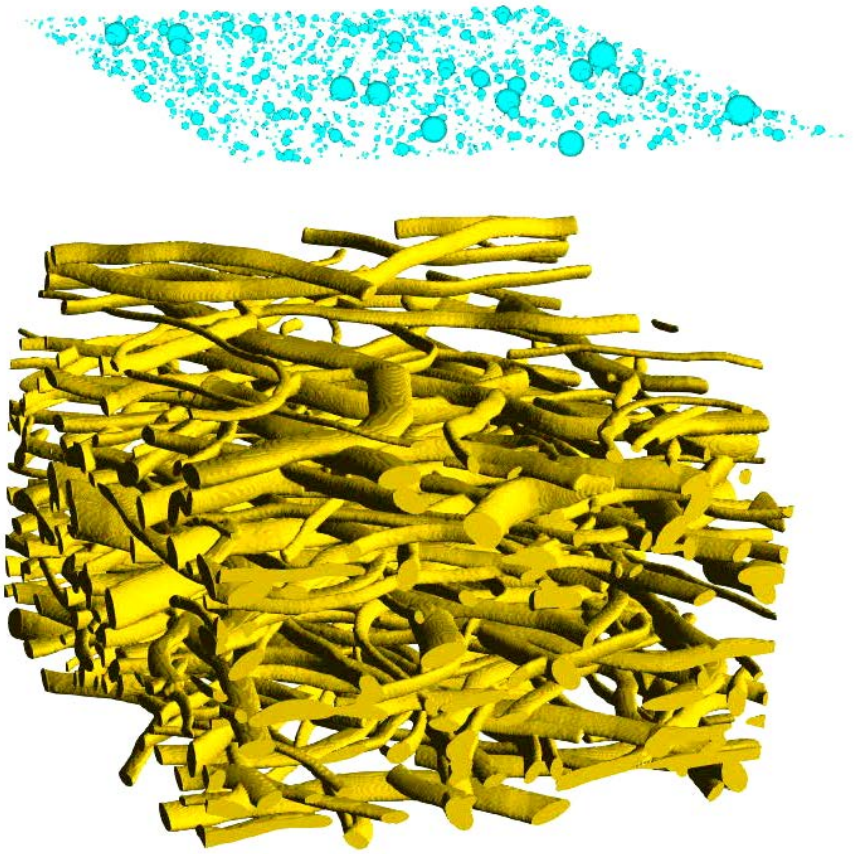
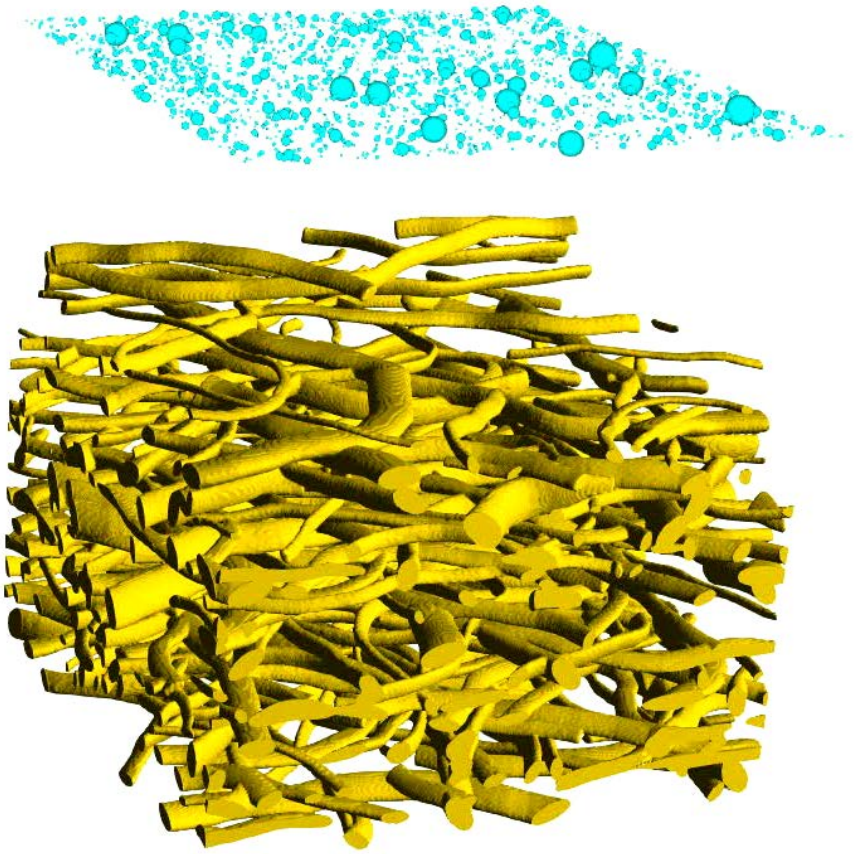
- Multi pass test
- Sieving model
- Particles diameters: 2 – 40 µm



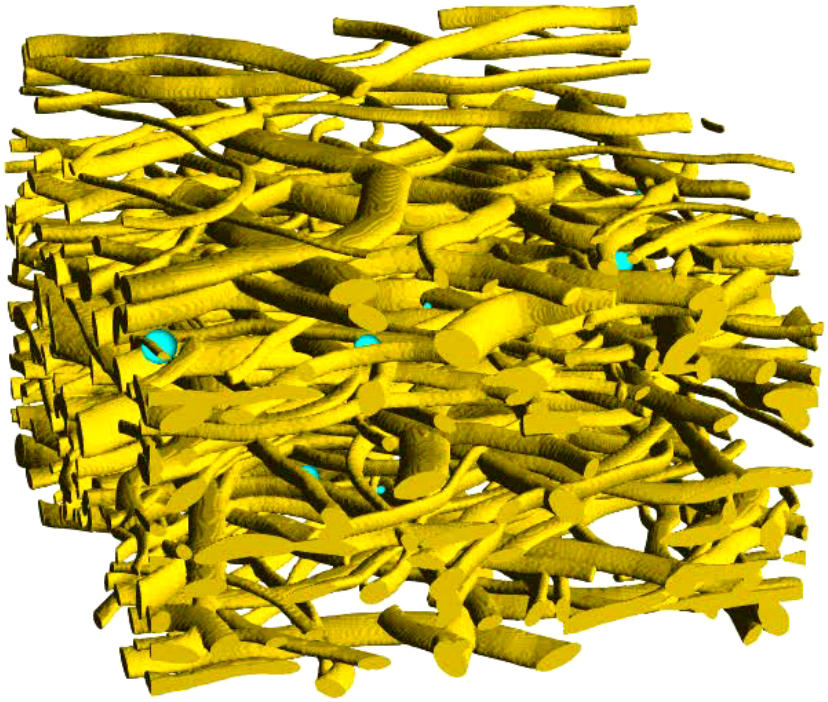
Particle Deposition

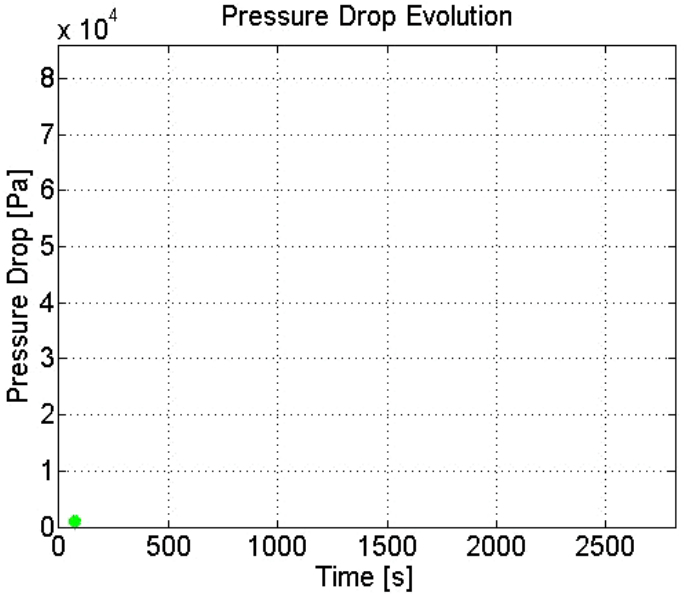
- Fluid: oil
- Multi pass test
- Sieving model
- Particles diameters: 2 – 40 µm



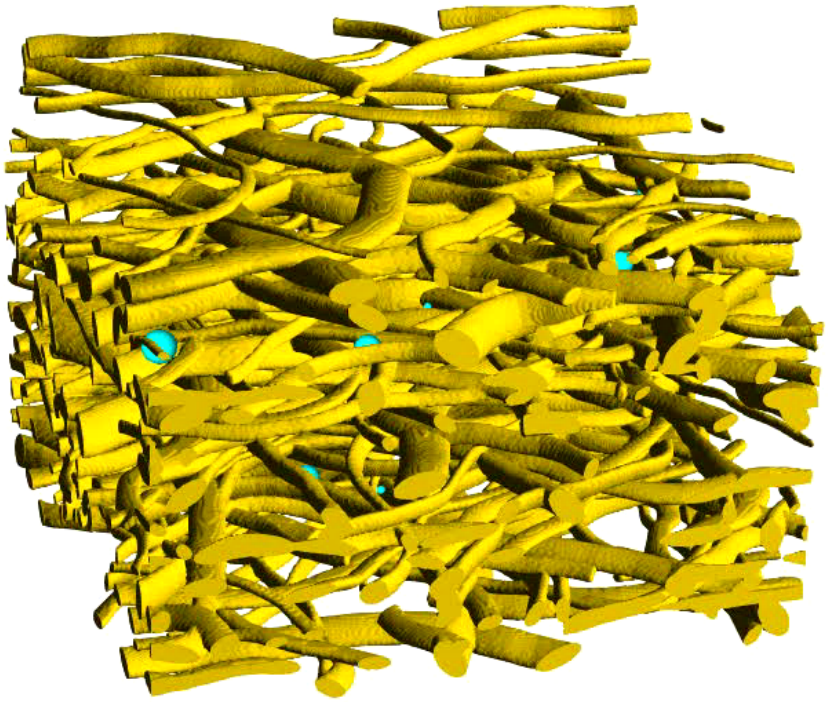
Filter Capacity and Life Time

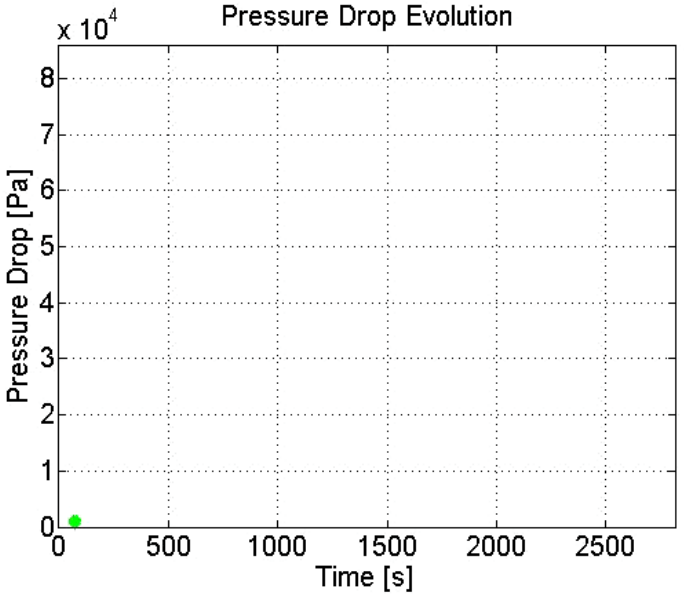
Filter Capacity and Life Time



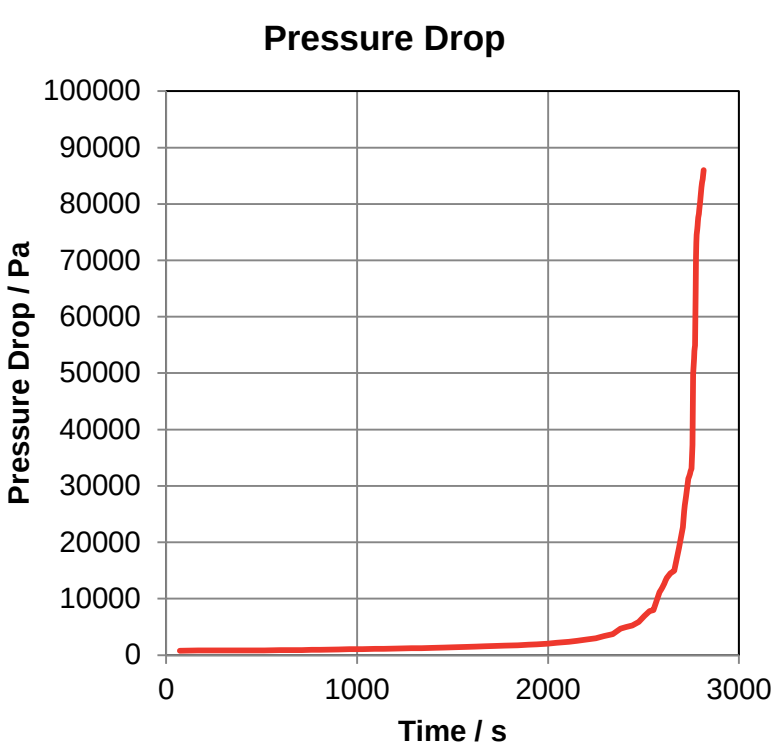


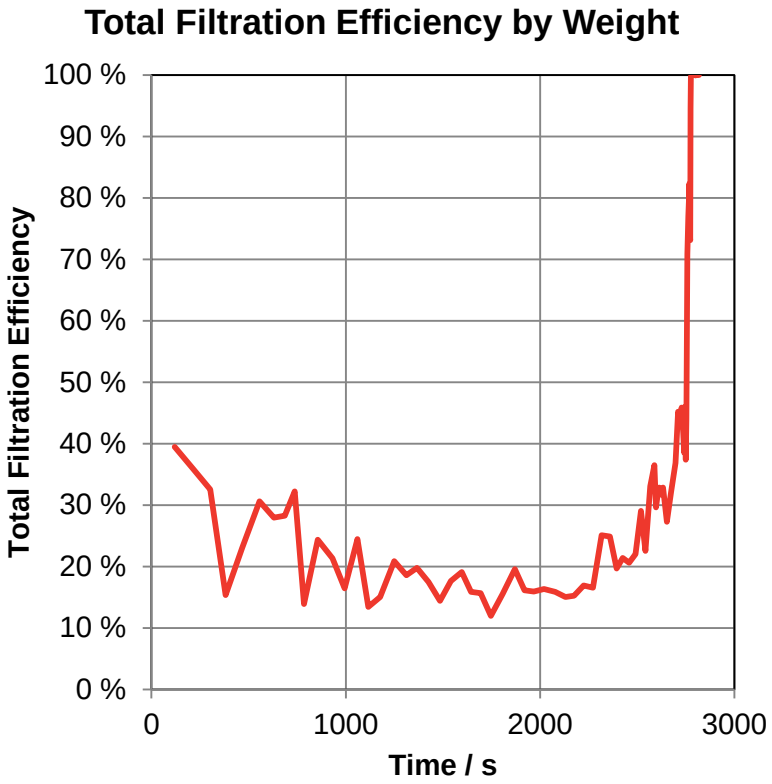
Filter Capacity and Life Time





Efficiency





After 2780 s, efficiency reaches 100% (filter is completely clogged)

Initial pressure drop: 0.8 kPa, after 2000 s: 2.1 kPa, at 2780 s: 75 kPa

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Thank You !

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