Design of Fibrous Filter Media Based on the Simulation of Pore Size Measures

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Design of Fibrous Filter Media Based on the Simulation of Pore Size Measures

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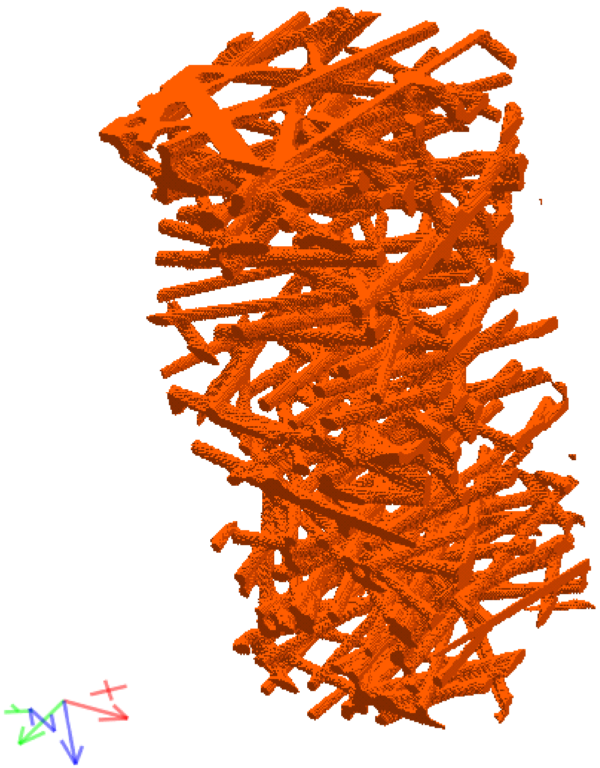

Overview:

- Pore size distribution(s)
- Simulation of mercury intrusion porosimetry (MIP)
- Simulation of liquid extrusion porosimetry (LEP)
- Comparison of results

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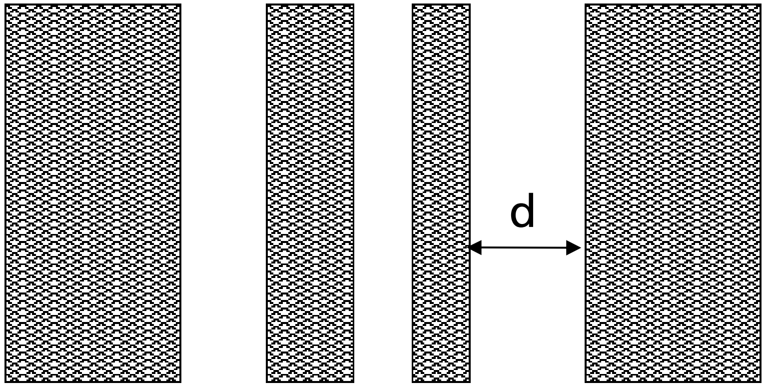
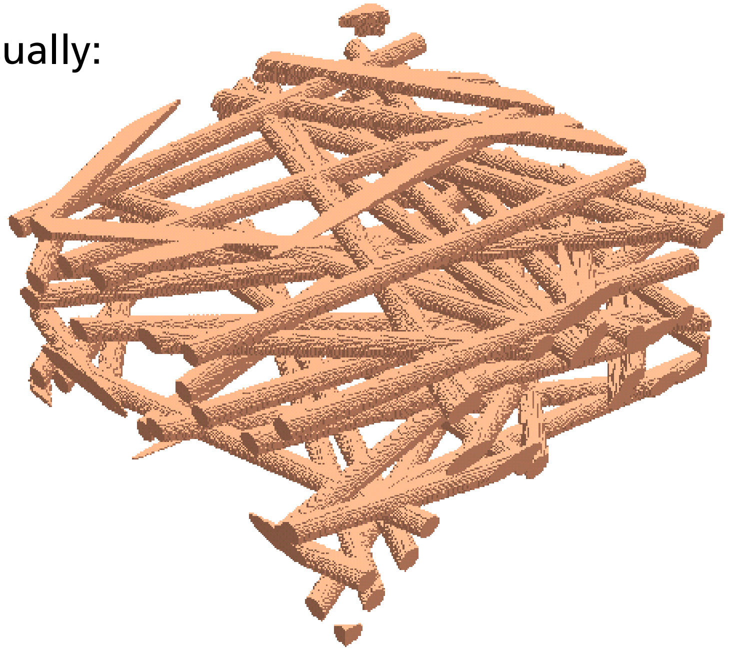
Pore Size Distribution

simple geometry:



Pore sizes well defined and easy to measure

usually:



How to define a pore size ?

What is measured?

Defining Pore Sizes - Geometric Approach

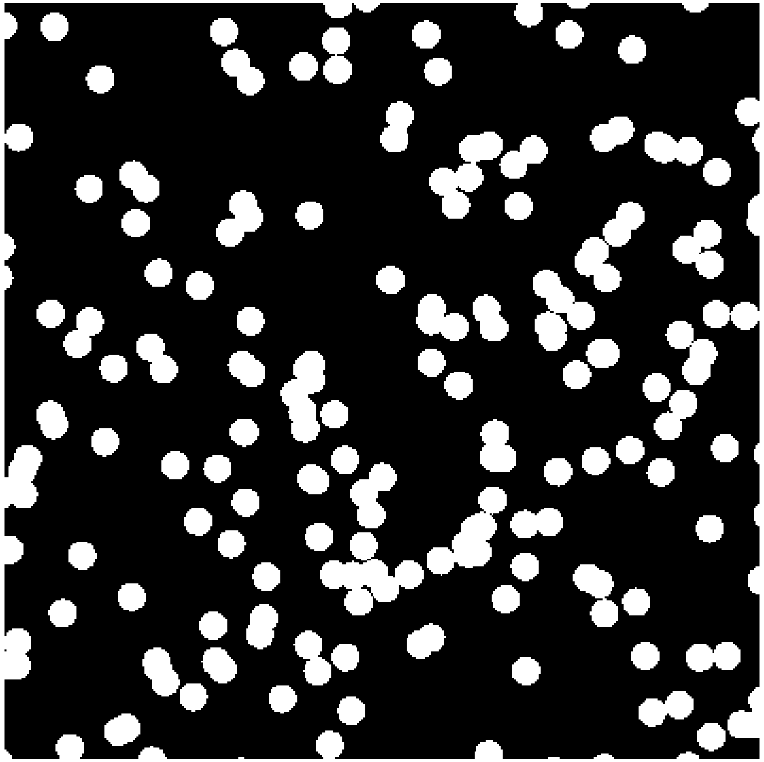
Pore space : *X*

Opening of radius *r* :

$$O_r(X) = \bigcup_{B_{r,x} \subset X} B_{r,x}$$

Volume of pores with radius $r_1 \leq r \leq r_2$:

$$O_{r_1}(X) - O_{r_2}(X)$$



dark grey: $r \geq 20$
light grey: $16 \leq r < 20$

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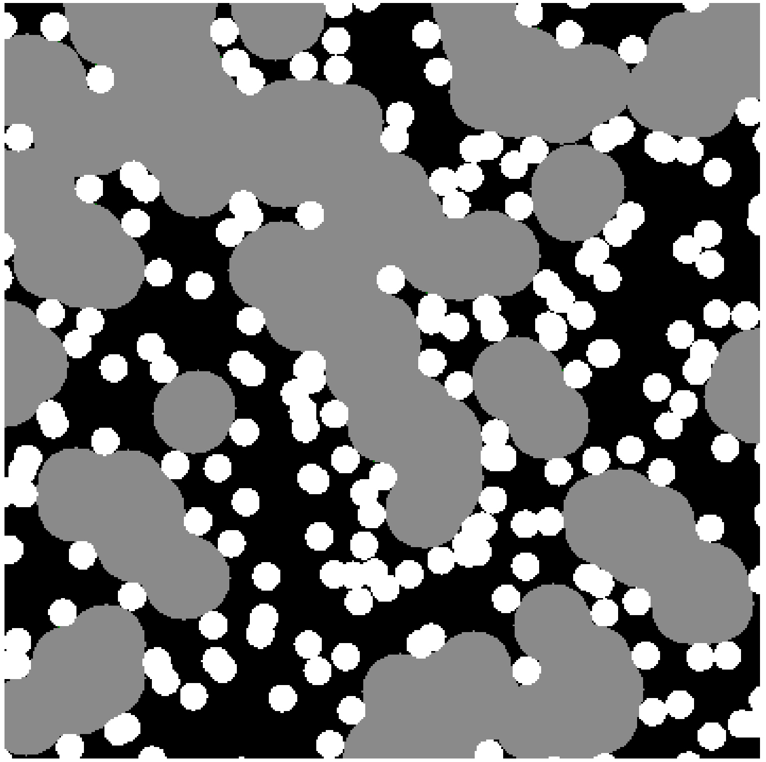

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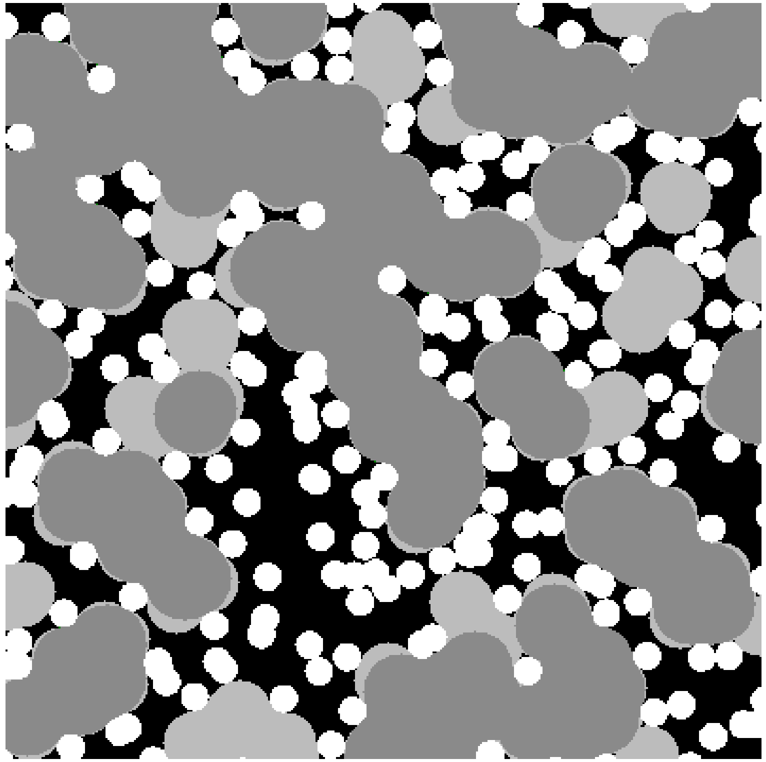

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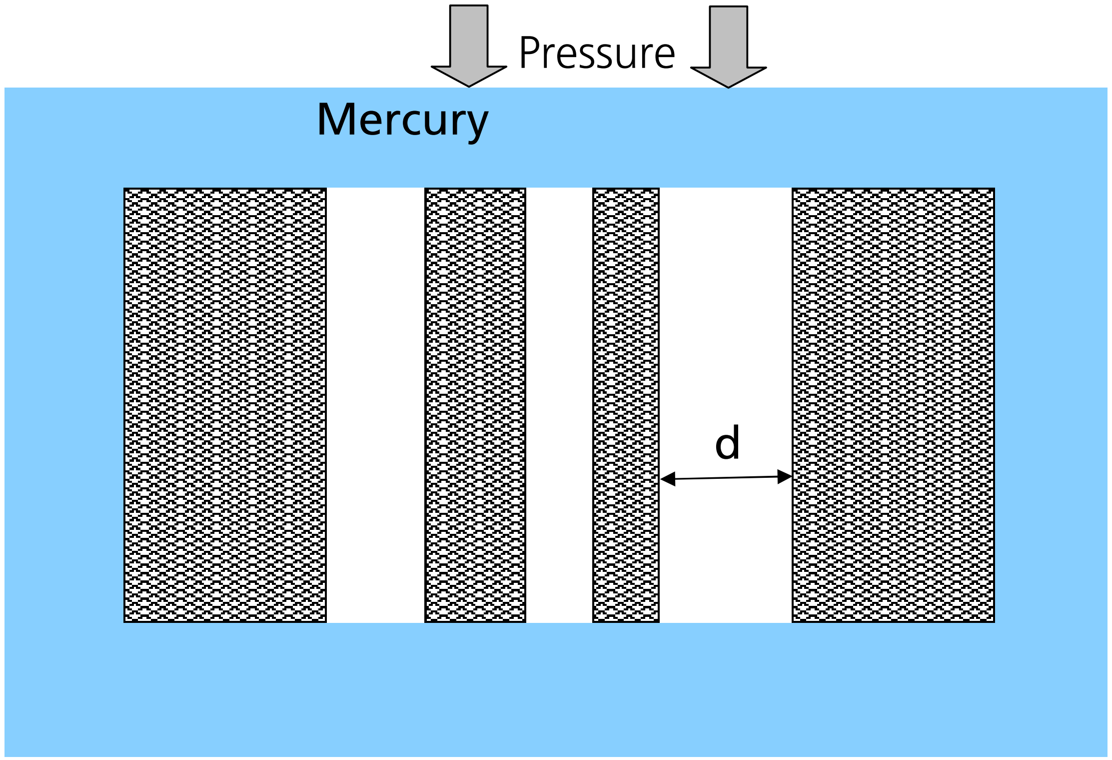
Mercury Intrusion Porosimetry



- mercury (non-wetting) fills the pores, if pressure becomes large enough:

$$p = \frac{4\gamma}{d}\cos\theta$$

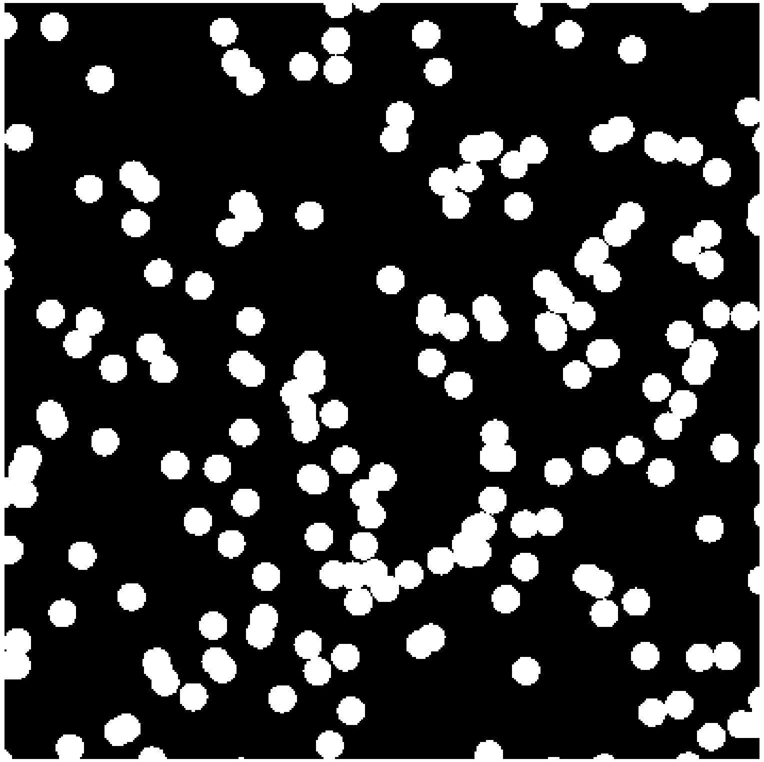
- volume of intruding mercury gives pore size distribution

Simulation of MIP

- pores filled with mercury are a subset of $O_r(X)$
- pores filled must be connected to the mercury reservoir

algorithm: **fast and efficient !**

- erode the pore space by r to find possible centre points
- remove parts unconnected to reservoir
- dilate the remaining pore space by r



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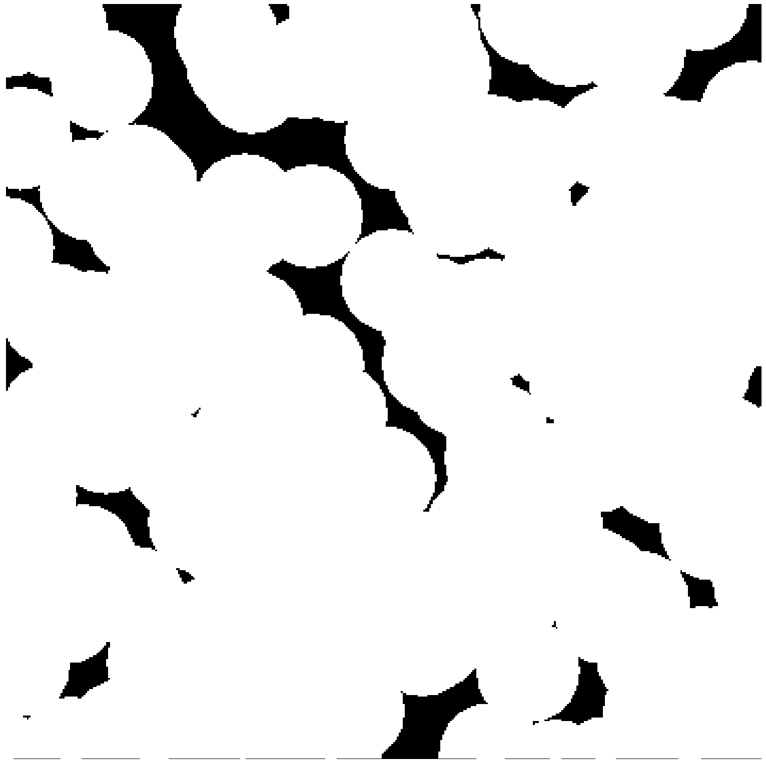

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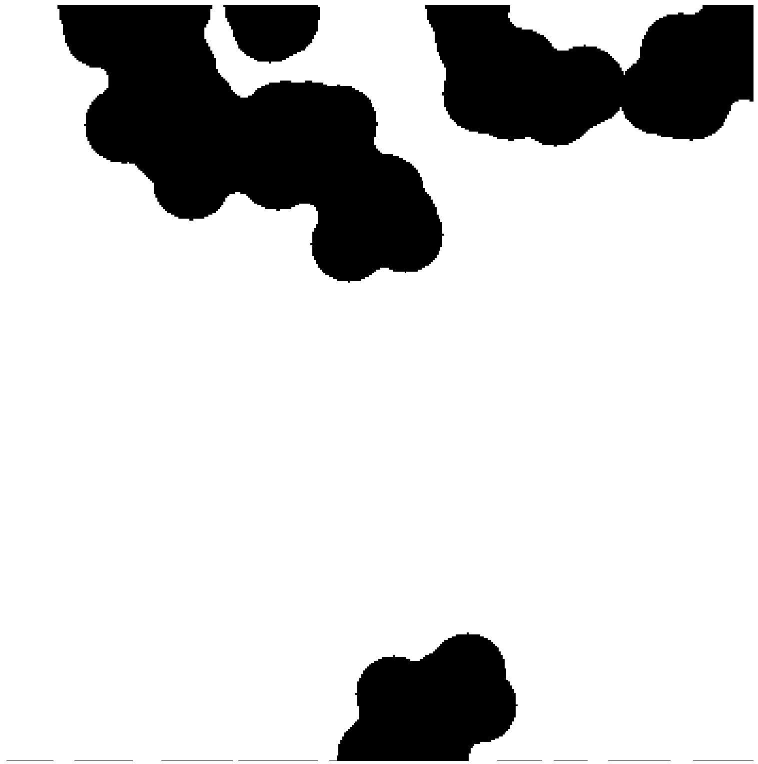

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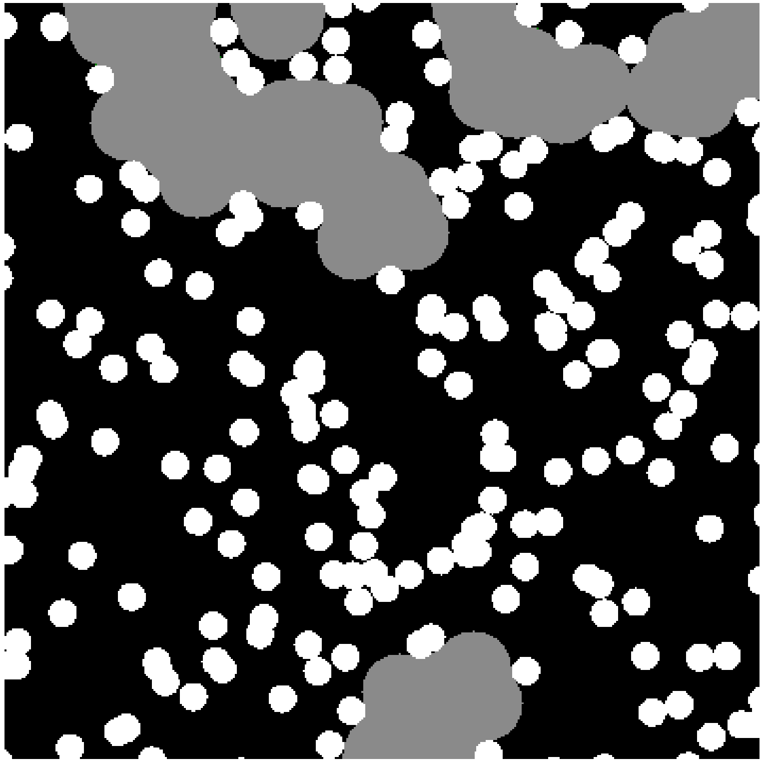

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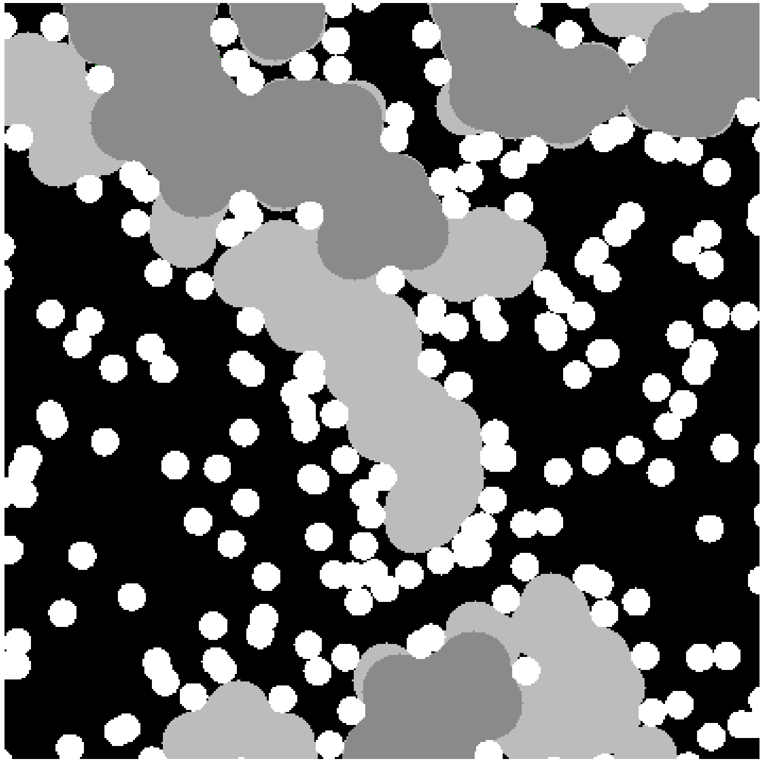

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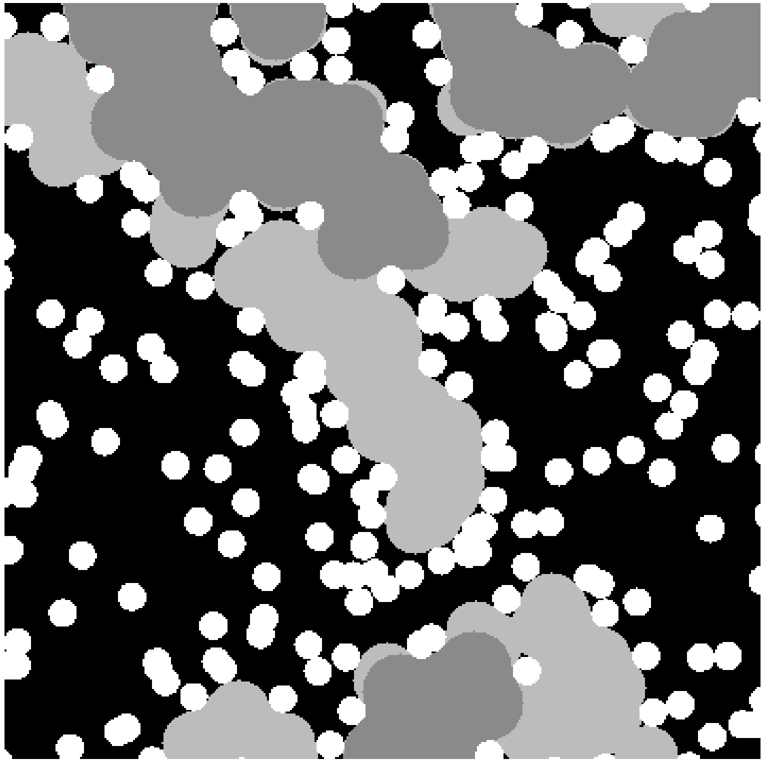
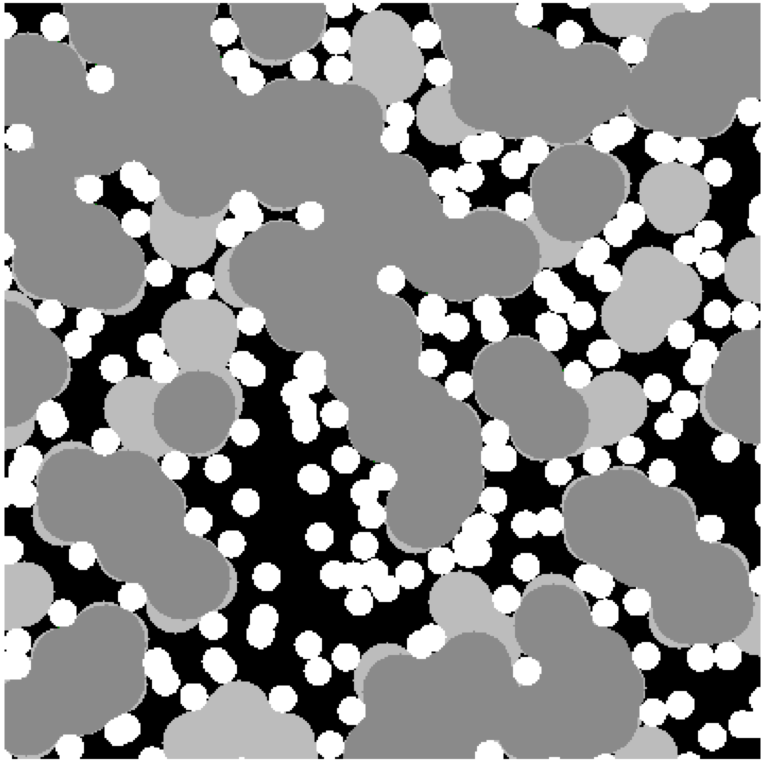
Comparison of MIP Simulation and Geometric Approach



MIP



Geometric

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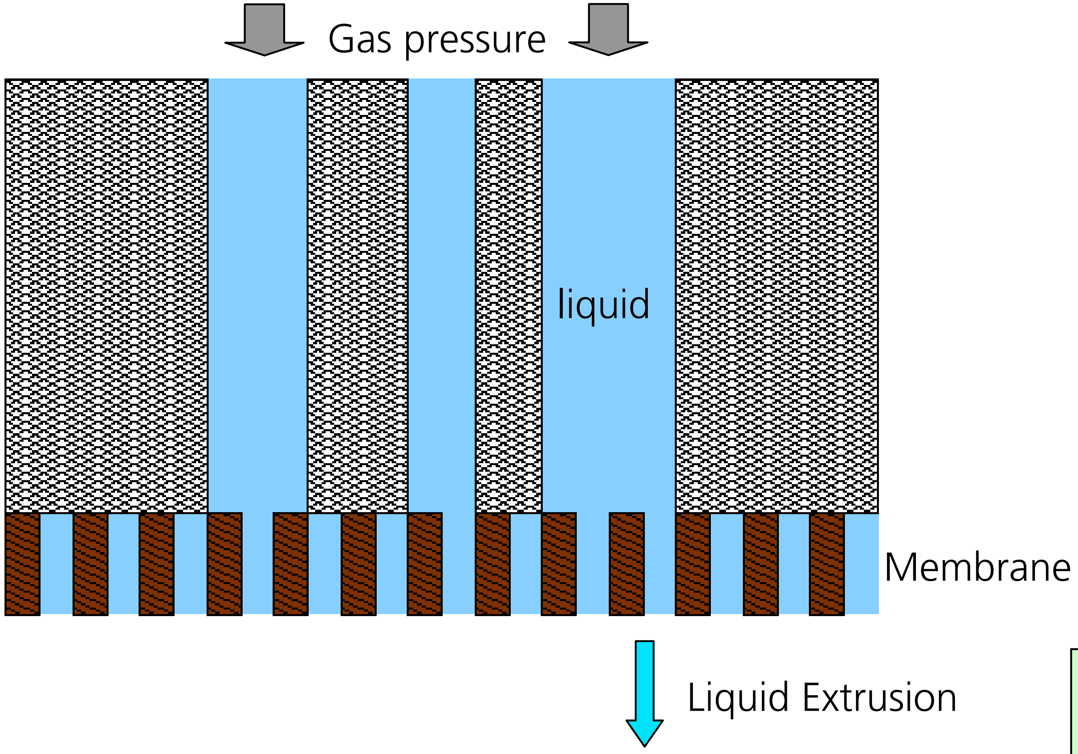
Liquid Extrusion Porosimetry



- sample and membrane initially filled with wetting liquid.
- air is pressed into the pores and fills pores with large enough diameter:

$$p = \frac{4\gamma}{d} \cos\theta$$

- volume of extruded liquid is used to calculate pore size distribution

Simulation can use methods developed for MIP (but other reservoir position)

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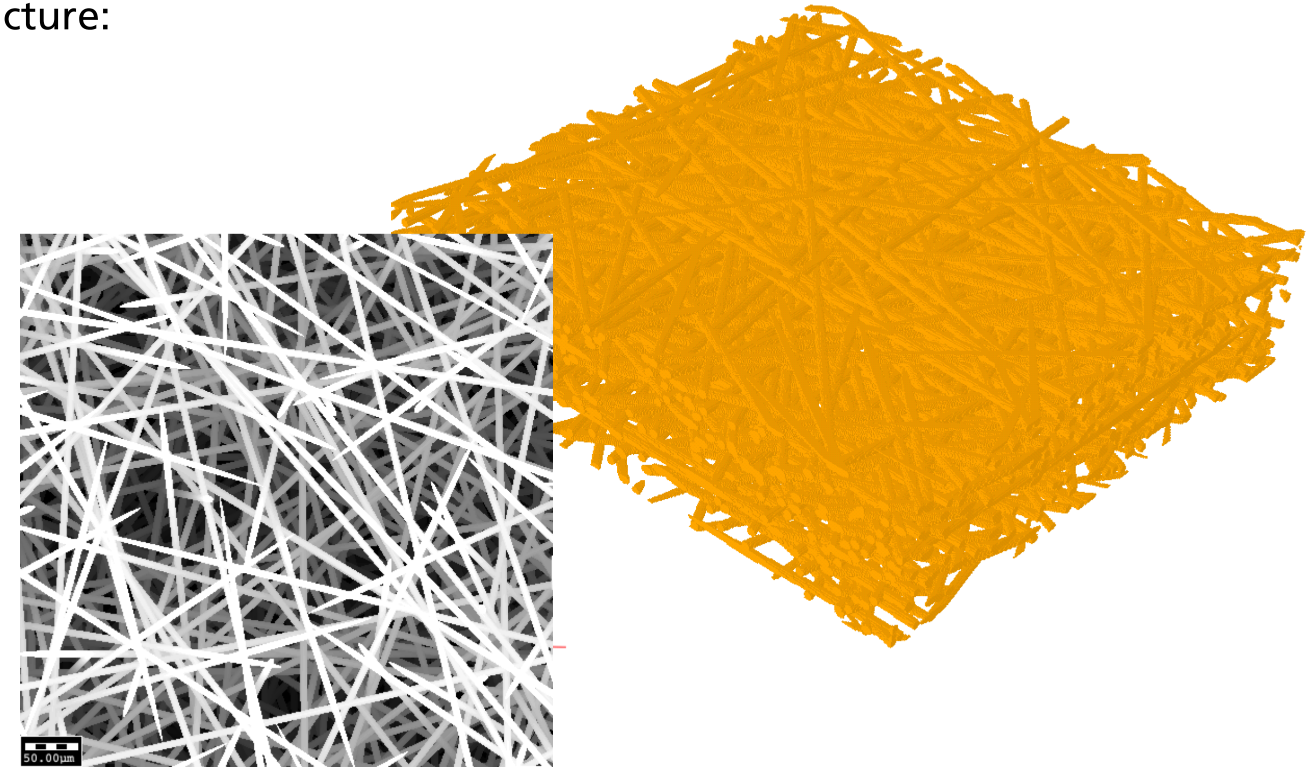
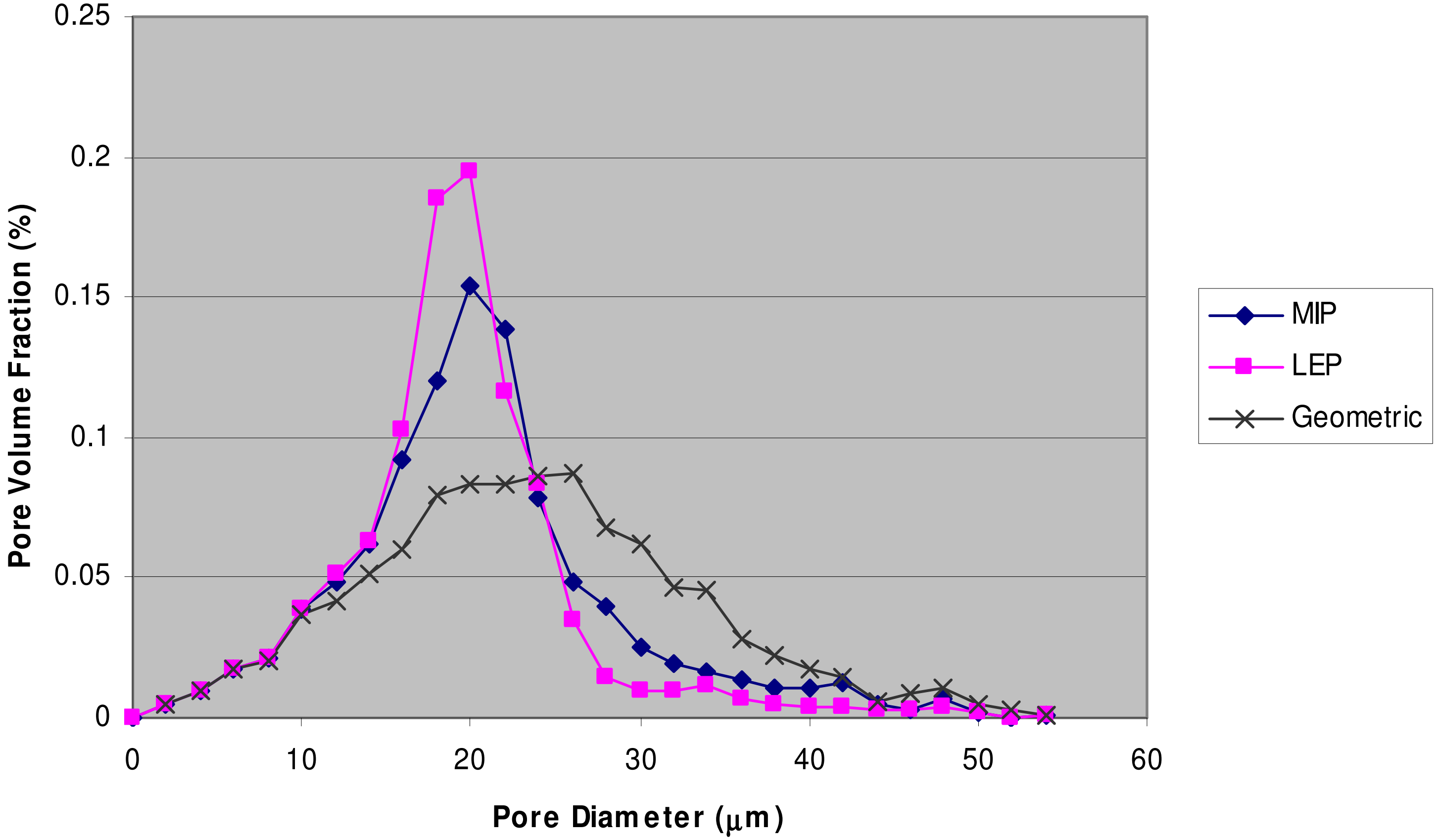
3D Sample Structure

virtually created 3D fibre structure:

- fibre diameter 7µm
- porosity 82%
- highly anisotropic



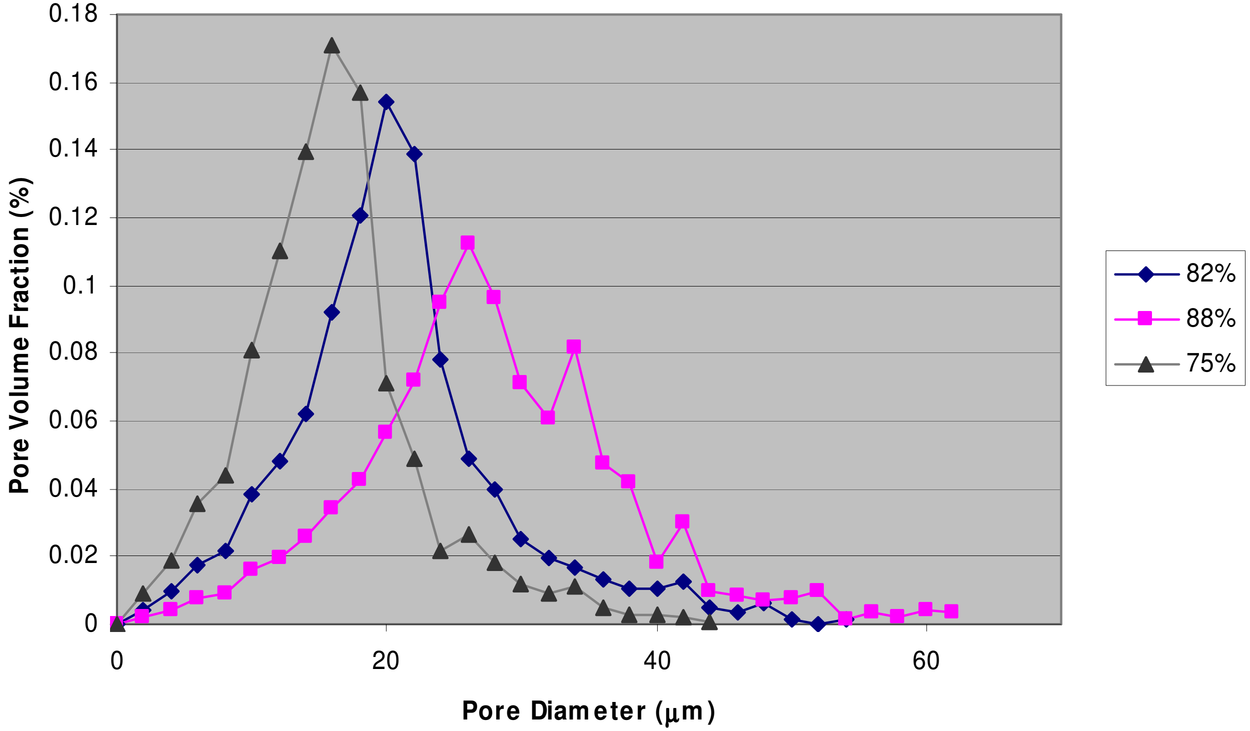
Results of the Simulation



Dependence of Pore Size Distribution on Design Parameters (Example)

• virtually created fibre media with different porosities (75%, 82%, 88%).

• chart shows results of simulated MIP.



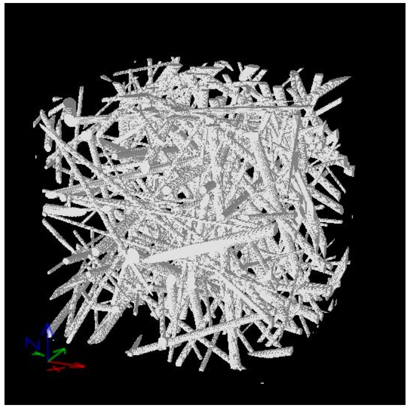
Comparison of Measurement and Simulation

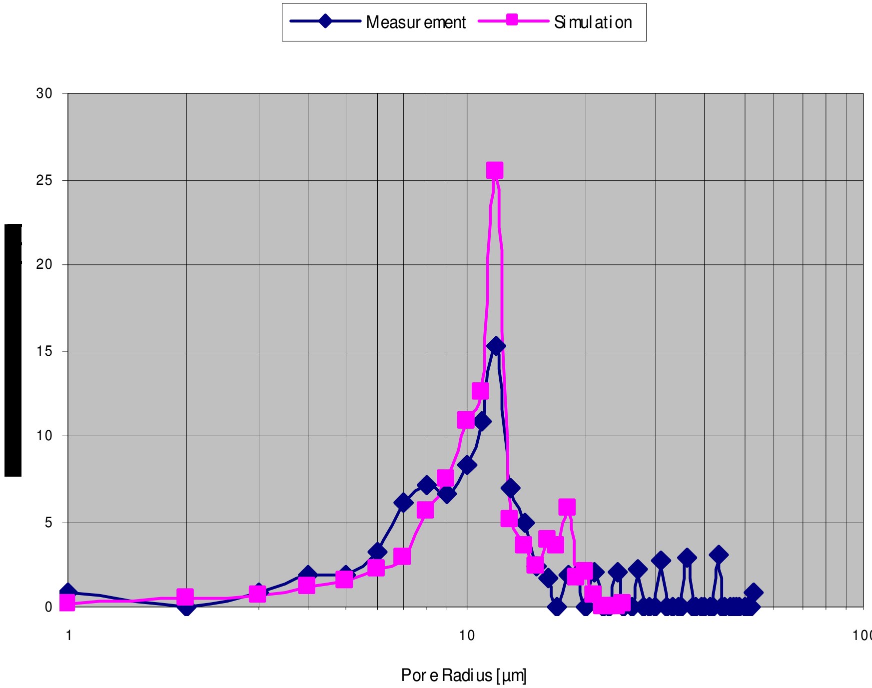
Measurement: MIP

Simulation:

- virtually created fibre structure using known values for porosity and fibre thickness distribution.

- simulated MIP





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Summary / References

- Different measurement techniques measure different "Pore Size Distributions" (see A. Jena, K. Gupta, Fluid Particle Separation J. 4, 2002, pp. 227-241)
- MIP and LEP results can be predicted numerically.
- Both techniques underestimate the number of large pores when compared to a purely geometric approach
- Software used: GeoDict (www.geodict.com)

Flow Porometry (??)