



## Segmentation and characterization of fibers

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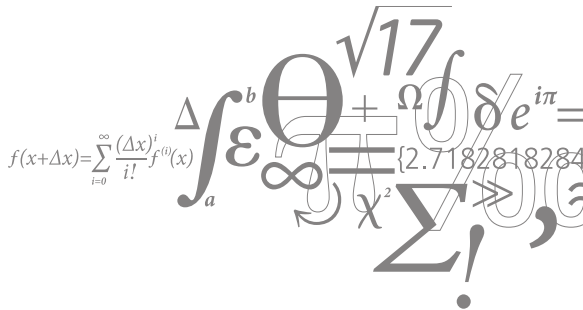
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## Segmentation and characterization of fibers

Vedrana Andersen Dahl, DTU Compute

September 2015



# Introduction

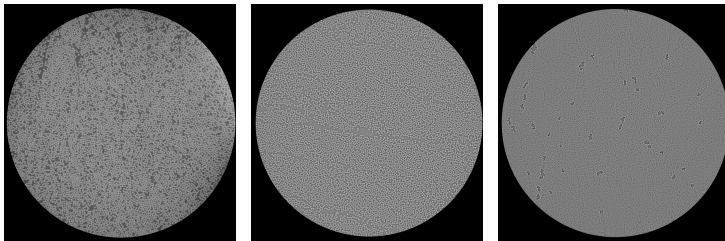
## Background

- ▶ My background
- ▶ DTU imaging industry portal, industrial application, scientific advice, and research within 3D imaging
- ▶ CINEMA, the allianCe for ImagiNg of Energy MAterials, a five year DSF project with participants from both academia and the industry
- ▶ CINEMA at DTU Compute:
  - ▶ Tomographic reconstruction using movable meshes
  - ▶ Volume segmentation using movable meshes
  - ▶ Texture based volume segmentation

## Presenting (mostly) the work of

- ▶ Monica Jane Emerson, PhD student, DTU Compute
- ▶ Anders BJORHOLM DAHL, associate professor, DTU Compute

## Segmentation (and quantification) of fibers



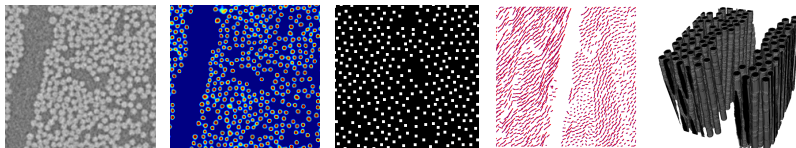
### Focus areas

- ▶ Micro-CT of glass fiber, thick carbon fiber and thin carbon fiber
- ▶ Segmentation and quantification (orientation and alignment)

### Motivation

- ▶ Quality control – mechanical tests for each production protocol. Time aspect.
- ▶ Quality control – quantification of fibers based on imaging, simulation using FEM.
- ▶ Our part: from images to fibers.

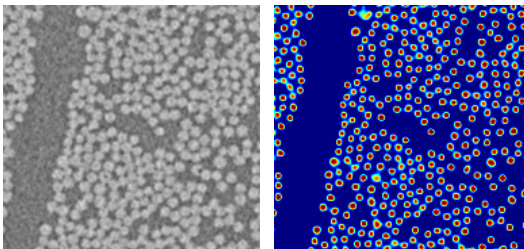
## Segmentation (and quantification) of fibers



### Pipeline

- ▶ Probabilistic fiber center detection. Dictionary based.
- ▶ Discretization. Treasholding or blob detection.
- ▶ Tracking. Nearest neighbour heuristics.
- ▶ Radius estimation. Back to blob detection response.

## Probabilistic fiber center detection



### Dictionary based approach

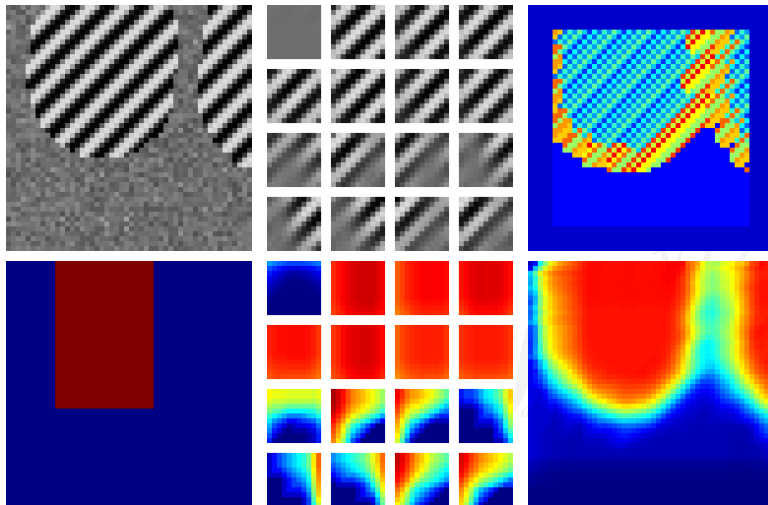
- ▶ Fiber detection vs. fiber center detection.
- ▶ Closely related to dictionary based segmentation of textured images.

## Dictionary based segmentation of textured images

### Recent segmentation methods

- ▶ Anders L Dahl and Rasmus Larsen, *Learning dictionaries of discriminative image patches*, BMVC, 2011.  
Training-testing approach. Computation based on averaging.
- ▶ Anders B Dahl and Vedrana A Dahl, *Dictionary snakes*, ICPR, 2014.  
Deformable model, snakes. Requires initialization. Computation based on averaging.
- ▶ Anders B Dahl and Vedrana A Dahl, *Dictionary based image segmentation*, SCIA, 2015.  
Deformable model, level sets. Requires initialization. Graph based representation.
- ▶ Monica J Emerson, Kristine M Jespersen, Peter S Jørgensen, Rasmus Larsen, and Anders B Dahl, *Dictionary based segmentation in volumes*, SCIA, 2015.  
3D version. Training-testing approach.

## Dictionary based texture representation





## Dictionary based texture representation

### Graph (matrix) based representation

- ▶ Biadjacency matrix  $\mathbf{B}$  representing binary relation between image pixels and dictionary elements, given by a dictionary assignment image

$$b_{ij} = \begin{cases} 1 & \text{if } i \sim j \\ 0 & \text{otherwise} \end{cases}$$

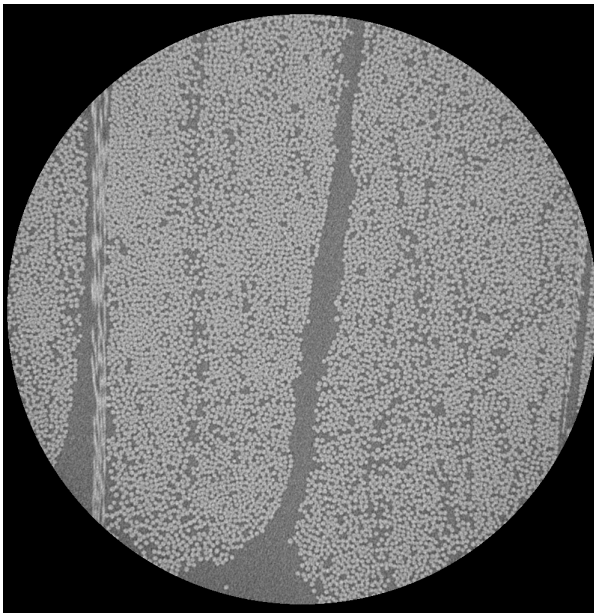
- ▶ Self similarity matrix

$$\mathbf{S} = (\mathbf{D}_B)^{-1} \mathbf{B}^T (\mathbf{D}_{B^T})^{-1} \mathbf{B}$$

- ▶  $\mathbf{B}$  is a  $n \times m$  matrix, where  $n$  is the size of the image, and  $m$  is the size of the dictionary.

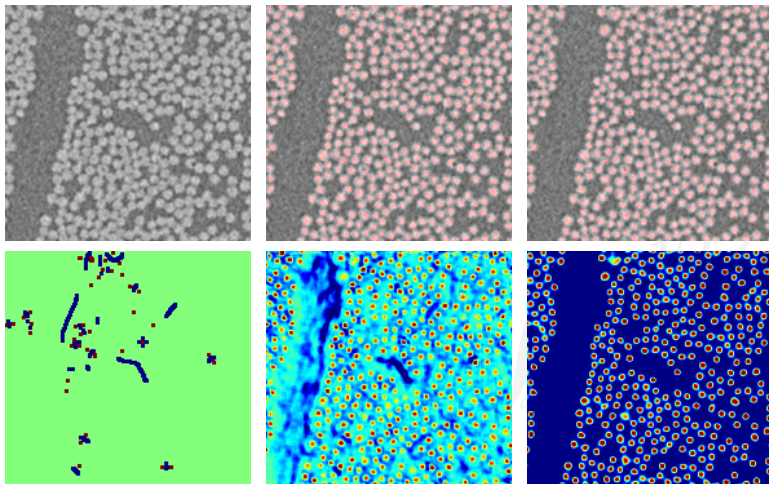
Demo

## Anders' example, glass fiber

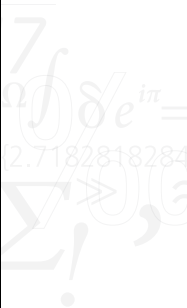
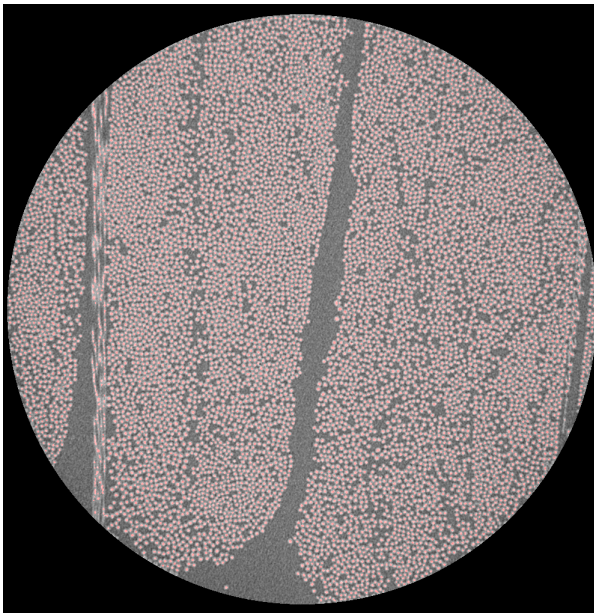


$7$   
 $\alpha f \delta e^{i\pi} =$   
2.7182818284  
 $\Sigma$   $\gg$   $\circ$   $\circ$   $\circ$

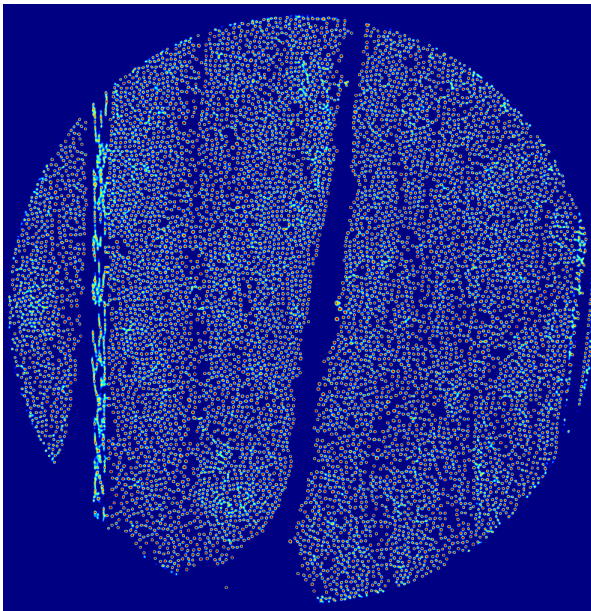
## Anders' example, glass fiber



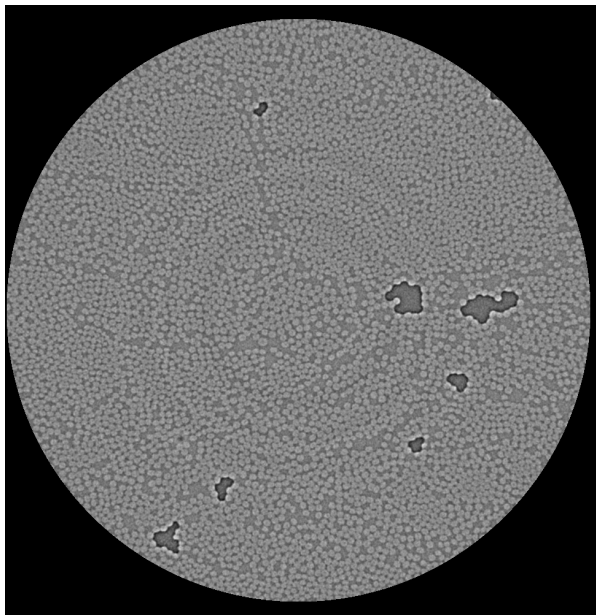
## Anders' example, glass fiber



## Anders' example, glass fiber

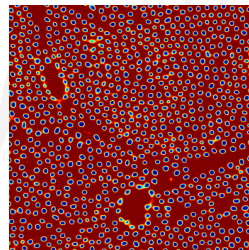
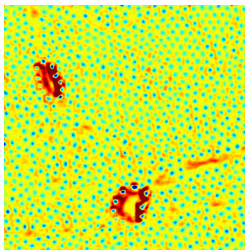
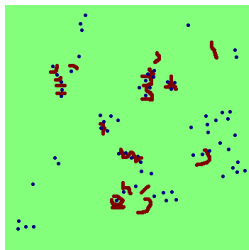
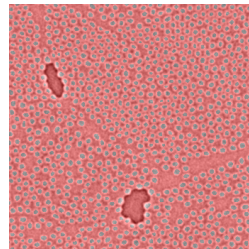
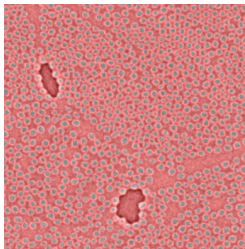
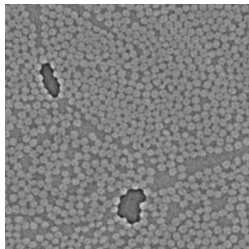


# Anders' example, carbon fiber

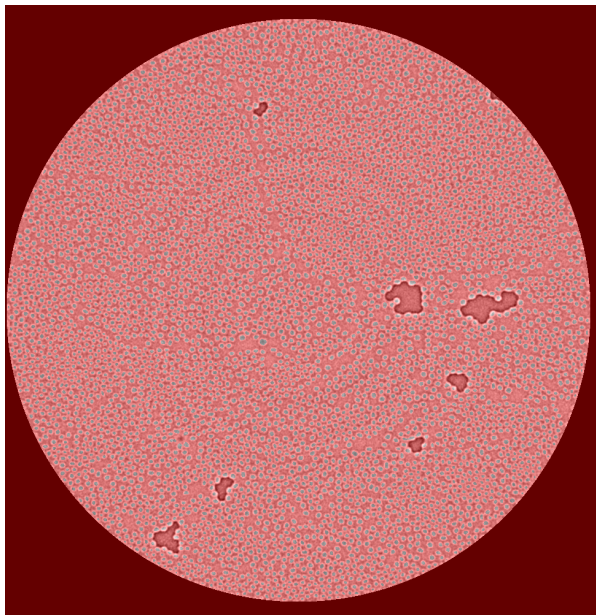


$7$   
 $\alpha \int \delta e^{i\pi} =$   
2.7182818284  
 $\Sigma$   $>$   $0$   $6$   
!

## Anders' example, carbon fiber



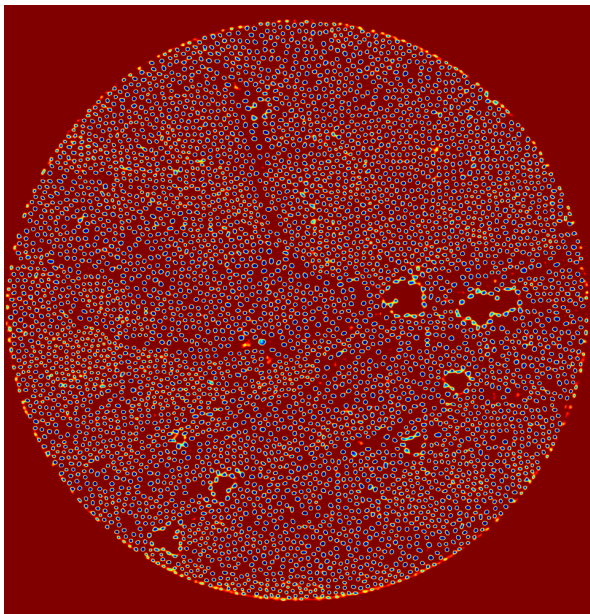
# Anders' example, carbon fiber



$7$   
 $\Omega \int \delta e^{i\pi} =$   
2.7182818284  
 $\Sigma$   $>$   $0$   $6$   
 $\Sigma$   $!$   $'$



# Anders' example, carbon fiber



$7$   
 $\alpha f \delta e^{i\pi} =$   
2.7182818284  
 $\Sigma!$

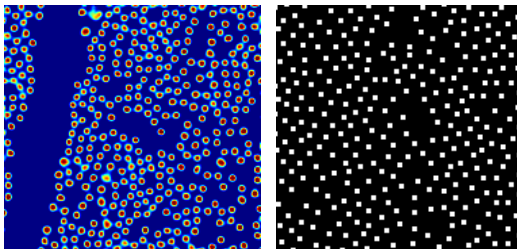
## Research topics

### Current research topics

- ▶ Generalization to 3D
- ▶ User input, small and easy
- ▶ Dictionary, when and how
- ▶ Handling big data

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$

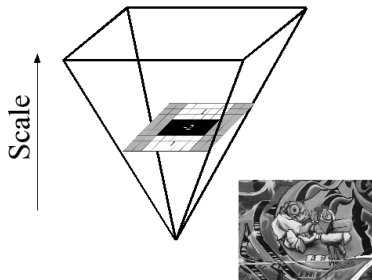
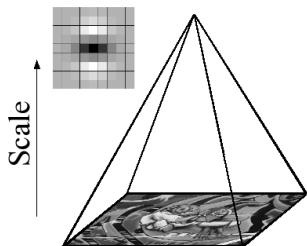
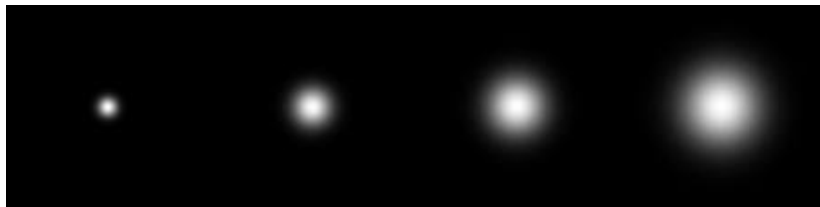
## Discretization



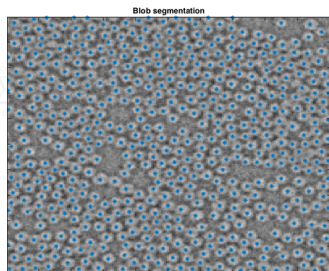
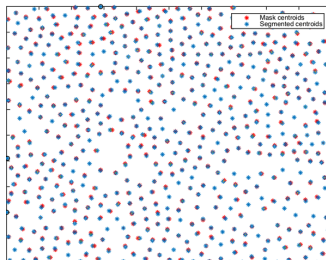
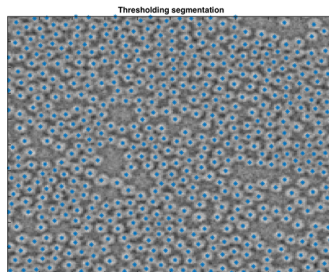
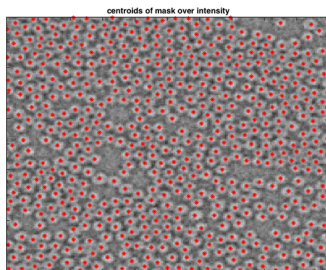
### Tested options

- ▶ Treasholding
- ▶ Scake space blob detection

# Discretization, scale space blob detection



# Discretization, Monicas results



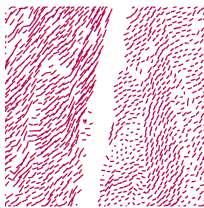
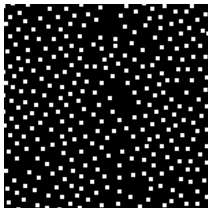
## Discretization, Monicas results

True positive ratio depending on discretization, in percentages

	thresholding	blob detection
glass fiber	99.1	93.4
thick carbon fibre	100	98.9
thin carbon fibre	95.5	100

$$f(x+\Delta x) = \sum_{l=0}^{\infty} \frac{(\Delta x)^l}{l!} f^{(l)}(x)$$

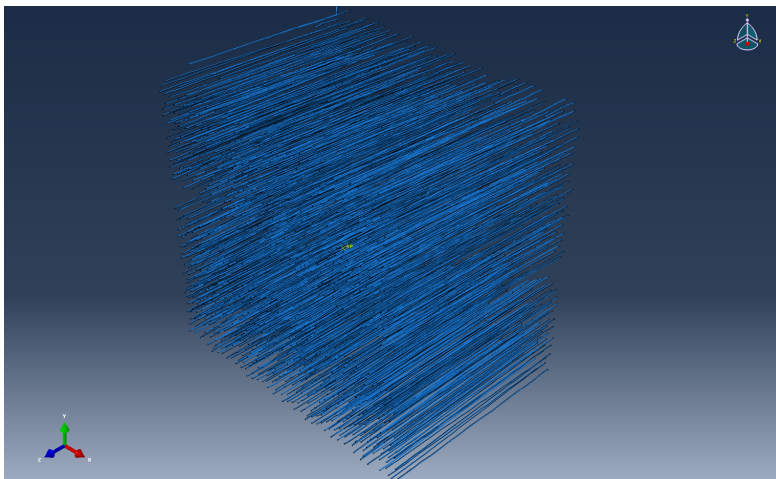
# Tracking



## Tested options

- ▶ Nearest neighbor heuristics

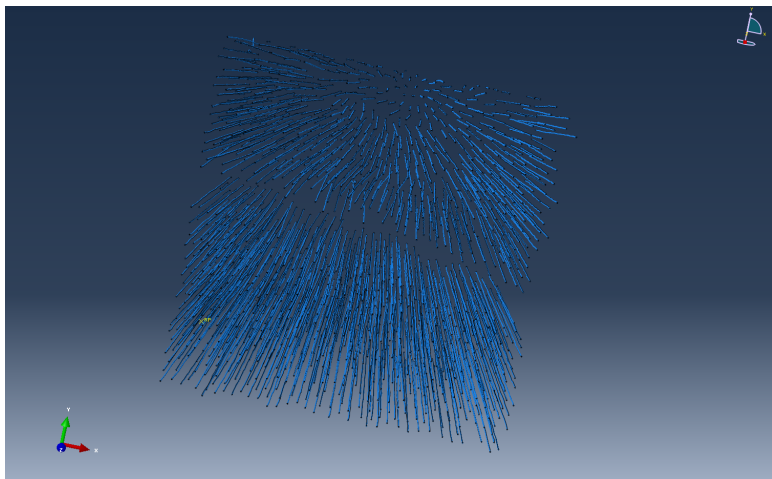
## Fibers in abaqus



Visualization of fiber centers by Kristine Munk Jespersen, DTU Wind Energy.

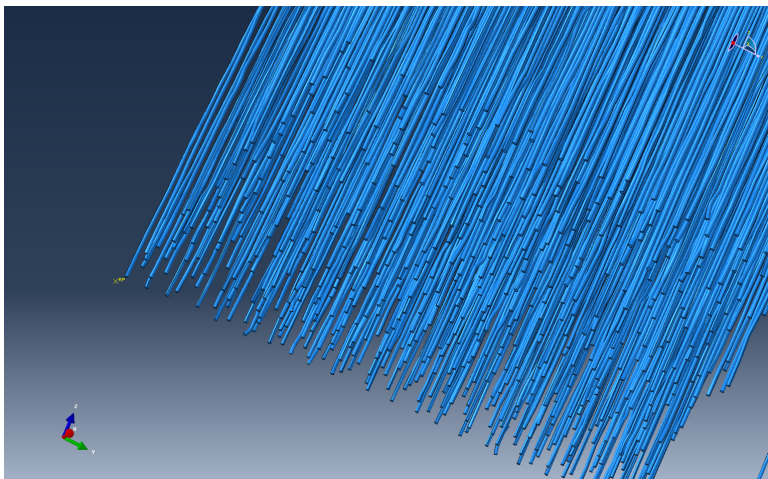


## Fibers in abaqus



Visualization of fiber centers by Kristine Munk Jespersen, DTU Wind Energy.

## Fibers in abaqus

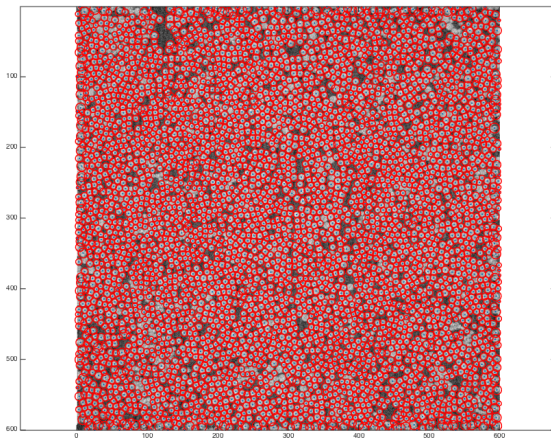


Visualization of fiber centers by Kristine Munk Jespersen, DTU Wind Energy.

## Radius estimation

### Tested options

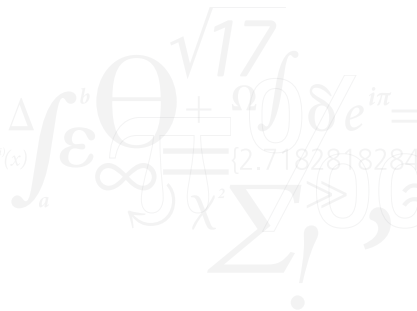
- ▶ Blob detection response



Monicas results, visualization of fiber radii.

Thank you!

Questions?


$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x)$$