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An evaluation of scale and noise sensitivity of fibre orientation estimation in volume images

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Introduction

Fibre orientation is an important structural property of fibre-based materials. It determines for example mechanical properties and the tendency of paper to curl and twist. We present a new method for estimating the fibre radius or scale of the fibres that is applicable to solid fibres. We also present an evaluation of the method for estimating fibre orientation in volume images with respect to noise and scale.

Fibre orientation estimation

1. Calculate a local structure tensor in a neighbourhood of each voxel using six quadrature filters.
2. Smooth the tensor field component-wise to obtain better estimates and remove local errors. The fibre orientation is assumed to vary slower than the small-scale variations and noise that are suppressed.
3. Calculate the eigenvalues and eigenvectors of each tensor and sort the eigenvalues in descending order.
4. The fibre orientation is estimated as the orientation of the eigenvector with the smallest eigenvalue.
5. A corresponding certainty measurement, c_2, is calculated for each orientation estimate using the eigenvalues.

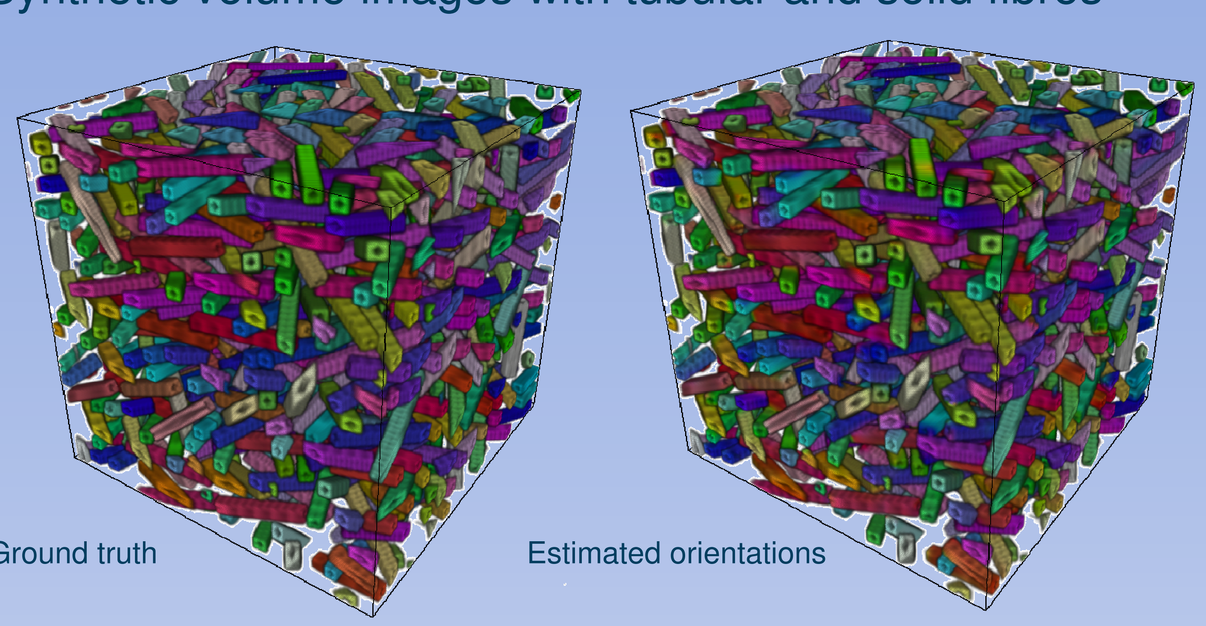
Method for estimating fibre radii

1. Obtain a binary representation of the fibre network by smoothing and binarising the volume image.
2. Calculate the 3D distance transform of the fibres.
3. Divide the fibres into segments by applying the watershed transform to the distance transform.
4. Label all segments using the distance maximum in each segment. This label image can now be used as a weight image to select scale in fibre orientation estimation or provide input for an estimate of the fibre size distribution.

Results

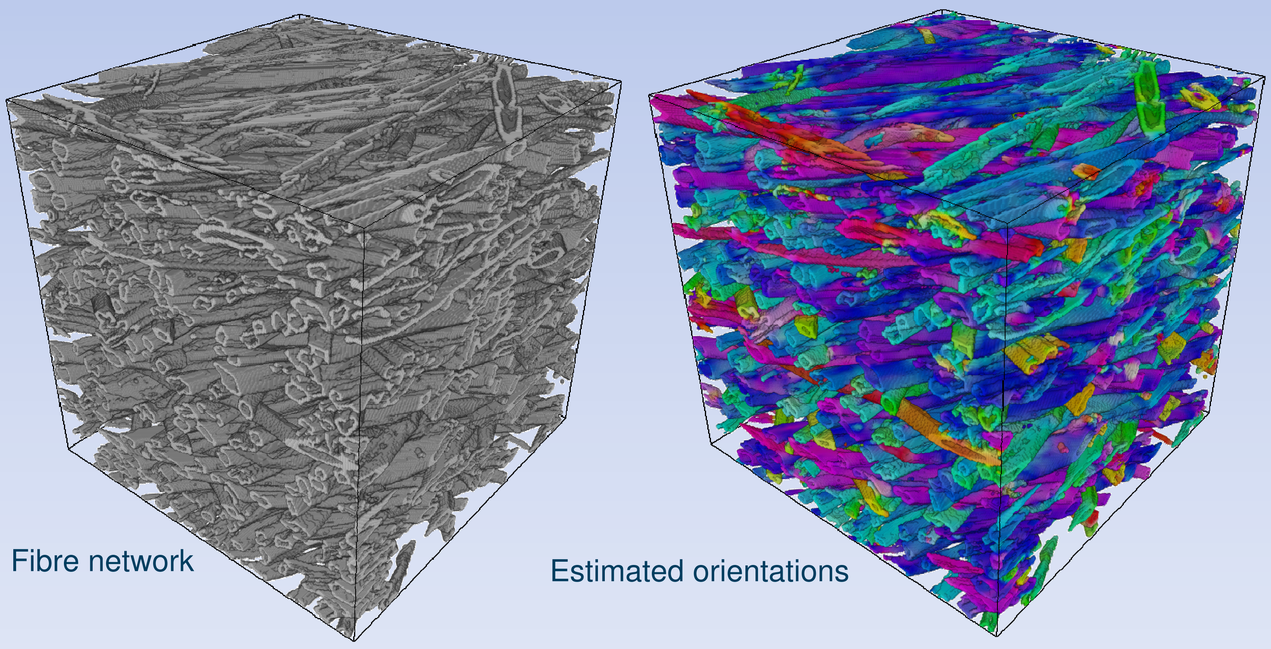
- ✓ The evaluation of the fibre orientation estimation shows that the method performs well both on different scales and in noisy images. It provides an estimate of the error that can be expected when the method is applied.
- ✓ The new method for estimating fibre radii can be used for automatic scale selection when estimating fibre orientation for solid fibres. In addition, it can provide an approximation of the fibre size distribution.

Synthetic volume images with tubular and solid fibres



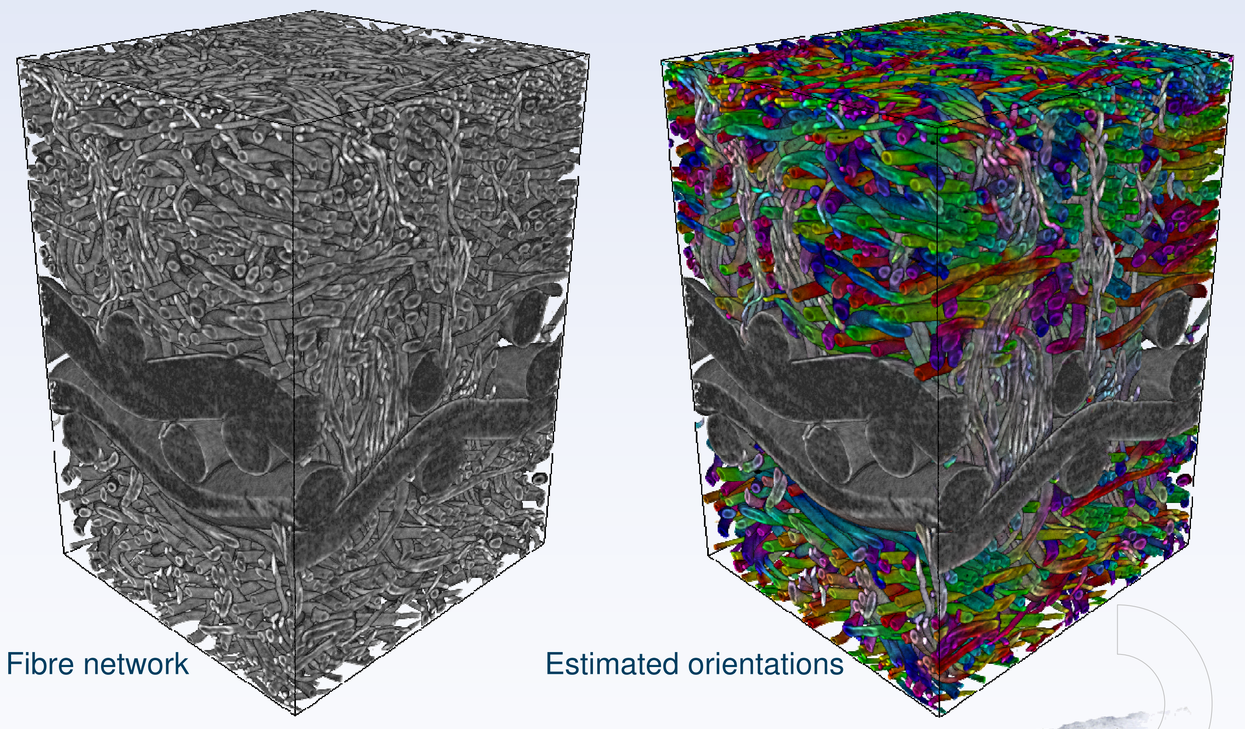
Ground truth — Estimated orientations

Tubular fibres in wood fibre composites

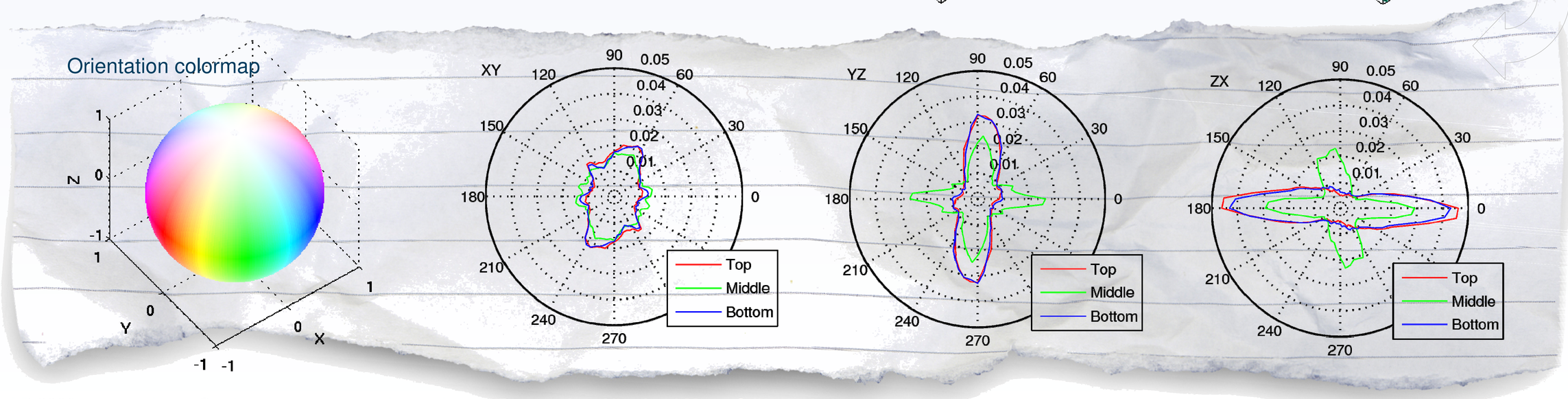


Fibre network — Estimated orientations

Solid fibres in press felts



Fibre network — Estimated orientations



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