Tampereen yliopisto
Tampere University

FibreNet

Microrobotic Automation for Fibers Characterization

Presenter: Ali Zarei (ESR 2)

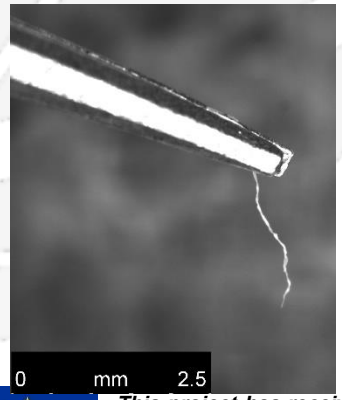
Supervisor: Prof. Pasi Kallio

Motivation:

Tampereen yliopisto
Tampere University

paper products

paper fiber



Flax linen

CHARACTERIZATION

Flax fiber

wound healing tape

Cellulose-based aerogel fiber

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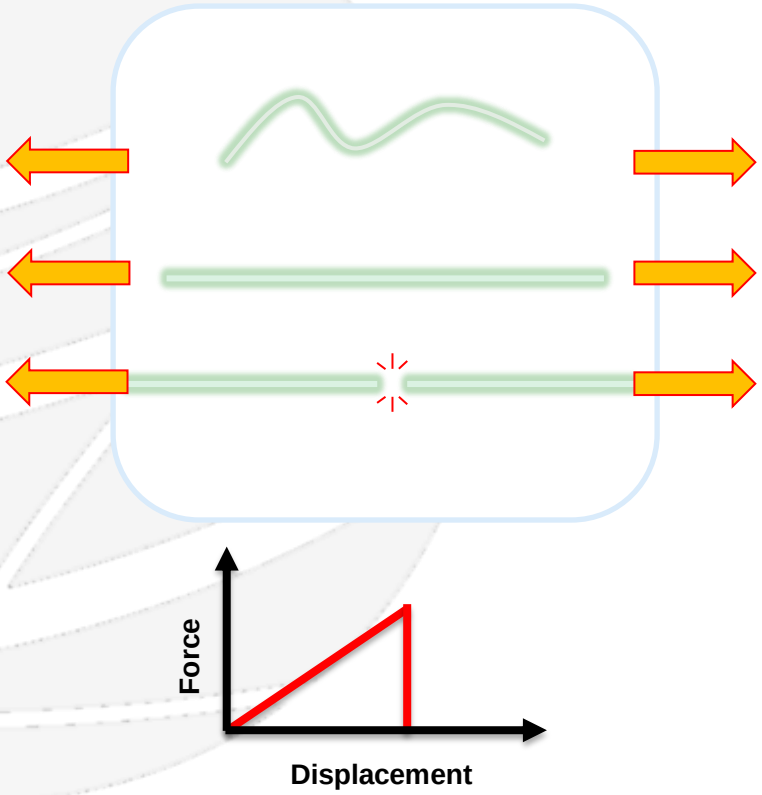
Fiber Characterization:

Tensile measurements



Micro-fibril Angle measurements

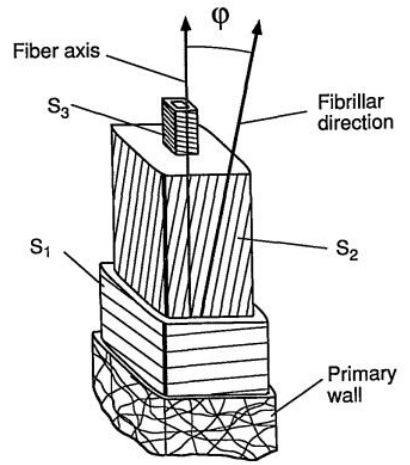
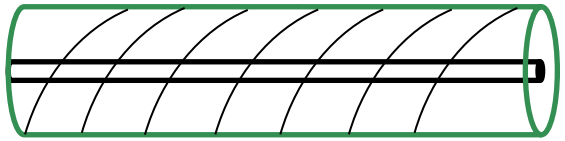


Fig. 1. Schematic representation of the layer structure of a single wood fiber: φ, fibril angle (see text).



$\phi = ?$

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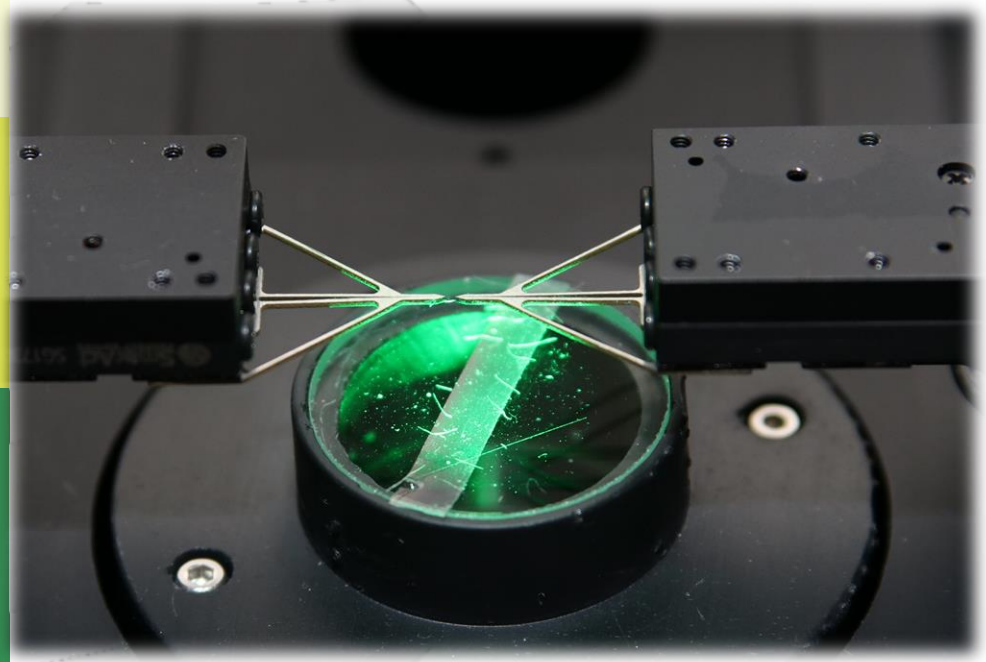
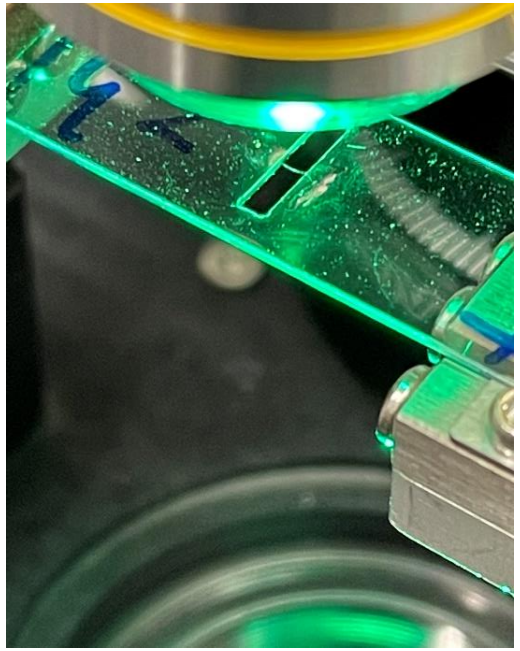
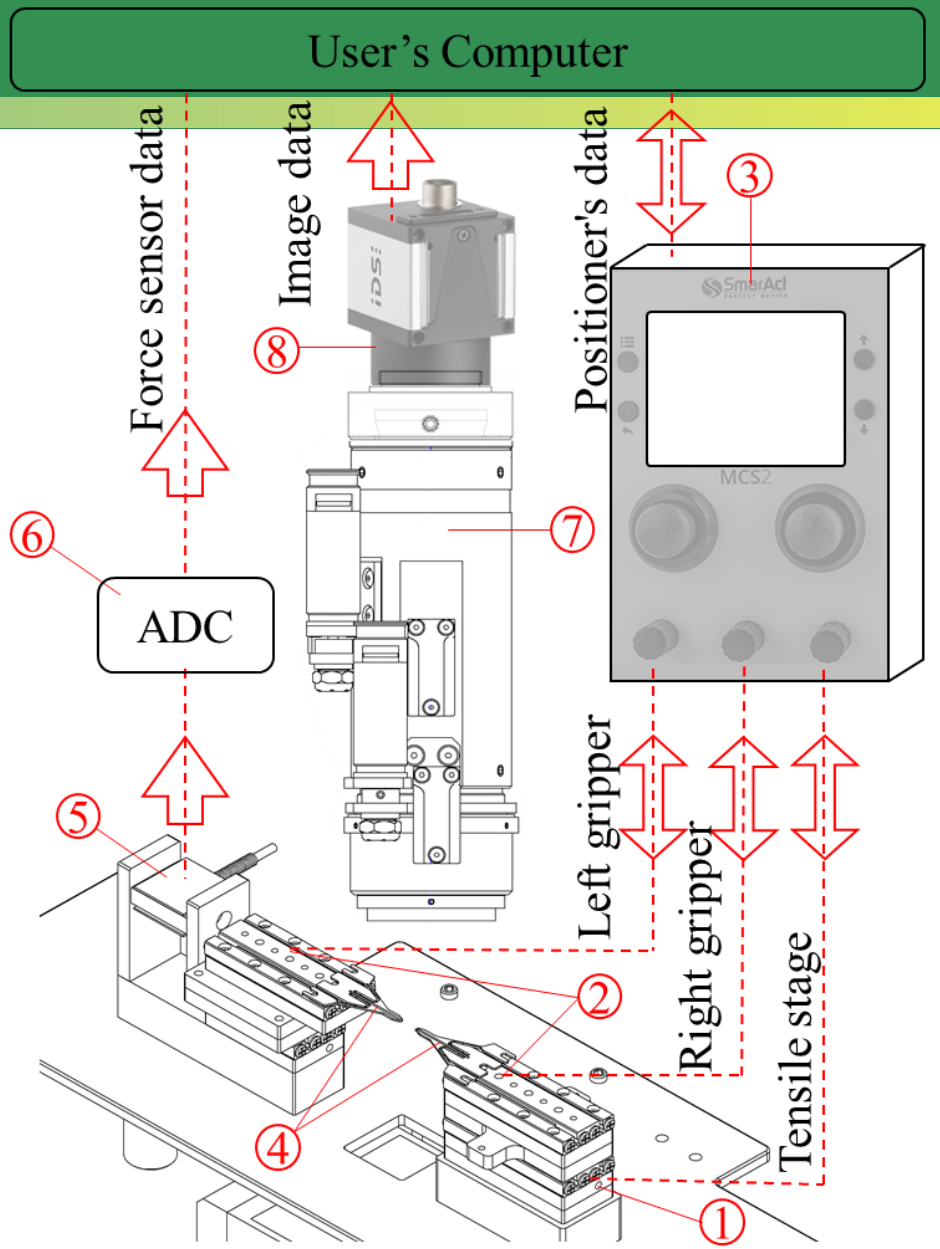
Microrobotic:







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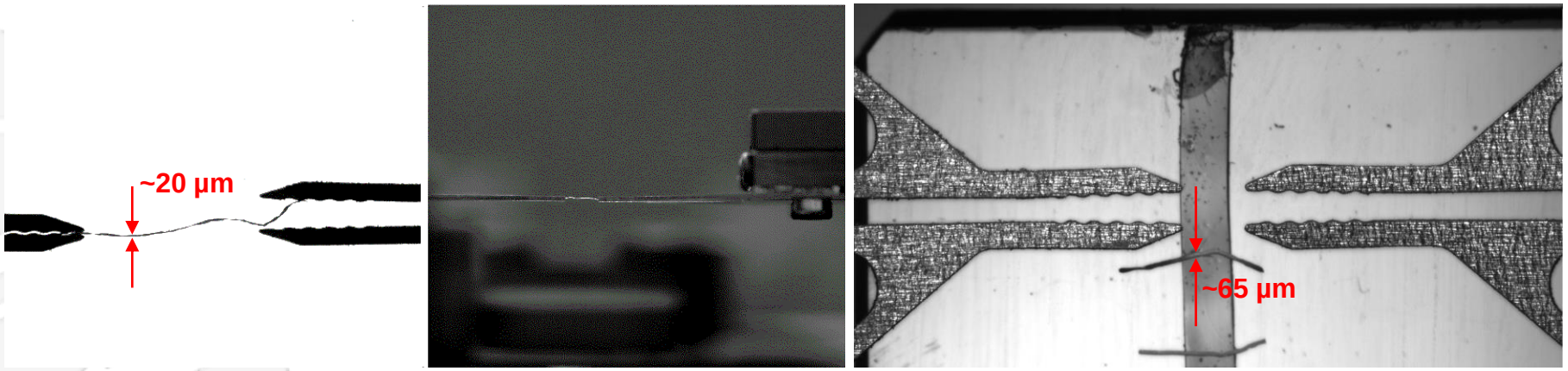
Microrobotic Automation:



Saving Time

- Collecting organized data
- Faster specimen manipulation

More and Reliable Data

- Higher throughput of successful experiments
- Less failures, less-destructive manipulation

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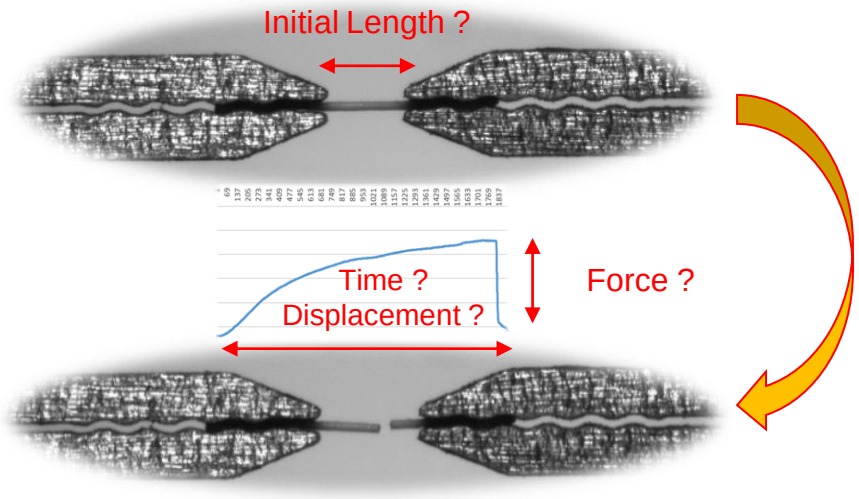
Automation – grasping and tensile test:

Tensile test

Collect the data



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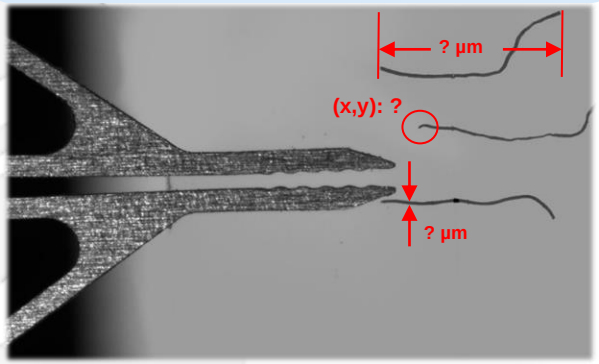
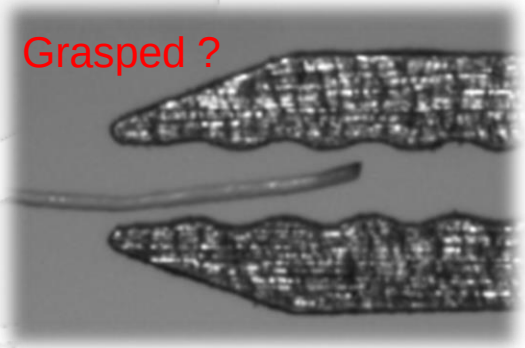
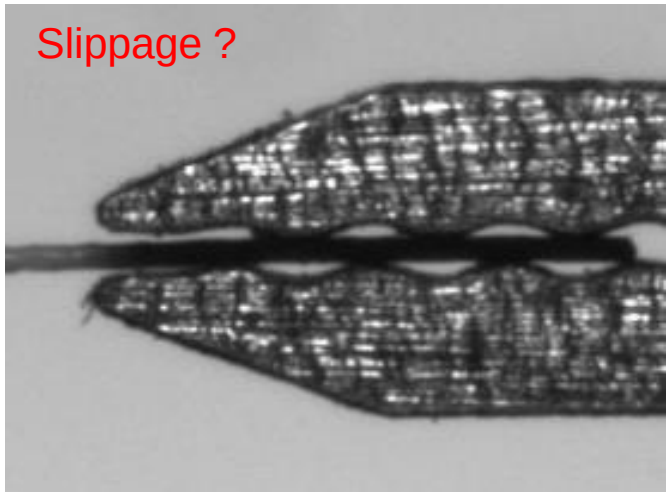
Automation – grasping and tensile test:

Fiber grasping





Failure Management



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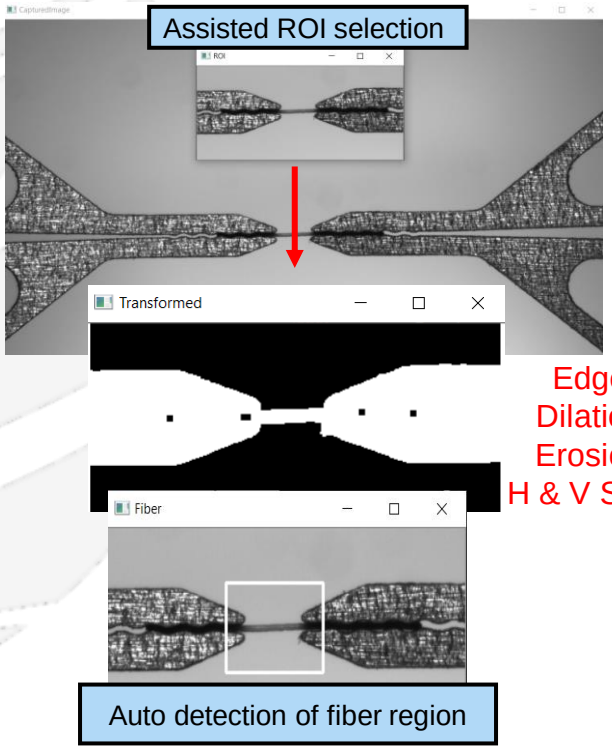
Automation – tensile test:

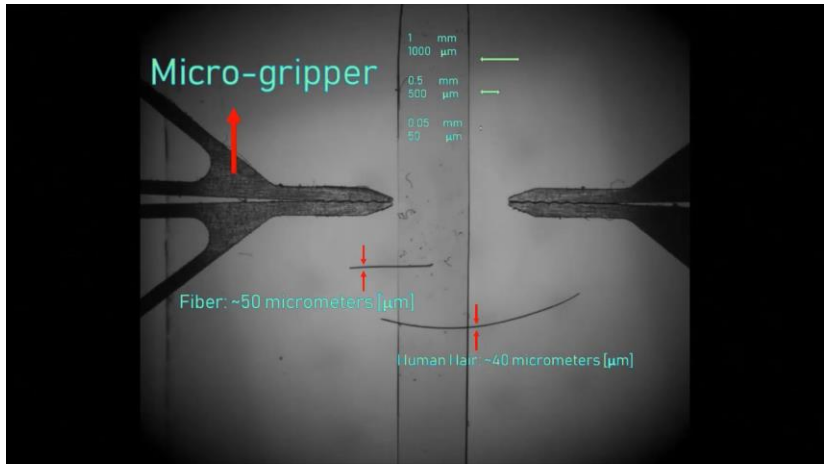
Solution

Set and click for tensile test

Semi-Automated test and data collection



Edge
Dilation
Erosion
H & V Scan



Displacement
Force
Time

Initial length

15-20 tensile test per hour

[65 µm cellulose-based aerogel fibers of IRP #4]

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FibreNet

Automation – grasping:

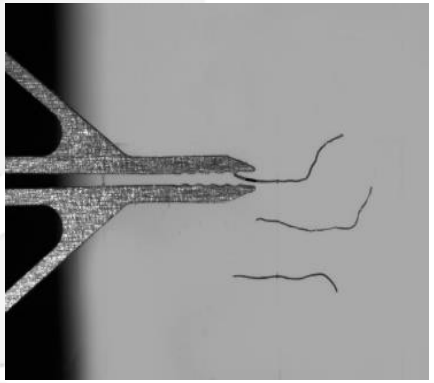
Spotlight

Locating objects
(grippers and fibers)

Solution

Collecting dataset and feed a model
(images and manual annotation)

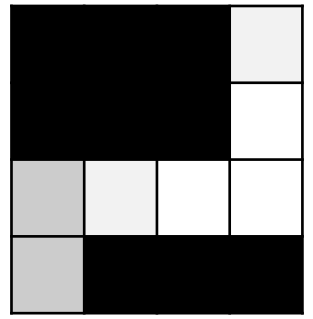
Training

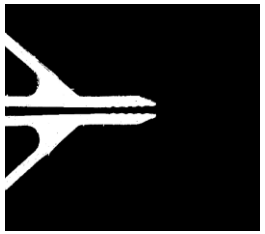


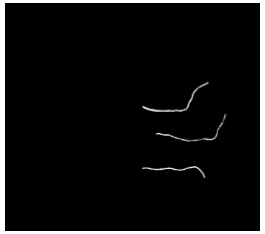
Convolutional Neural Network (CNN)

"U-Net"

Trained for either Gripper or Fiber







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FibreNet

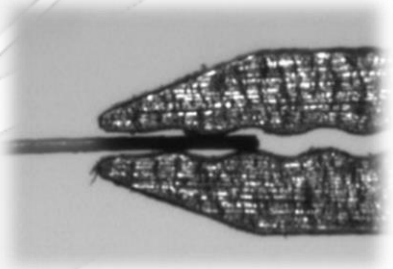
Automation – grasping:

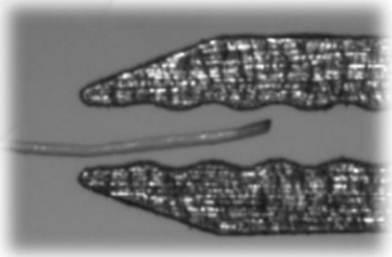
Spotlight

Grasp Recognition

Solution

Collecting dataset and feed a model (images)





Training

Convolutional Neural Network (CNN)

Transfer Learning "VGG16" + custom layers

Pre-trained by "imagenet" trained for Left/Right Slippage

Grasped
0/1

- Grasped
- Not

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Automation – grasping and tensile test:

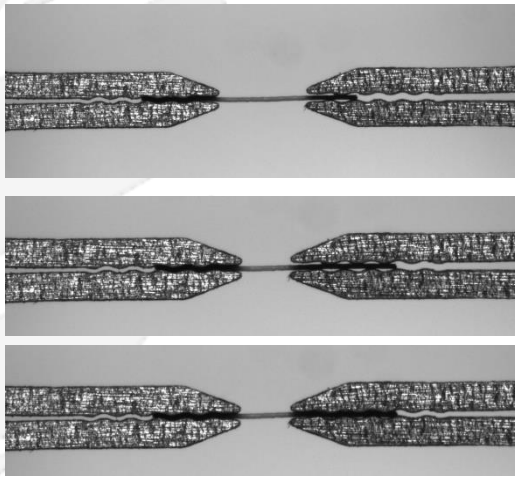
Spotlight

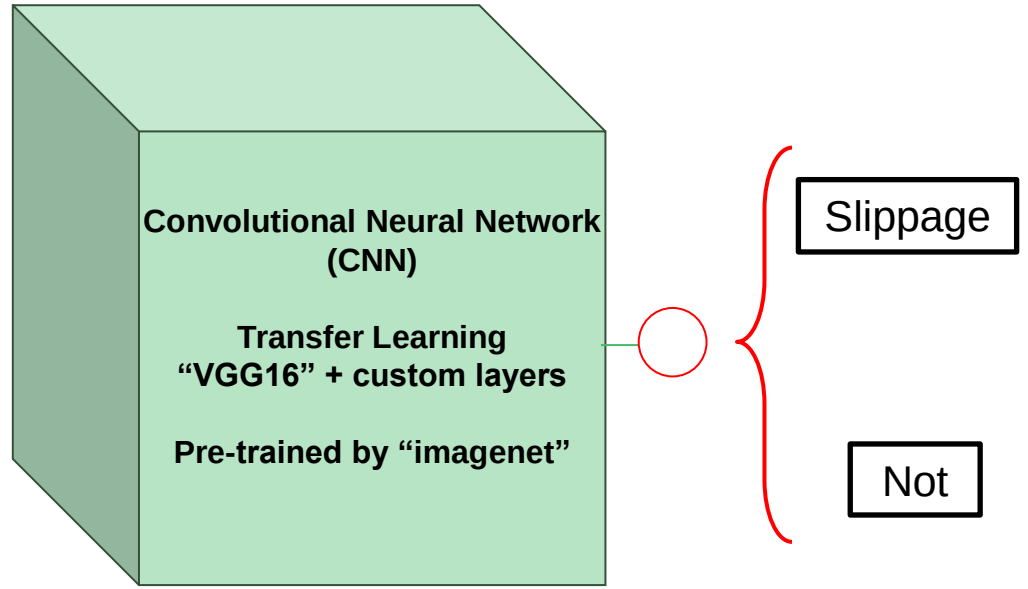
Slippage Prediction

Solution

Collecting dataset and feed a model (images)

Training





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Automation – grasping and tensile test:

Title	Method	Result
Assisted ROI Selection, Detecting free region of grasped fiber automatically	Morphological methods on image	Extracting initial length of grasped fiber before test
State recognition of fiber (Grasped or Not)	CNN on images (transfer learning using VGG16)	**94.2 %** accuracy in average
Slippage prediction before test	CNN on images (transfer learning using VGG16)	Left slippage prediction: **71.4 %** Right slippage prediction: **71.53 %** Successful test prediction: **84.35 %**
Automatic object segmentation for scene understanding	CNN on images (using U-Net)	Segmentation of fibers and grippers (>**80%** of pixels)

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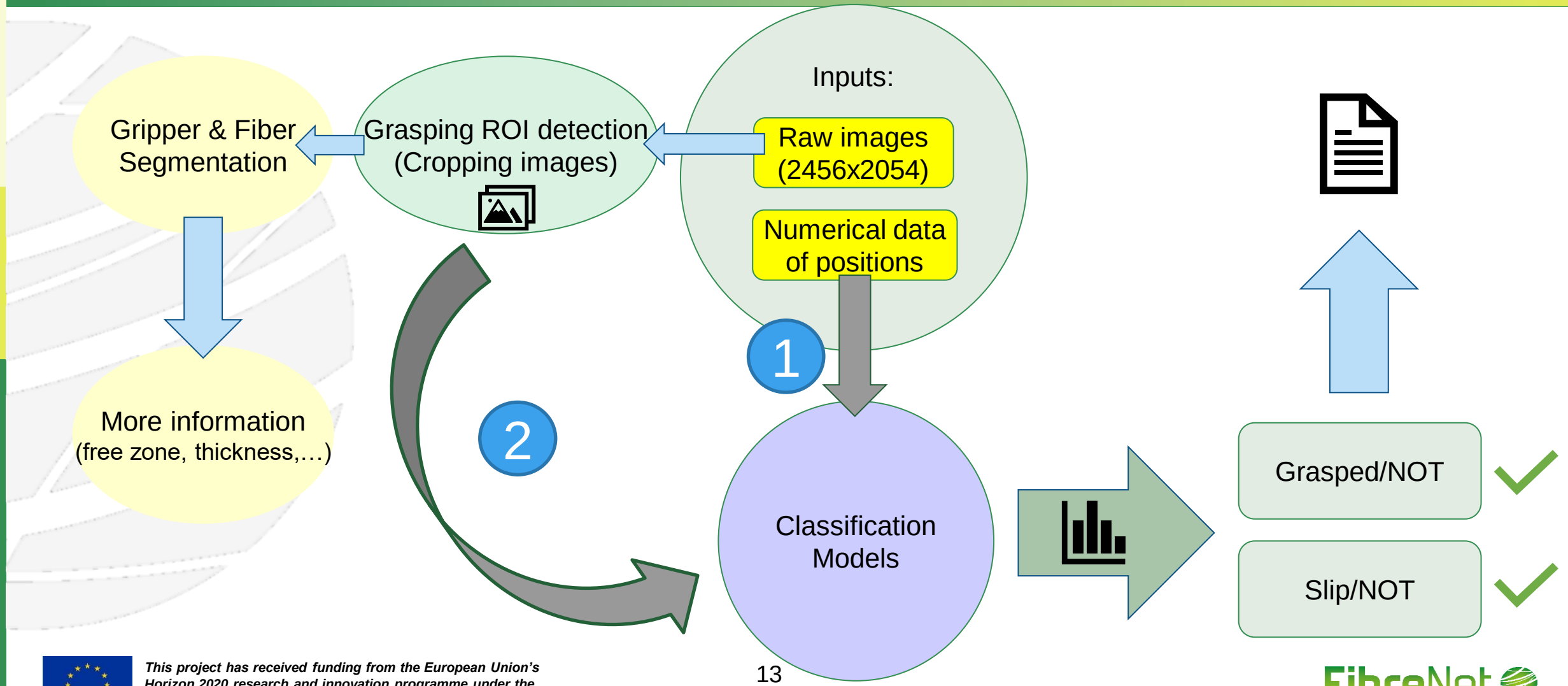
Automation – grasping and tensile test:



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Challenges – grasping and tensile test:

- High diversity of dimensions and shapes of natural fiber
  - Needs our methods to become more generalized
- Initial length is hard to measure,
  as the contact point is unknown
- Hard to extract interaction information
  between paper fibers (<20 μm) and gripper's surface

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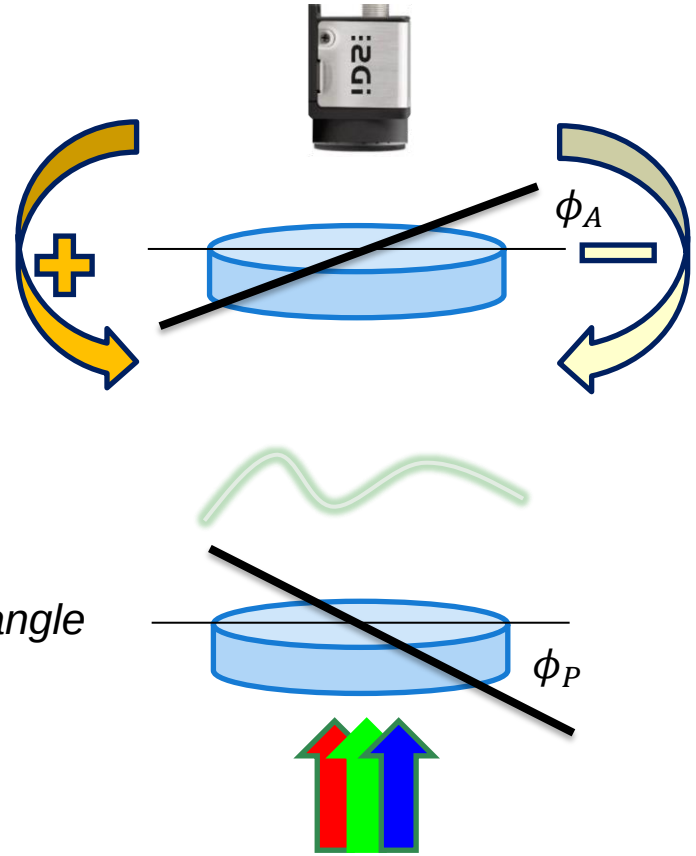
Automation – MFA:



Camera view

analyzer ϕ_A: rotating [0:5:180]

fiber

polarizer $\phi_P = -45\ degrees$

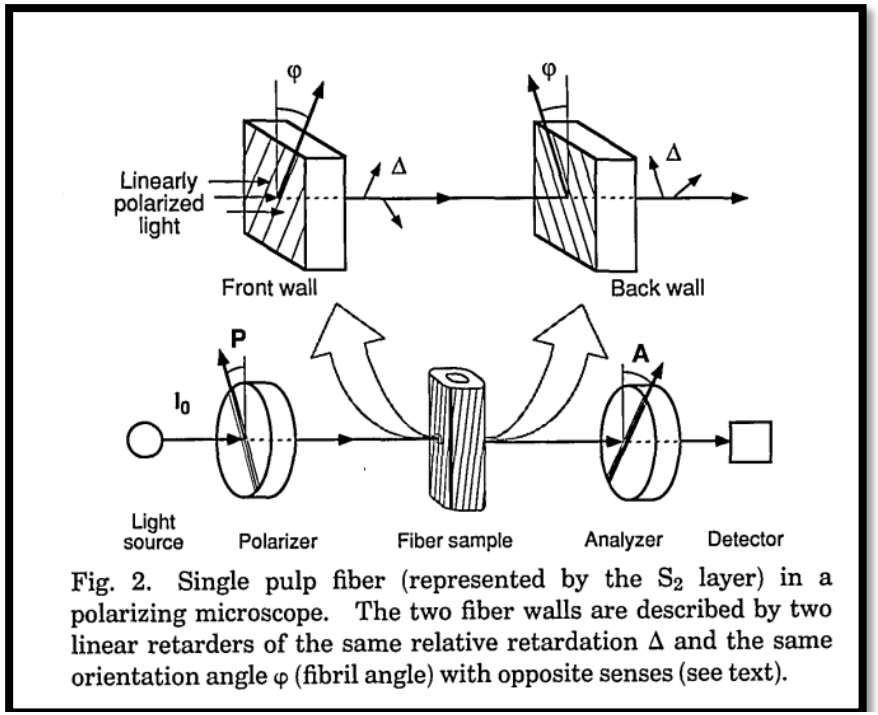


Fig. 2. Single pulp fiber (represented by the S_2 layer) in a polarizing microscope. The two fiber walls are described by two linear retarders of the same relative retardation Δ and the same orientation angle φ (fibril angle) with opposite senses (see text).

Ye, Chun, M. Olavi Sundström, and Kari Remes. "Microscopic transmission ellipsometry: measurement of the fibril angle and the relative phase retardation of single, intact wood pulp fibers." *Applied optics* 33.28 (1994): 6626-6637.

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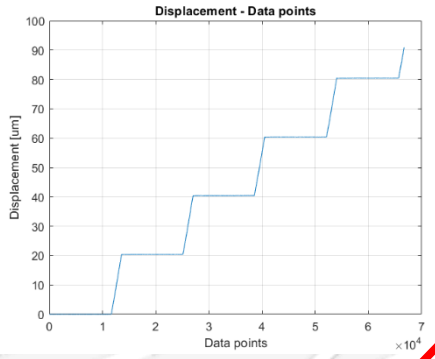
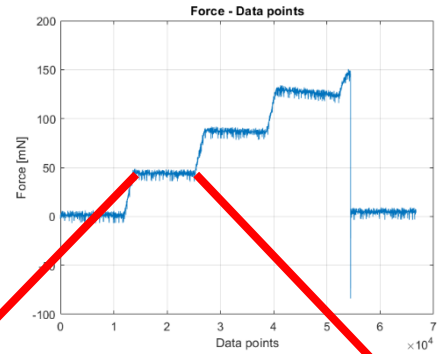
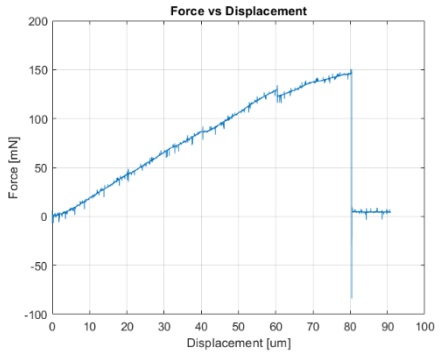
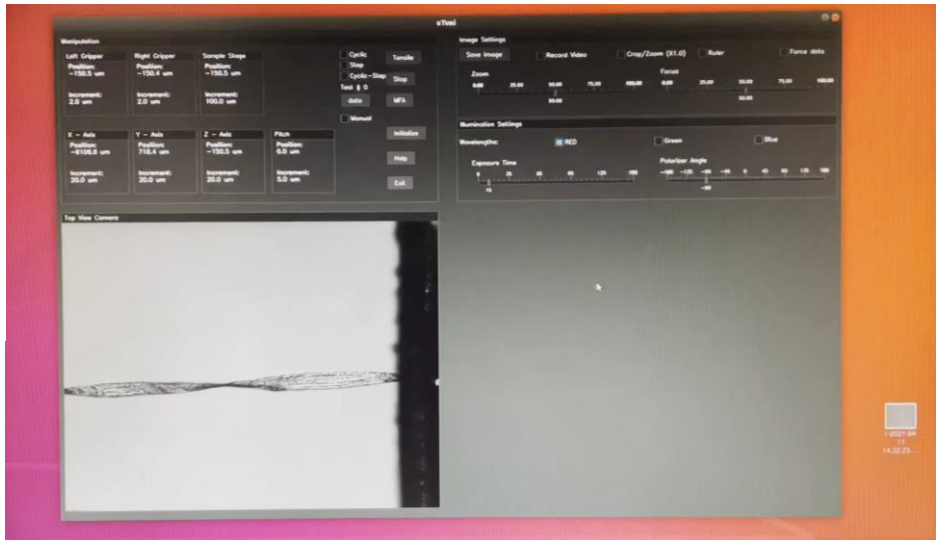
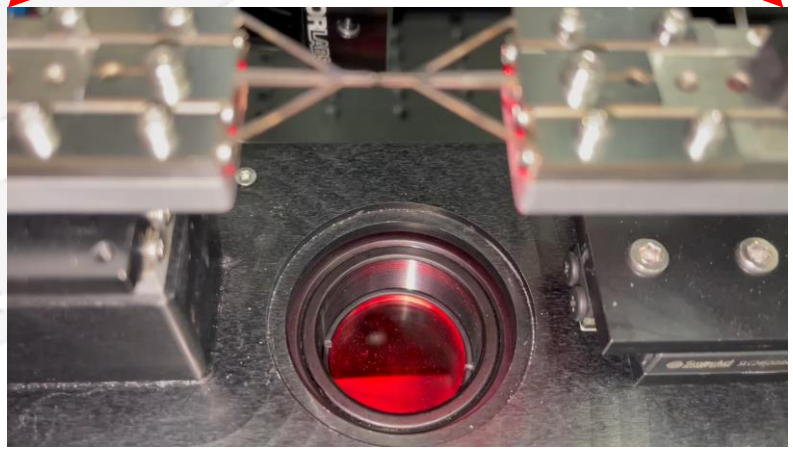
Automation – MFA:

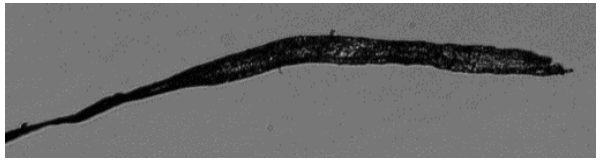


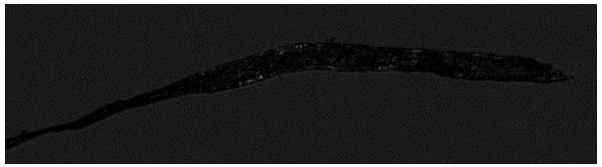












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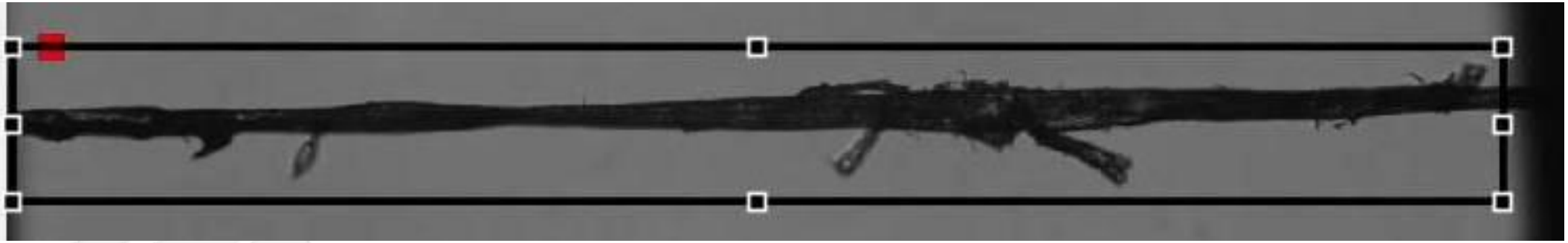
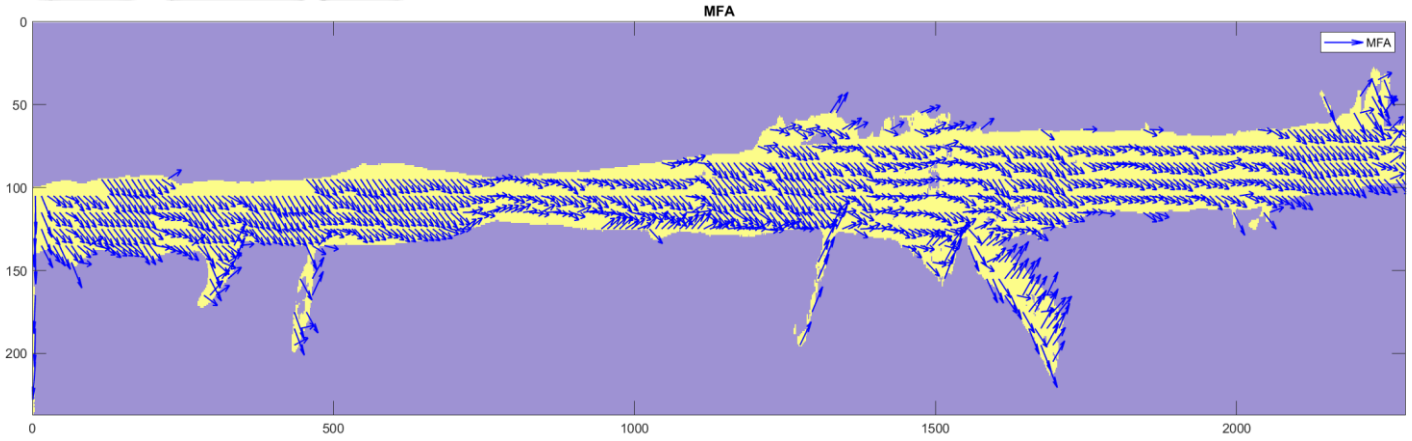
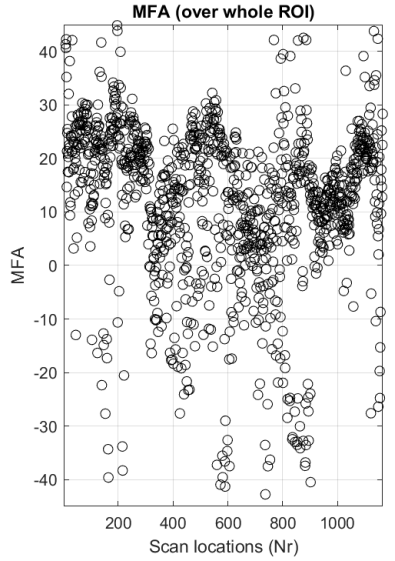
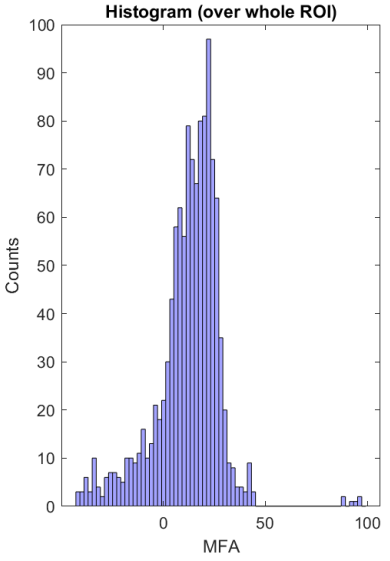
Automation – MFA analysis:









- Analysis by Dr. Dhanesh kattipparambil Rajan (dhanesh.kr@tuni.fi)

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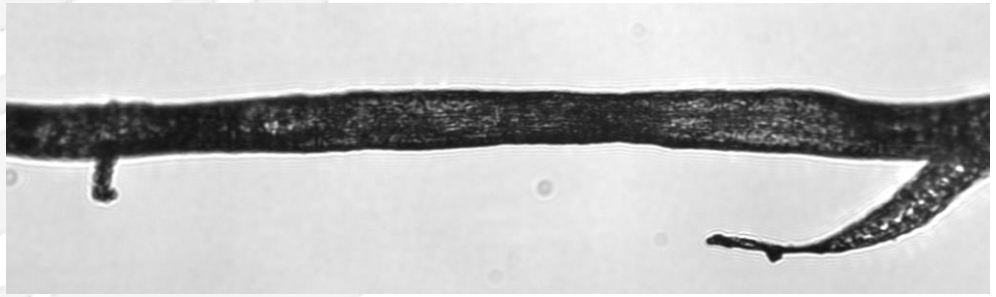
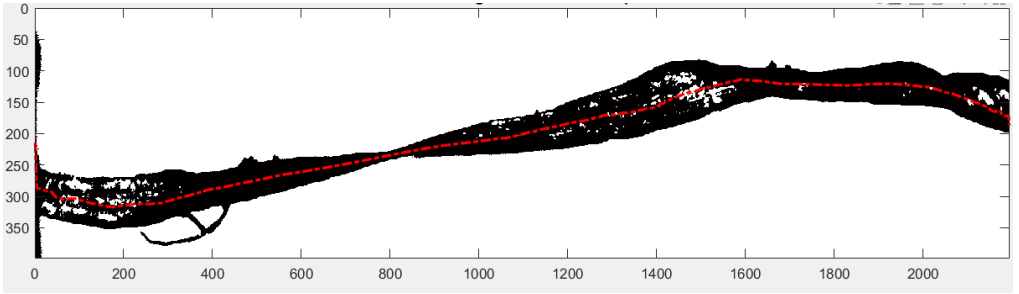
Challenges – MFA:

- **Fibre orientation**
  - **Chun Ye MFA method:** Straight fibres Vs twisted/curved fibres





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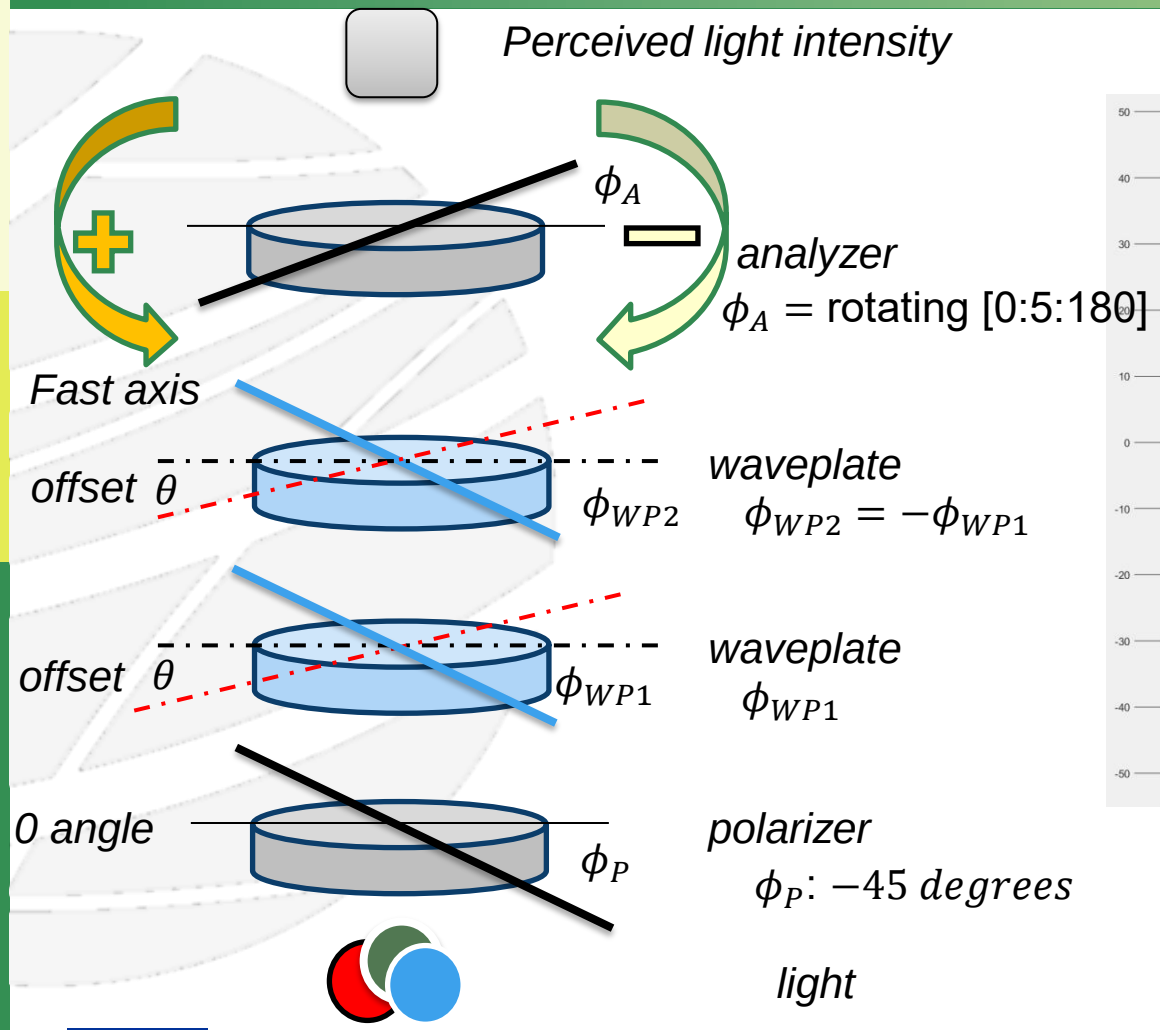
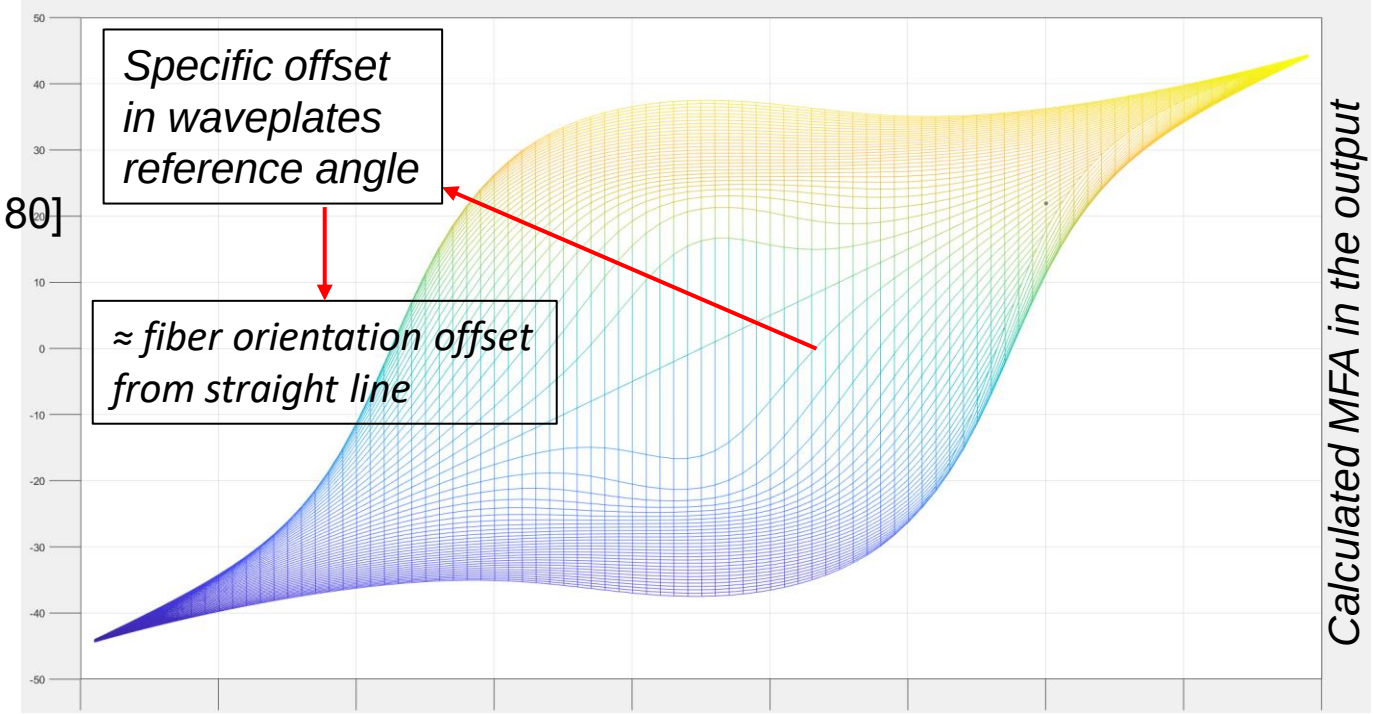
Challenges – MFA:





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Summary and future works:

- Automation of Grasping and tensile test
  - ✓ User-friendly software to perform the tensile test and collect data with a few clicks
  - ✓ Automatic initial length detector
  - ✓ ML-based method for samples and gripper segmentation
  - ✓ ML-based method to recognize the Grasped state of fiber
  - ✓ Slippage prediction of the fiber subject to tensile test inside the grippers (for 65 μm aerogel fibers)
- MFA measurement using light polarization
  Integrated in microrobotic platform for tensile test
- Reference method to extract real MFA

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FibreNet

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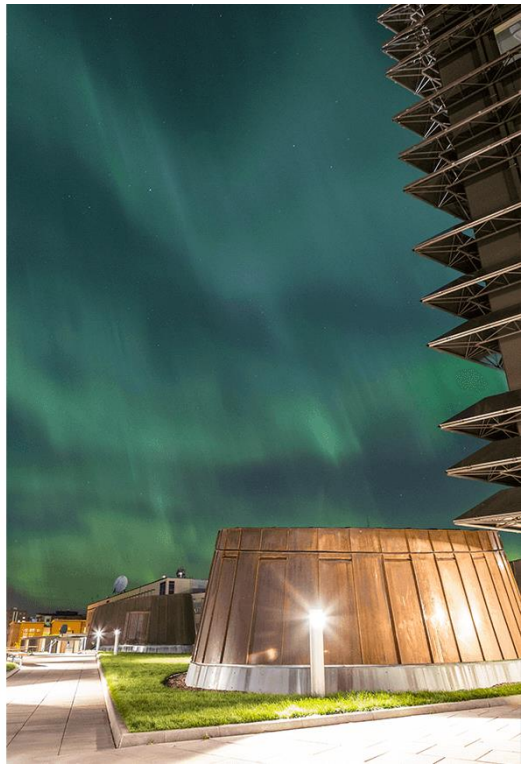
Thanks to our collaborators:

Research:
Dhanesh Kattipparambil Rajan
August Brandnerg
Marko Žižek
Matin Rostamitabar

Hardware design and implementation:
Olli Tanhuanpää
Markus Kakkonen

Supervision:
Pasi Kallio
Artem Kulachenko
Ulrich Hirn



More info: http://fibrenet.eu/

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