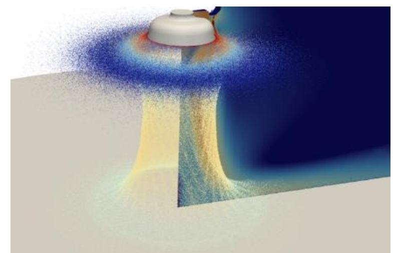
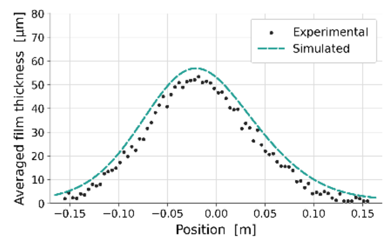
FRAUNHOFER CHALMERS
RESEARCH CENTRE FOR INDUSTRIAL MATHEMATICS

Master thesis proposal

Optimization of spray brush generation





Surface treatment is a critical industrial process that directly affects product performance, durability and visual quality. At the Fraunhofer-Chalmers Centre, we have developed simulation methods covering all standard surface-treatment processes in a Virtual Paint Shop: electrocoating, spray painting, powder coating, sealing and oven curing. This enables users to plan painting processes already in the design phase, optimize workflows virtually and reduce the need for physical trials.

The goal

To design an optimization procedure to generate brushes that numerically describe the parametrization of an electrostatic rotary bell sprayer

Main tasks

- Review relevant literature on spray painting
- Design an optimization algorithm to generate spray droplet size distributions from experimental paint thickness measurements
- Validate on a real industrial case together with Volvo Car Corporation, partner from the Vinnova funded project: AI-Boosted Automated Painting

Expected outcome

A validated optimization algorithm, which provides an inverse solution to the atomization of the spray, by generating spray droplet size distributions that produce an experimentally measured thickness profile. The dependence on input parameters should be analyzed. Criteria for a minimum DOE used as input.

Student profile

Master student in mechanical engineering, applied physics, engineering mathematics, or similar. Experience in numerical methods and simulation, especially CFD, is meriting. Programming skills (Python, C++ or similar) are advantageous. It may be possible to start with a part-time student position during fall 2026.

Supervisors
Dr Tomas Johnson, tomas.johnson@fcc.chalmers.se
Johan Göhl, johan.gohl@fcc.chalmers.se

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FRAUNHOFER CHALMERS
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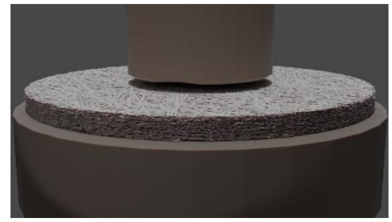
Master thesis proposal

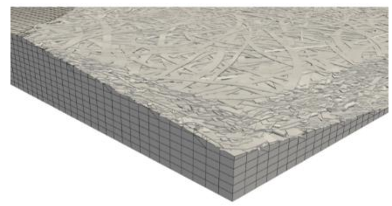
From Fiber Networks to Continuum Models: Multiscale Simulation of Paperboard

The mechanical properties of paperboard originate from the underlying network of fibers and fiber-fiber bonds. Micro-mechanical simulations provide detailed insight into how fiber and network properties influence the response of the material. However, due to their computational cost, such models are limited to small representative volumes, while industrial-scale analyses rely on continuum finite element models. Establishing links between these modelling approaches is therefore an important step towards predictive multiscale simulation tools for paperboard materials and products.



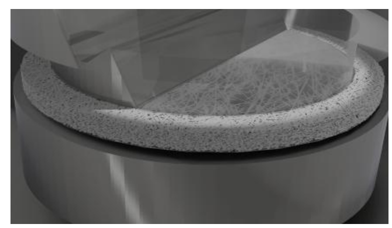
The goal

The goal of this thesis is to investigate how information from micro-mechanical fiber-network simulations can be used to define material models for continuum finite element analyses of paperboard.



Main tasks

- Review existing multiscale modelling approaches.
- Generate material properties from micro-mechanical fiber-network simulations.
- Develop methods for incorporating these properties into continuum FEM models.
- Investigate the effect of spatially varying and non-linear material descriptions.
- Evaluate and compare predictions at different scales.



Expected outcome

The thesis aims at developing and evaluate methods for transferring information from micro-mechanical simulations to continuum FEM models. The work may include both spatially varying material properties and non-linear constitutive descriptions derived from micro-scale simulations. The results will contribute towards predictive multiscale simulation tools for paperboard materials and products.

Student profile

The project is suitable for students with an interest in computational mechanics, finite element methods, material modelling, and scientific computing. Experience in numerical simulations and programming is advantageous but not required. Students interested in starting earlier may have the opportunity to work part-time on related projects during the autumn semester before the thesis begins.

Supervisors
Gustav Kettil, gustav.kettil@fcc.chalmers.se, 0731-450233
Morgan Görtz, morgan.gortz@fcc.chalmers.se, 0731-450258

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Master thesis proposal

Modelling Tree Root Systems for Stability Analysis

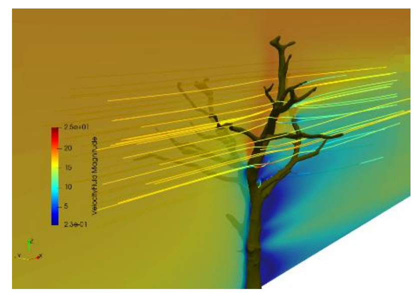
Tree stability under wind loading is governed by the interaction between the crown, stem, root system, and the soil. While forces generated by wind act primarily on the canopy, the overturning moments are transferred through the stem to the roots, which provide the mechanical anchorage necessary to prevent failure. Root architecture and mechanical properties, and root–soil interaction are the key factors controlling resistance against uprooting. Coupled DEM–FEM modelling offers a powerful approach to investigate the complex interaction between roots and soil and to quantify the anchorage behavior of trees under wind-induced loads.

The goal

Develop and evaluate a numerical framework for modelling tree root systems and their interaction with soil to estimate the mechanical stability of trees under loading.

Main tasks

- Utilize an existing DEM–FEM framework to model root–soil interaction.
- Investigate the influence of root architecture and soil properties on tree stability.
- Perform sensitivity analyses to identify the most influential modelling parameters.
- Evaluate the capabilities and limitations of the proposed modelling approach.



Expected outcome

- A modelling strategy for stability estimates of tree roots
- Increased understanding of how root architecture influences tree anchorage.
- Identification of model parameters that require experimental calibration.
- Recommendations for future validation studies.

Student profile

Master student in mechanical engineering, applied physics, computational science, or similar. Experience in numerical methods and CFD simulations is meriting. Programming skills in Python are advantageous. When writing the master thesis in spring 2027, there is the possibility to start with a part-time student position during autumn 2026.

Supervisors

Dr. Franziska Hunger, franziska.hunger@fcc.chalmers.se, 0731-450230

Dr. Gustav Kettil, gustav.kettil@fcc.chalmers.se, 0731-450233

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FRAUNHOFER CHALMERS
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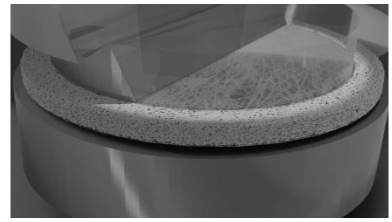
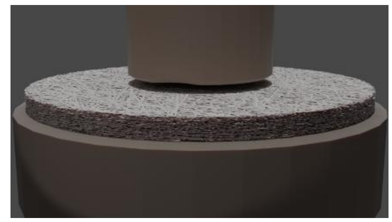
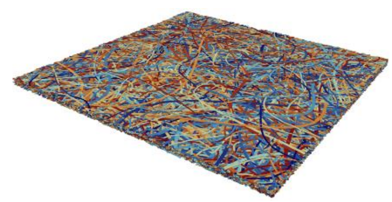
Master thesis proposal

Evaluation of Non-linear Beam Models for Fracture Simulation in Micro-mechanical Fiber Networks

Paperboard is a fiber-based material whose mechanical properties are governed by the fibers and fiber-fiber bonds. Micro-mechanical network models provide a powerful tool for studying how the structure influences material behavior. Linear mechanical models may limit the accuracy when large deformations and damage occur. With non-linear FEM, it becomes possible to investigate how non-linear beam behavior influences the predicted response and fracture of fiber networks.







The goal

The goal of this thesis is to evaluate the influence of non-linear beam mechanics on fracture simulations of micro-mechanical fiber networks, by comparing linear and non-linear model predictions for different mechanical tests relevant to paperboard.

Main tasks

- Review the current fiber-network fracture simulation approach.
- Perform mechanical simulations using linear and non-linear models.
- Compare stress-strain response, damage evolution, and failure behavior.
- Investigate how model differences depend on loading conditions and network characteristics.
- Assess when non-linear modelling is required for accurate predictions.

Expected outcome

The thesis is expected to provide increased understanding of how non-linear mechanics influences stress-strain behavior, damage development, and fracture processes in fiber-based materials, and will help establish guidelines for when non-linear modelling is required in micro-mechanical simulations of paperboard.

Student profile

The project is suitable for students with an interest in computational mechanics, finite element methods, material modelling, and scientific computing. An interest in programming and numerical simulations is advantageous, but prior experience with fiber-based materials is not required. Students interested in starting earlier may have the opportunity to work part-time on related projects during the autumn semester before the thesis begins.

Supervisors
Gustav Kettil, gustav.kettil@fcc.chalmers.se, 0731-450233
Morgan Görtz, morgan.gortz@fcc.chalmers.se, 0731-450258

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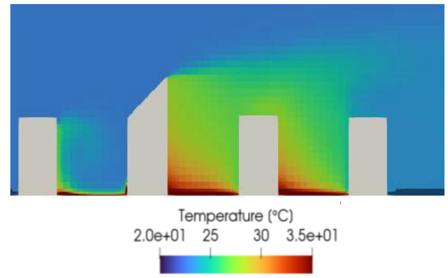
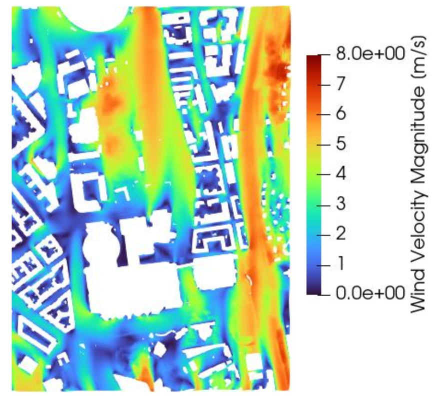
Master thesis proposal

Simulation of urban heat incorporating trees



Urban heat is an increasing challenge in many cities, making effective mitigation strategies essential for sustainable development. Trees contribute to cooling through shading and evapotranspiration, but they also alter airflow and ventilation. Understanding these competing effects requires advanced modelling.
This master's thesis project applies the immersed boundary method within Computational Fluid Dynamics to simulate wind, heat transfer, and radiative processes, with a particular focus on representing trees as source and sink terms in the model.

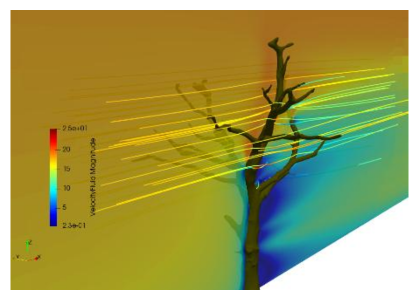
The goal



Extend an existing CFD modelling framework by incorporating thermal source and sink terms that represent tree evapotranspiration and perform simulations for verification and validation.

Main tasks

- Develop and implement thermal methods to include evapotranspiration effects of trees within the existing CFD framework
- Perform a study to evaluate the influence of key source-term parameters
- Conduct simulations to assess the impact of trees on urban heat conditions
- Analyse simulation data to understand the interplay between shading, cooling, reduced ventilation
- Shading, evaporative cooling, and reduced ventilation



Expected Outcome

A validated modelling strategy for tree-induced thermal effects in CFD, robust analysis methods for evaluating urban heat mitigation strategies and clear, effective, and visually appealing communication of results.

Student profile

Master student in mechanical engineering, applied physics, computational science, or alternatively Architecture or Urban Planning with strong knowledge of urban physics and fluid dynamics. Experience in numerical methods and CFD simulations is meriting. Programming skills in Python are advantageous. When writing the master thesis in spring 2027, there is the possibility to start with a part-time student position during autumn 2026.

Supervisors
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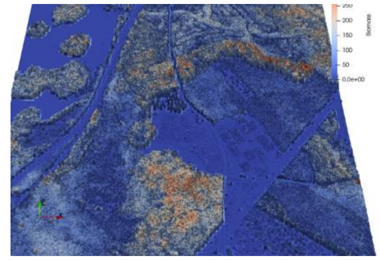
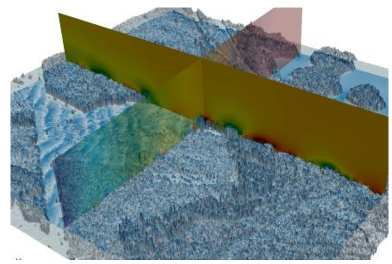
Master thesis proposal

Accelerated Prediction of Forest Wind Flow Using Machine Learning and CFD

Prediction of wind flow in forests is essential for assessing wind damage risk, understanding microclimates, and supporting forest management. High-fidelity CFD simulations can capture the influence of complex forest structures but are computationally expensive, limiting their use in large-scale analyses. This project investigates how machine learning can be used to enable rapid prediction of wind fields while retaining much of the accuracy of high-fidelity models.





The goal

Develop a machine-learning surrogate model capable of predicting three-dimensional wind flow in forests based on terrain, vegetation, and atmospheric conditions.

Main tasks

- Investigate machine learning architectures for spatial prediction of wind fields.
- Generate or utilize an existing CFD dataset covering different wind conditions.
- Develop a workflow that combines GIS-based terrain and forest data with machine learning.
- Train and evaluate models for predicting wind velocity fields.
- Compare prediction accuracy and computational performance with full CFD simulations.

Expected Outcome

A proof-of-concept framework demonstrating how machine learning can accelerate wind flow prediction in complex forest environments. The project will evaluate the trade-off between computational efficiency and prediction accuracy and identify suitable approaches for integrating AI with physics-based simulations.

Student profile

Master student in mechanical engineering, applied physics, computational science, or similar. Experience in numerical methods and CFD simulations is meriting. Programming skills in Python and familiarity with GIS data handling are advantageous. Students interested in starting earlier may have the opportunity to work part-time on related projects during the autumn semester before the thesis begins.

Supervisors

Dr. Franziska Hunger, franziska.hunger@fcc.chalmers.se, 0731-450230

Dr. Gustav Kettil, gustav.kettil@fcc.chalmers.se, 0731-450233

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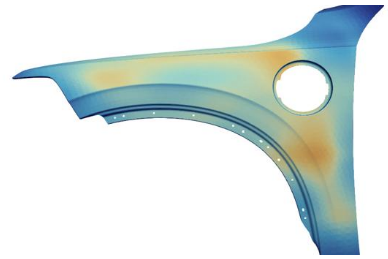
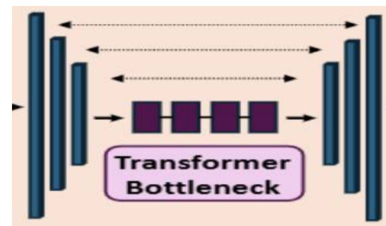
Master thesis proposal

Probabilistic Machine Learning for Robotic Paint Simulations



Surface treatment is an important industrial process impacting the performance, durability, and appearance. At Fraunhofer-Chalmers Centre we have successfully developed simulation methods for all standard surface treatment processes in a Virtual Paint Shop: electrocoating, spray-painting, powder coating, sealing, and oven curing. This enables the users to efficiently plan the painting process during the design phase and optimize the workflow without interrupting production.

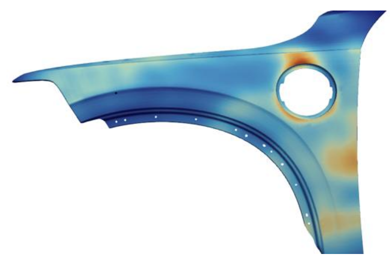


The goal

To further improve the predictive capabilities of an ML model by simultaneously modeling several different paint brushes, using brush-conditioned or parametrized ML methods, and incorporating uncertainty estimates.

Main tasks

- Review literature on robot painting and probabilistic machine learning
- Extend the ML model to operate with different paint brush profiles
- Incorporate probabilistic framework to obtain estimates of uncertainty



Expected outcome

The current framework works with a single brush and outputs a paint thickness point estimate. The proposed work is expected to result in 1) a model that incorporates different paint brush profiles 2) a probabilistic extension to the model that allows for paint thickness posterior prediction.

Student profile

Master student in engineering mathematics, complex adaptive systems, data science and AI, or similar. Experience in numerical methods and simulation and programming skills in e.g., Python, are advantageous. It may be possible to start with a part-time student position during fall 2026.

Supervisors

Dr Marcus Baaz, marcus.baaz@fcc.chalmers.se

Anders Sjöberg, anders.sjoberg@fcc.chalmers.se

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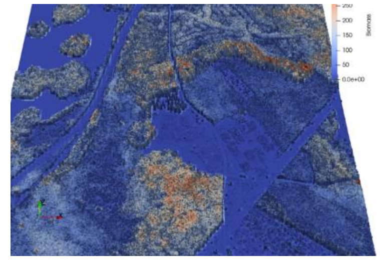
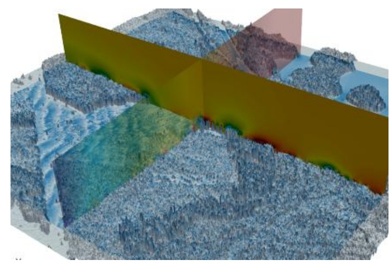
Master thesis proposal

Network-Based Modelling of Wildfire Propagation in Forest Landscapes





Accurate wildfire spread prediction is essential for risk management and forest planning. Continuum-based models can be computationally expensive at tree-resolved scales. A network approach—treating individual trees as nodes and possible fire-transfer pathways as edges—offers a scalable, discrete alternative that can naturally incorporate stand structure, terrain, moisture, biomass and wind effects.

The goal

Develop and evaluate a network-based model of wildfire spread where trees are nodes and edges represent spread pathways.

Main tasks

- Develop a network model using GIS data and spread dynamics based on local conditions (biomass, soil moisture, terrain, etc.).
- Analyze the effects of key parameters on the dynamics of fire spread.
- Assess model performance against reference data or simplified spread models.

Expected outcome

A network-model framework for wildfire spread driven by GIS and wind data, with quantified sensitivity to key environmental factors and an assessment of predictive performance versus reference data or models.

Student profile

Master student in computational science, applied mathematics, environmental modelling, or similar. Experience with graph models, numerical simulation, or spatial data is beneficial. Programming skills in Python are advantageous. Students interested in starting earlier may have the opportunity to work part-time on related projects during the autumn semester before the thesis begins.

Supervisors
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Dr. Franziska Hunger, franziska.hunger@fcc.chalmers.se, 0731-450230

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