Aalto Science Institute (AScI) international summer research programme

2023 project list

(draft 28.12.2022)

For more information on the program and how to apply, see
https://www.aalto.fi/en/aalto-science-institute-asci/aalto-science-institute-international-summer-research-programme

School of Chemical Engineering

Department of Bioproducts and Biosystems

1101 - Towards renewable liquefied petroleum gas: Purification and in vitro biochemistry of cofactors derived from methanogens		
Field of study:	Biochemistry	
For students currently studying:	Master’s	
Number of positions offered:	1 or 2	
School:	School of Chemical Engineering	
Department:	Department of Bioproducts and Biosystems	
Professor:	Silvan Scheller	silvan.scheller@aalto.fi
Academic contact person:	Maxime Laird	maxime.laird@aalto.fi

Background + Overall goal:
Methanogens are microbes with the ability to reduce CO2 to methane (biogas, a one-carbon fuel). The individual reduction steps are carried out at cofactors, such as F420 and H4MPT.
The overall research goal is to extend this chemistry towards producing 2-4-carbon fuels (liquefied petroleum gas: ethane, propane or butane) that can be easily liquefied at room temperature. It serves the purpose of converting CO2 with renewable energy to a storable fuel.

Cofactor research:
We are isolating different cofactors from methanogenic archaea, which we cultivate under hydrogen in 10L bioreactors. Purified cofactors are loaded with C1 or C2-4 carbon substrates. Next, reducing equivalents and different enzymes are added and the reaction is followed using UV-Vis and/or NMR spectroscopy. This way, we want to find out which cofactors and enzymes have to potential to reduce multi-carbon substrates.

Tasks for summer students:
- Cultivate methanogens (Methanothermobacter marburgensis) in a 10L fermenter under hydrogen and CO2
- Harvest biomass via continuous centrifugation
- Isolate different cofactors; done under strictly oxygen-free conditions (anaerobic chamber)
- Extend our library of purified cofactors and enzymes
- Perform in vitro experiments (test different combinations of C1/C2 substrates + cofactors + enzymes), to test the ability to process multi-carbon substrates
- Carry out analytic analyses (e.g. MALDI-MS, UV-Vis, NMR) to assess purity or to verify reaction progress
- Potentially: Heterologous expression of new enzyme variants

Necessary skills:
- Skilled in doing labwork (“not being clumsy”): Being able work with small, precious samples under strict exclusion of oxygen (anaerobic chambers), but also to work with 10L fermenter and hydrogen
- Preferentially: Solid understanding of (bio)chemistry, experience in chromatography

Preferentially: Experience (or theoretical knowledge) of advanced spectroscopic methods

1102 - Development of genetic tools for methanogens

Field of study:	Molecular biology	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Chemical Engineering	
Department:	Department of Bioproducts and Biosystems	
Professor:	Silvan Scheller	silvan.scheller@aalto.fi
Academic contact person:	Ping Zhu	ping.zhu@aalto.fi

Background:
Methanogens are microbes with the ability to reduce the substrate CO2, generating the product methane (CH4, biogas). They are champions for both processes: 1) for the CO2 reduction and 2) to produce methane. On the other hand, they are not good in utilizing or producing multi-carbon substrates or products.

Overall goal:
The overall goal is to extend the substrate and product scopes of methanogens. We want to achieve this by introducing additional genes that extend the metabolism. To enable efficient gene edition, we are currently developing better genetic tools for those organisms.

Possible tasks for summer students (depends also how the current research is progressing):
- Apply our current CRISPR toolbox for faster and smarter editing of genomes
- Extend toolbox to other methanogen species
- Explore potential targeting-sites in genome
- Insertion of genes to enlarge the metabolic potential of methanogens (metabolic engineering)

Necessary skills:
- Ample experience in molecular biology: molecular cloning, PCR, electrophoresis, etc.
- Carry out lab work independently
- Hard-working

1201 - Electrochemical Reduction of CO_2 on Electrodeposited Cu using Zero-gap Flow Cell

Field of study:	Electrocatalysis	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Chemical Engineering	
Department:	Department of Chemistry and Materials Science	
Professor:	Tanja Kallio	tanja.kallio@aalto.fi
Academic contact person:	Milla Suominen	milla.suominen@aalto.fi

Background: Cu is the only known electrocatalyst capable to produce further reduced products, such as ethylene and ethanol, from CO_2. However, several issues remain including improving the selectivity on Cu while maintaining high activity. It is known that certain structures of Cu prefer these products while also the cation in the electrolysis medium affects the selectivity slightly. It has also been shown that CO_2 electroreduction does not take place effectively without the presence of cations during CO_2 electrolysis, but the effects of incorporating them in the catalyst itself has not been addressed.

Main aims of the summer project: Main aim of the work is to study how the incorporation of different cations in the electrodeposition medium affects Cu electrodeposits and their CO_2 electroreduction selectivity and activity.

Tasks for the summer student:
- Electrodeposition of Cu nanoparticles on gas diffusion electrodes from varying electrodeposition media
- Physico-chemical characterization of the electrodeposited films (XRD, Raman, SEM/EDS)
- Electrochemical characterization of the electrodeposited films (cyclic voltammetry, impedance spectroscopy)
- Electrochemical reduction of CO_2 in a zero-gap flow cell
- Analysis of the CO_2 reduction products using chromatographic analysis techniques (GC, HPLC)
- Taking part in the weekly maintenance of the chromatographic analysis instruments (GC, HPLC)

Necessary skills:
- Skilled in doing independent laboratory work in the field of chemistry
- Previous knowledge in electrochemistry is an asset
- Previous knowledge in chromatographic analysis techniques (GC, HPLC) is an asset

School of Electrical Engineering

Department of Signal Processing and Acoustics
(Department of Information and Communications Engineering from 01.2023)

2101 - Visible light communications		
Field of study:	Signal processing, communications engineering	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Signal Processing and Acoustics (Department of Information and Communications Engineering from 01.2023)	
Professor:	Risto Wichman	risto.wichman@aalto.fi
Academic contact person:	Mehmet Ilter	mehmet.ilter@aalto.fi

Background: Visible light communications exploit common LEDs for data transmission. When the LEDs are used for illumination the data transmission comes for free - in principle. In addition, the frequency band is unlicensed and free of charge, the communication is inherently secure as light waves do not penetrate through walls, and the technology is cheap compared to Terahertz communication, for instance. In practice, there are a few technical problems to solve. Common LEDs have not been designed for data transmission and therefore the communication link is subject to various distortions. To this end, it is necessary to find a suitable modulation technique given the characteristics of LEDs, develop receiver algorithms, and techniques to compensate the distortion in the transmitter and the receiver.

Tasks: Operate our home-brew visible light communication system to collect data. The system consists of GNU Radio transceiver running on Linux desktop, a driver for LED, the LED, and a photodetector. Using the collected data develop transmitter and receiver algorithms using Matlab or Python offline. Implement the most promising algorithms in GNU Radio in real time.

Prerequisites: Knowledge on signal processing, signals and systems, wireless communication systems, programming experience in Matlab or Python. Understanding C++ helps with GNU Radio.

Department of Communications and Networking
(Department of Information and Communications Engineering from 01.2023)

2201 - Visual Search on User Interfaces		
Field of study:	Computer Science - Human-Computer Interaction, Cognitive Science, Eye-tracking	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Aini Putkonen	aini.putkonen@aalto.fi

Are you interested in ways eye-tracking data can inform UI design? In this project, we focus on a fundamental task on UIs: visual search. This task consists of finding a target among distractors (e.g., an icon on a crowded desktop). Whereas visual search has been studied extensively using experimental stimuli, tasks on realistic user interfaces are rare. Better understanding of visual search on realistic UIs could help designing better UIs and understanding how users allocate attention while searching for items. The project focuses on analysing and modelling human behaviour based on an eye-tracking dataset.

Some example tasks for the intern include (depending on the interests of the candidate):

- Analysis of eye-tracking data
- Developing models of human behaviour (using techniques like reinforcement and deep learning)
- Developing demos for showing how visual search models can inform UI design

We are looking for exceptional candidates with the following skill-sets:

- Proficiency in Python
- Interest in modelling human behaviour

2202 - Saliency Optimization Based on designer inputs		
Field of study:	Computer Science - Human-Computer Interaction, Deep Learning, Eye-Tracking	
For students currently studying:	Bachelor’s or Master’s	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Antti Oulasvirta	antti.oulasvirta@aalto.fi

Objective of this assignment is to automatically optimize the graphical user interface (GUI) based on the saliency values opted by the designer. The model takes user inputs for saliency values and compares them to the baseline to establish the changes needed in the associated UI components. Example properties of the UI components that will be managed by the model include color, size, typography, contrast, position either independently or in combination.

We are looking for exceptional candidates with the following skill-sets:

- Proficiency in Python
- Interest in modelling human behaviour
- Experience in analysis of large-scale datasets
- Software engineering experience is a plus

2203 - Generate designs based on design guidelines

Field of study:	Computer Science - Human-Computer Interaction, Natural Language Processing, Deep Learning	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Antti Oulasvirta	antti.oulasvirta@aalto.fi

Goal of this project is to automatically generate UI prototypes based on company guidelines and designer's individual styles/preferences. For the purpose of this project our existing optimization engine (GRIDS) will be used.
https://userinterfaces.aalto.fi/grids/

Designer populates a frame with the UI components (from the design system) required to complete a given UI design. So the model receives constraints placed on the default UI components. Also, the model analyzes individual design patterns that a UI designer follows; for e.g. background color, component placement and generates UI designs that may not be a 100% final but definitely useful options for a UI designer. Also, ML for user experience improves the options each time by learning from the designer's behavior. UX designers still make the final call on how the end product will look and function but can use the options proposed by the model as a starting point.

We are looking for exceptional candidates with the following skill-sets:

- Proficiency in Python, optimization techniques
- Experience in analysis of large-scale datasets
- Familiarity with machine learning models is an advantage

2204 - AI-assisted Color Design

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, Visual Design	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Lena Hegemann	lena.hegemann@aalto.fi

Choosing and applying colors is an essential part of virtually any domain of visual design. However, this frequent and important task is complicated for many designers. Well-chosen colors support the aesthetics, purpose of the design, and accessibility to name just a few common requirements.

During this internship, you will help us with the development of computational tools for color design. An interest in design processes, as well as programming skills (preferably python and javascript), are required. Skills in user interface design or machine learning would be beneficial.

2205 - Interactive prior elicitation

Field of study:	Computer Science - HCI, Probabilistic Machine Learning, Cognitive Science, Bayesian Methods	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Suyog Chandramouli	suyog.chandramouli@aalto.fi

Description: Prior elicitation, during which subjective knowledge and beliefs of experts are elicited is an important part of the Bayesian methodology which is used very widely in artificial intelligence and computational modeling. However, there are many sources of variance in elicited beliefs due to (i) actual differences in experts' beliefs, (ii) cognitive biases of the experts in uncertain settings, (iii) measurement noise in prior elicitation methods, (iv) elicitor induced biases, and (v) methodological flexibility in the elicitation procedure. The goal of any good prior elicitation method is to capture to the extent possible, the true unbiased beliefs of an expert while making sensitive measurements.
Prior elicitation methods are often developed independently, and seldom comprehensively tested for validity. Additionally, variance in elicited beliefs are often assumed to be only due to differing views of experts. In this project we will develop a new interactive prior elicitation procedure which views human judgments as a result of sampling from subjective mental representations, after a training phase using data generating distributions that are known to us. This procedure which collects many such samples from participants will then be used as a gold standard along with the true generating distributions, against which existing elicitation methods (which we believe may be quicker but less accurate) would also be compared. [This work is associated with the Finnish Center for AI (fcai.fi).]

Preferred Skills/qualification: Experience with one or more of the following:
a) Bayesian statistical methods, e.g. MCMC sampling
b) Programming HCI or Psychology experiments, e.g. using PsychoPy
c) Cognitive modeling
d) R, Python

2206 - User Interface Image Captioning

Field of study:	Computer Science - Human-Computer Interaction, Natural Language Processing, Deep Learning	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Yue Jiang	yue.jiang@aalto.fi

By analyzing the connection between GUIs and their corresponding functional natural language descriptions, we can improve the design and usability of GUIs. The CLARITY dataset [1] is a large collection of descriptions for screenshots from popular Android applications. Our goal is to build a model that can automatically generate both high-level description, i.e., the overall information of the GUI, and low-level descriptions, such as the functionality of each element on the GUI, building on our previous work [2]. This would be useful for software developers to automatically generate tutorials and walkthroughs, and could also help motor-impaired users navigate the software more easily by enabling accessibility features.

Requirements: The applicants are expected to be used to programming in PyTorch. It is a plus to have some prior experience in computer vision or natural language processing, or both.

[1] https://static1.squarespace.com/static/53065911e4b0cca0183fc14a/t/626d6aac59d57a54a100edf3/1651337902060/Clairty-SANER22-CRC-Final.pdf

[2] https://dl.acm.org/doi/abs/10.1145/3564702

2207 - User Interface Optimization Based on Eye-Tracking Data		
Field of study:	Computer Science - Human-Computer Interaction, Deep Learning, Eye-Tracking	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Yue Jiang	yue.jiang@aalto.fi

The goal of this project is to use eye-tracking data to automatically optimize graphical user interfaces (GUIs) in order to improve the design and functionalities of the GUIs.
By understanding how users view and interact with GUIs, the proposed model should make informed decisions about how to arrange UI elements and highlight important components. It will significantly reduce the effort required by designers to improve the design of their GUIs. Additionally, by analyzing scanpaths, the proposed model should be able to understand the visual flows of the interfaces and adjust them to encourage users to view the UI in the correct order to further enhance the user experience. We aim to make it easy and efficient for designers to create effective user interfaces.
Requirements: The applicants are expected to be used to programming in PyTorch.

2208 - Simulation-based Optimization of User Interfaces		
Field of study:	Computer Science - Human-Computer Interaction, Reinforcement Learning, Machine Learning, Optimization	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Finnish Center for AI and Department of Communications and Networking (Department of Information and Communications Engineering from 01.2023)	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Yi-Chi Liao	yi-chi.liao@aalto.fi

How to design a great physical interface, for example, a push-button or a tangible display? The traditional approach in design requires several iterations of ideation, prototyping, evaluation, and analysis. We believe that simulation-based methods could revolutionize design in this area [1]. The challenge has been the lack of realistic **user models**, including key aspects of their perceptual and motor capabilities. With biomechanical user simulations, this is changing now, however [2], and it is time to revisit the topic. The idea in a nutshell: A search algorithm (e.g., Bayesian optimization or RL) will generate candidate designs for the user model to evaluate.

Requirements: The applicants are expected to have strong programming skills in Python, and sufficient experience in reinforcement learning and/or optimization methods.

[1] https://dl.acm.org/doi/fullHtml/10.1145/3564038

[2] https://github.com/aikkala/user-in-the-box

School of Engineering

Department of Civil Engineering

3201 - Digitization of construction- Digital twins		
Field of study:	Construction management	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Civl Engineering	
Professor:	Olli Seppänen	olli.seppanen@aalto.fi
Academic contact person:	Olli Seppänen	olli.seppanen@aalto.fi

Description: Digital twins is an emerging concept which has drawn attention in manufacturing as well as in construction industry. Digital twins are digital replicas of a physical system, be it a construction site or a finished facility. If properly developed, they can be used to enhance the monitoring and control of construction activities, or better manage a facility in its operations and maintenance phase. Accurate digital twins will be helpful in streamlining the process activities, reducing delays, maintaining cost, as well as limiting carbon footprint. A vital part of a successful digital twin is automating data capturing and interpretation. The methods employed to automate the interpretation of captured data in the field of construction require further research before they can be practically utilized for converting site data to digital information. The aim of this project is to explore such methods on actual construction sites, where captured data can be converted to usable information. For instance, automating the interpretation of captured data can be used to automatically generate guidance to construction personnel based on latest up-to-date site status. In addition, the interpreted data can be used to forecast project performance allowing for proactive measures.

The intern will collaborate in designing and developing the framework (including writing code, possibly in Python), for construction related data interpretation. This may also include data management related to a building construction. For example, how certain type of data like humidity from construction site may be interrelated to a construction site image.

The intern is therefore expected to have the following skills:

- Intermediate coding. Preferred language: Python
- Knowledge of deep learning libraries like tensorflow, keras, pytorch
- Basic to intermediate computer vision knowledge
- Basic to intermediate database management knowledge
- Interest in object detection/semantic segmentation
- Good communication skills
- Willing to work in a team
- Inquisitiveness

3301 - Optimizing the parameterization of a universal failure model for hydrogen storage applications

Field of study:	Mechanics, materials, machine learning, modeling	
For students currently studying:	Bachelor's and Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Junhe Lian	junhe.lian@aalto.fi
Academic contact person:	Zinan Li	zinan.li@aalto.fi

With the development of high-strength metallic materials to fulfill the requirements of lightweight component design for sustainable use of energy, especially for the storage and transportation of hydrogen, the damage and fracture behavior of these materials needs to be very carefully studied. With a unique hybrid experimental and numerical method developed at our lab, the damage and failure behavior of metallic materials could be very accurately predicted. The applications include forming a cup by deep drawing, crashworthiness behavior of a car crash, burst fracture of a pipeline for hydrogen transportation, etc. The models we developed are powerful and provide engineers with a digital twin to design their products and plan any applications. The key element for success is an efficient and robust parameterization of the model, which could be complicated and time-consuming. This project will explore the parameterization process by using various optimization algorithms (e.g., genetic algorithm, Bayesian algorithm, etc.) or machine-learning models. It eventually aims to develop an efficient and automatic parameter calibration process on the Finnish supercomputer platform (CSC).

In this project, you will learn advanced theories and knowledge on the mechanics of materials with a focus on strength and failure, as well as hydrogen-related new applications. More importantly, you will be trained with various optimization algorithms and modern data-driven models based on deep learning, such as ANN and LSTM. Finally, you will have the chance to apply these models and even further develop these models to predict the mechanical behavior of materials with outstanding accuracy and efficiency to solve pressing and top-notch scientific problems.

Prerequisites and skills in coding with python or MATLAB, experience with optimization algorithms or machine-learning modeling, and knowledge of the mechanics of materials are highly appreciated.

3302 - Feasible shipping paths identification based on big data in ice-covered waters

Field of study:	Marine technology	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Mashrura Musharraf	mashrura.musharraf@aalto.fi
Academic contact person:	Cong Liu	cong.1.liu@aalto.fi

As climate changes, navigation in ice-covered waters is becoming prevalent. However, the existence of ice may cause hazards to shipping in icy waters. Examples of such hazards include risk of getting beset in ice, damage on the ship hull, oil spilling after ship ice collision, etc. Feasible shipping path identification in ice-covered waters in the Baltic Sea region can provide objective insights into a better understanding of the winter navigation network. Currently, these paths are represented by a series of waypoints estimated by the icebreaker's captain. And waypoints may change along with the change in ice conditions. All merchant vessels to be assisted by icebreakers should wait at the waypoint assigned by the captain. The efficiency of winter navigation based on the subjective assignment of waypoints and shipping routes are hard to be evaluated quantitatively.

In this project, the aim is to identify feasible paths and critical waypoints in the Baltic Sea based on historical traffic and ice data. A dataset consisting of traffic data and ice variables will be utilized to present the historical navigational condition. Based on big data, ship voyage information (e.g., destination, leaving port, or entering port), waypoints, and their corresponding ice variables in both temporal and spatial dimensions will be extracted. With this knowledge, the assignment of waypoints for merchant vessels can be guided.

Necessary skills:
1. Ability to work independently and in a team
2. Experience in programming, e.g., MATLAB and/or Python
3. Time series data processing
4. Any previous experience with Automatic identification system (AIS) data analysis and/or winter navigation system in the Baltic Sea area will be considered an asset.

3303 - Potential of explainable AI in enhancing trust in vessel automation

Field of study:	Computer Science, Marine Technology	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Mashrura Musharraf	mashrura.musharraf@aalto.fi
Academic contact person:	Ketki Kulkarni	ketki.kulkarni@aalto.fi

In the first few degrees of vessel automation, the AI and humans would need to coexist and cooperate in a highly complex socio-technical system. If and how trust in these increasingly functional AI can be enhanced by making the models explainable is yet to be explored. The *Intelligence in Marine Systems* group is working to answer this question.

In this project, you will develop a method to assess the potential of explainable AI in enhancing trust in vessel automation. The development will be guided by the more mature fields of automation such as autonomous vehicles. By performing a systematic literature review you will - define the notions of explainability and trust for autonomous vehicles, find if explainability has an impact on trust, and summarize how that impact is measured. Together with the rest of the team, we then find out how the lessons learned can be translated for the marine industry.

Necessary skills:
Any student with an interest in AI and/or automation is welcome to apply. Students with experience in systematic literature review will be given preference.

3304 - Winter navigation database creation

Field of study:	Computer Science, Marine Technology	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Mashrura Musharraf	mashrura.musharraf@aalto.fi
Academic contact person:	Ketki Kulkarni	ketki.kulkarni@aalto.fi

Winter maritime traffic in Finland and the surrounding Baltic Sea is faced with critical challenges of navigating safely in ice. The *Intelligence in Marine Systems* group is working on developing data-based models of ships navigating in ice. The group is involved in multiple research initiatives involving real-life cases of maritime traffic.

The research requires extensive use of ice data from multiple sources and in different formats. This short-term project involves merging of the different data streams into one SQL database. Here, you will need to consider the structure of raw ice data coming in different formats from different sources, understand what they represent, and then organize them based on timestamp and geographical information (latitude, longitude). You will work closely with a doctoral student and a postdoc to understand typical query formats. The database created by this work is expected to connect with existing traffic simulation models.

Necessary skills:
We are looking for a candidate with proficiency in SQL databases (creation and querying) and some experience in computational coding. A background in marine technology and/or ice data will be considered an asset.

School of Science

Department of Computer Science

4101 - Deep Learning for Extreme Scale Classification		
Field of study:	Computer Science, Machine Learning	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Rohit Babbar	Rohit.babbar@aalto.fi
Academic contact person:	Rohit Babbar	Rohit.babbar@aalto.fi

Large output spaces with hundreds of thousand labels are common in Machine learning problems such as ranking, recommendation systems and next word prediction. Apart from the computational problem of scalability, data scarcity for individual labels poses a statistical challenge and especially so for data hungry deep methods. The goal of the project is to investigate and design deep learning based architectures for simultaneously addressing the computational and statistical challenge in learning with large output spaces. As the target domain is textual data, the project also involves exploring recent advances in NLP, such as Bert and TransformerXL, towards exploring the common grounds for further research in this area.

References:

[1] LightXML: Transformer with Dynamic Negative Sampling for High-Performance Extreme Multi-label Text Classification, AAAI 2021.
Code : https://github.com/kongds/LightXML

[2] CascadeXML - https://arxiv.org/pdf/2211.00640.pdf

[3] SiameseXML: Siamese networks meet extreme classifiers with 100M labels, ICML 2021.

4301 - Developing a virtual reality environment to study mental rotation in humans.

Field of study:	Computer Science and Neuroscience (the projected is cross listed in the Department of Neuroscience and Biomedical Engineering.)	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Neuroscience and Biomedical Engineering	
Professor:	Stephane Deny	stephane.deny@aalto.fi
Academic contact person:	Stephane Deny	stephane.deny@aalto.fi

Topic: Mental rotation is the ability that humans have to imagine objects in various poses, allowing them to recognise and compare objects in their everyday life. It is still unknown what algorithms are employed by the brain to perform mental rotation. This project consists in building a virtual reality environment (using the Unity3D framework) in order to study how humans perform mental rotation of 3D objects. Part of the project will consist in developing the 3D environment and part of the project will consist in designing and running pilot experiments to study mental rotation.

About the lab: The 'Bidirectional Research in AI and Neuroscience' (BRAIN) lab is joint between the Department of Neuroscience and Biomedical Engineering and the Department of Computer Science at Aalto University. The objective of the lab is to deliver fundamental advances in our understanding of the brain algorithms, and inspire the next generation of models for AI.

Preferred skills: Some experience in programming. Some interest for the topic.

4103 – Deep Representation Learning, etc. *(5 positions in multiple topics)*		
Field of study:	Machine Learning, Reinforcement Learning, Deep Learning, Computational Biology, NLP, (Applied) Math, Quantum Computing, Physics, UI/UX, Algorithms, etc.	
For students currently studying:	Bachelor's, Master's, and PhD	
Number of positions offered:	5	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Vikas Garg	vikas.garg@aalto.fi
Academic contact person:	Vikas Garg	vikas.garg@aalto.fi vgarg@csail.mit.edu;

Applications are invited for various internship positions in our group, widely known for its contributions to representation learning, generative models, and multiagent systems [1-10]. We encourage candidates from underrepresented backgrounds and those affected by hostile geopolitical conditions to apply. An ideal student would be eager to push the frontiers of science; have strong mathematical, theoretical, statistical, or algorithmic background; and be comfortable programming in a deep learning library (e.g., PyTorch). We also have a position for UI/UX designers having solid experience in frontend and backend.

Topics of particular interest include but are not limited to:
(1) 3D Generative Models
(2) Graph Neural Networks
(3) Neural ODEs/PDEs/SDEs, Deep Equilibrium Models, Implicit Models
(4) Differential Geometry/Information Geometry/Algebraic Methods for Deep Learning
(5) Learning under limited data, distributional shift, and/or uncertainty
(6) Bayesian Neural Networks, Probabilistic Graphical Models, & Approximate Inference
(7) Fair, diverse, and interpretable representations
(8) Off-policy reinforcement learning, inverse reinforcement learning, and causal reinforcement learning (9) Multiagent systems and AI-assisted human-guided models
(10) Compression and learning on the edge (i.e., resource constrained settings such as IoT devices)
(11) Applications in NLP, drug discovery, material design, synthetic biology, quantum chemistry, etc.
(12) Quantum Machine Learning

Representative publications:

(1) J. Ingraham, V. Garg, R. Barzilay, and T. Jaakkola. Generative Models for Protein Design. NeurIPS (2019).
(2) V. Garg, S. Jegelka, and T. Jaakkola. Generalization and Representational Limits of Graph Neural Networks. ICML (2020).
(3) V. Garg and T. Jaakkola. Solving graph compression via Optimal Transport. NeurIPS (2019).
(4) V. Garg, L. Xiao, and O. Dekel. Learning small predictors. NeurIPS (2018).
(5) V. Garg and T. Jaakkola. Predicting Deliberative Outcomes. ICML (2020).
(6) Y. Verma, S. Kaski, M. Heinonen, and V. Garg. Modular Flows: Differential Molecular Generation. NeurIPS (2022).
(7) A. Souza, D. Mesquita, S. Kaski, and V. Garg. Provably expressive temporal graph networks. NeurIPS (2022).
(8) G. Mercatali, A. Freitas, and V. Garg. Symmetry induced disentanglement on graphs. NeurIPS (2022).
(9) D. Alvarez-Melis(*), V. Garg(*), and A. Kalai(*). Are GANs overkill for NLP? NeurIPS (2022).
(10) V. Garg and T. Pichkhadze. Online Markov Decoding: Lower Bounds and Near-Optimal Approximation Algorithms. NeurIPS (2019).

4104 - Transformers for Synthetic Time Series Generation

Field of study:	Computer Science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Samuel Kaski	
Academic contact person:	Alexander Nikitin	alexander.nikitin@aalto.fi

In this project, we will explore transformers (https://en.wikipedia.org/wiki/Transformer_(machine_learning_model)) for various time series tasks and try to apply them to synthetic time series generation. We will publish the results in an open-source library for time series generation.

Synthetic time series generation is a problem of generating synthetic data which resembles real data and does not reveal private information. Moreover, these synthetic data can be used for augmenting the datasets and then employed for training large deep learning models. Transformers are particularly interesting in this context because of their success in generative NLP models (e.g., GPT), and we aim to do the same for time series.

The project requires:
A good understanding of modern deep learning: attention, transformers, recurrent neural networks, etc.
Python programming skills, experience with TF/PyTorch.

References:

[1] https://arxiv.org/abs/2202.07125
[2] https://huggingface.co/docs/transformers/model_doc/time_series_transformer

4105 - Automatic summarization of clinical text

Field of study:	Computer Science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Samuel Kaski	
Academic contact person:	Hans Moen	hans.moen@aalto.fi

This project will focus on the task of generating text summaries of patients' visits to the hospital. We will use the text written by doctors in the patients' electronic health records. As there can be many documents (clinical notes) to summarize, the tentative plan is to explore a two-step approach that involves first selecting and extracting the most relevant information to include as the basis for generating the final summary.

The first step will focus on training a text classification model to select the most important sentences (based on training data) from the care episode that is to be summarized. This part will possibly also involve taking into consideration queries from the users that specifies their information needs (human in the loop). The next step, the text generation part, will focus on training an autoregressive text generation model that takes the output from the first step as the starting prompt for generating the final summary in an abstractive manner. This approach is particularly inspired by Pilault et al. (2020) [1]. If time permits, we will also explore using this model/setup to generate summaries for other healthcare specialists, such as nurses, whose texts lack proper training data (transfer learning).

The data to use are electronic health records from a Finnish hospital. For the text generation, the plan is to fine-tune an existing pre-trained Generative Pre-trained Transformer (GPT) model, trained on Finnish text (GPT-2) [2].

The project requires:
Some knowledge of natural language processing (NLP).
Understanding of modern deep learning: recurrent neural networks, transformers, attention, etc.
Good Python programming skills and experience with PyTorch or Tensorflow.

References:
[1] Pilault et al. (2020). On extractive and abstractive neural document summarization with transformer language models. https://aclanthology.org/2020.emnlp-main.748/
[2] https://huggingface.co/Finnish-NLP/gpt2-finnish

4106 - Theoretical Computer Science *(7-14 positions with numerous professors)*

Field of study:	Theoretical Computer Science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	7-14	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Petteri Kaski	petteri.kaski@aalto.fi
Academic contact person:	Petteri Kaski	petteri.kaski@aalto.fi

The Theoretical Computer Science group at Aalto University consists of more than 10 professors and their teams pursuing leading-edge research across a broad range of topics in theoretical computer science, including:

- Algebraic Algorithms, Parameterized Algorithms (Petteri Kaski)
- Approximation Algorithms, Combinatorial Optimization (Parinya Chalermsook)
- Computational Geometry (Sándor Kisfaludi-Bak)
- Cryptography, Security & Complexity (Chris Brzuska and Russell Lai)
- Distributed and Parallel Computing (Jukka Suomela and Jara Uitto)
- Natural Computation (Pekka Orponen)
- Quantum Computing (Alexandru Paler)

We welcome applications from students interested in pursuing research work in theoretical topics in computer science based on your interests and strengths, which you are encouraged to highlight and explore in your cover letter to best match you to our teams.

A successful applicant in general has a strong background in computer science and mathematics as evidenced by excellent academic performance and possible other merits such as prior research experience and success in competitive activities. Good programming skills are a further asset as many of our research activities involve using computers to gain insight and drive our understanding of the mathematics of computation.

See https://research.cs.aalto.fi/theory/ for more information about the group and faculty members.

4107 - 3D visualisation of and pattern recognition from large-scale data from multi-physics simulations

Field of study:	Computer Science/Astroinformatics	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1-2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Maarit Korpi-Lagg	maarit.korpi-lagg@aalto.fi
Academic contact person:	Maarit Korpi-Lagg	maarit.korpi-lagg@aalto.fi

Large-scale simulations of, for example, magnetised fluids in stellar interiors produce huge amounts of three dimensional data, where each system state can comprise hundreds of Gigabytes or even Terabytes. Analysis, visualisation, and even storage of such data is challenging, and special tools are required.

From the visualisation perspective, we are looking for a summer intern, who could develop further our existing Python framework, with which we create 3D visualisations from the simulation data (https://owncloud.gwdg.de/index.php/s/iAq7VQ2Rb71Xfau#/files_mediaviewer/).

The task of the summer intern 1 is to enhance the existing toolbox by adding parallel processing capabilities, to better handle multiple snapshots of large datasets for animation. Prerequisites: Good knowledge in Python, and managing Jupyter notebooks. Some knowledge of supercomputing environments is a bonus.

From the analysis and storage perspective, we need to develop tools that are capable of recognising subregions of interest, and analyse and output data only from these regions, while storing the full system states will no longer be possible in the forthcoming Exa-scale computing era. The long-term aim of the project is to develop an online or offline structure-detector assistant for the large-scale simulation toolbox.

The tasks of the summer intern 2 include: To continue developing an existing code based on the FasterRCNN object detection model. The code also includes a data augmentation pipeline, which is necessary for increasing the training data size and diversity; Generating training data for the neural network using idealised simulation setups; use the generated training data for deep learning network; apply the trained network to detect the predefined structures and track their evolution in time from the real simulation data.

Prerequisites: Basic knowledge on ML is required, and being familiar with toolboxes like PyTorch or Tensorflow is an extra benefit.

4108 - Lockdown on the Web: The unequal impact of the COVID19 pandemic on people's web browsing behaviour

Field of study:	Computational social science, data science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Juhi Kulshrestha	juhi.kulshrestha@aalto.fi
Academic contact person:	Juhi Kulshrestha	juhi.kulshrestha@aalto.fi

The COVID-19 pandemic and the challenges resulting from associated lockdowns have introduced social, psychological, and economic hardships into people's lives and have disproportionately harmed vulnerable social groups, exacerbating pre-existing inequalities. However, it is yet unclear how the pandemic has altered people's information-seeking behaviour on the Web---an essential part of our lives today. We still only have a limited understanding of how these changes might have enduring effects on people's well-being, especially for socially disadvantaged groups.

This project will quantify and understand how the lockdowns in the physical space changed people's browsing behaviour on the Web and investigate whether these behavioural changes persist after the lockdown(s) were lifted.

First, we will statistically characterise individuals' web browsing traces before, during, and after lockdowns, using individual-level data. Then, we will focus our analyses of behavioural changes of different groups of individuals based on: (i) socio-demographic characteristics (e.g., gender, family status, economic status, size of place of residence), and (ii) self-reported experience of the lockdown.

Required skills: good python programming skills and interest in the topic
Desired skills: familiarity with data science methods and statistical models

4109 - Information overload: How much is too much? Examining inequities in information processing capacities of individuals on the Web

Field of study:	Computational social science, data science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Juhi Kulshrestha	juhi.kulshrestha@aalto.fi
Academic contact person:	Juhi Kulshrestha	juhi.kulshrestha@aalto.fi

How much information can we absorb before it becomes a burden? Can web browsing data help answer this question? While the vast amount of information available online aids people in their everyday decisions, from researching health issues to deciding who to vote for, too much of it can paradoxically cognitively overwhelm individuals and impair decision-making. Though information overload negatively affects our decisions on varied matters, it is still unclear how this phenomenon emerges on the Web and intertwines with our online browsing behavior.

In this project, we take steps in these directions by answering questions such as, how limited is the information processing capacity of individuals online? How does this capacity vary across individuals? How do browsing contexts affect this capacity?

Required skills: good python programming skills and interest in the topic.
Desired skills: familiarity with data science or complex systems methods.

4110 - NLP methods of characterising news articles to study polarisation

Field of study:	Natural language processing, Machine learning, Computational social science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Juhi Kulshrestha	juhi.kulshrestha@aalto.fi
Academic contact person:	Juhi Kulshrestha	juhi.kulshrestha@aalto.fi

Within a project focused on studying political polarisation in individualised online environments, we aim to analyse news articles to quantify constructs such as topics, sentiments, named entities, stance, sensationalism and linguistic complexity.

Required skills: good python/R programming skills, experience in machine learning and deep learning methods, familiarity with NLP.
Desired skills: knowledge of German language is beneficial since the articles are in German.

4111 - Lattice-based Cryptography

Field of study:	Cryptography	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Russell Lai	russell.lai@aalto.fi
Academic contact person:	Russell Lai	russell.lai@aalto.fi

Lattice-based cryptography has emerged as one of the main techniques for public-key cryptography. Besides potential security against both classical and quantum attackers and connections to well-studied computational lattice problems, lattices also provide rich algebraic structures enabling advanced functionalities such as fully homomorphic encryption (FHE), attribute-based encryption (ABE) for circuits, and succinct proof systems (SNARK).

We seek to advance lattice-based cryptography on many fronts. The concrete topic varies depending on the student's interests. Some examples are identifying and analysing new and existing cryptographic assumptions, constructing cryptographic primitives with new functionalities, and implementing recently proposed constructions.

The applicant is assumed to have mathematical maturity, i.e. feeling comfortable to read and write formal mathematical statements and proofs, and a good command of English. Applicants with prior knowledge in cryptography are prioritised. For implementation projects, strong programming skills are required. Helpful but not necessary are knowledge on lattice theory, number theory, and algebraic number theory.

4112 - Provable Image and Audio Steganography via Cover Source Switching

Field of study:	Steganography	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Russell Lai	russell.lai@aalto.fi
Academic contact person:	Russell Lai	russell.lai@aalto.fi

Steganography is the study of hiding secret information in innocuous cover objects in such a way that the presence of the information itself is concealed. A common yet unsatisfactory approach is to embed secret information by minimally distorting the cover objects, which results in stego objects with heuristic but non-provable security. An alternative approach, known as cover source switching, relies on the existence of multiple cover sources, e.g. photos with different ISO values, and seeks to generate stego objects whose distribution is close to that of a cover source, e.g. adding noise encoding secret messages to ISO 100 photos to make them look like ISO 200 photos.

We seek to further explore the possibility of provable steganography via the technique of cover source switching using images and/or audio as mediums. Depending on the student's interests, potential tasks include surveying the literature, identifying new cover sources suitable for steganographic purposes, conducting experiments to determine or verify noise models of cover sources, and implementing stego-encoders. For the latter tasks, the student likely needs to write tools to parse and manipulate digital image and/or audio files at bit level.

Strong programming skills and a good command of English are required. No prior knowledge in steganography is needed. Helpful but not necessary are knowledge on digital signal processing.

4113 - To be announced

Field of study:		
For students currently studying:		
Number of positions offered:		
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Janne Lindqvist	janne.lindqvist@aalto.fi
Academic contact person:	Janne Lindqvist	janne.lindqvist@aalto.fi

4114 - DNAforge: Design tools for DNA nanotechnology

Field of study:	Computer Science / Computational Biology	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1-2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Pekka Orponen	pekka.orponen@aalto.fi
Academic contact person:	Pekka Orponen	pekka.orponen@aalto.fi

The area of DNA nanotechnology, or more broadly nucleic acid nanotechnology [1] employs the nucleic acids DNA and RNA as generic building material for assembling nanoscale objects with dimensions in the order of 10-100 nanometres. In this area, our group is one of the world leaders in developing automated design tools for general 3D wireframe structures folded from DNA [2] or RNA [3].

The summer internships are part of a broader initiative to develop a distribution platform "DNAforge" for these tools that will bring them together in a common framework and provide the research community an open, extendible, browser-based interface to this powerful design methodology. In later stages of the project the platform will also be integrated to the oxDNA molecular dynamics simulation engine [4], so that the designed nanostructures can be directly exported for simulation.

A preliminary version of the platform that implements a specific design method is already available, and new complements to it will be added during Spring 2023. The details of the summer internships will depend on the topical needs of the project and the competences and personal interests of the available developers.

The project requires familiarity with basic algorithm design techniques, facility with combinatorial thinking, and good programming skills. Previous knowledge of biomolecules is not necessary, although it is an asset. For further information about our work, please see the research group webpage at http://research.cs.aalto.fi/nc/.

[1] https://en.wikipedia.org/wiki/DNA_nanotechnology

[2] Benson et al., Nature 2015, https://doi.org/10.1038/nature14586

[3] Elonen et al., ACS Nano 2022, https://doi.org/10.1021/acsnano.2c06035

[4] https://dna.physics.ox.ac.uk/

4115 - Deep Model-Based Reinforcement Learning Under Uncertainty

Field of study:	Machine Learning	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Arno Solin	arno.solin@aalto.fi
Academic contact person:	Aidan Scannell	aidan.scannell@aalto.fi

Model-based reinforcement learning (RL) methods have the potential to be more sample efficient than their model-free counterparts. However, learning a dynamics model from high-dimensional observations, such as images, is challenging. To this end, recent work has proposed to learn dynamics models in low-dimensional (latent) spaces, by simultaneously learning an encoder which maps the high-dimensional observations to the latent space [1–3]. Typically, these methods do not quantify their uncertainty, so RL agents are not aware of what they do not know. That is, they are not aware when their models are not able to predict accurately, due to being far away from their training data.

In this project, we will improve deep model-based RL by enhancing it with state-of-the-art uncertainty quantification. The selected candidate can choose from two exciting research ideas:

1. Improving uncertainty quantification in the encoder by combining recent advances in variational auto-encoders (VAE) [4] with a deep model-based RL method such as [3].
2. Developing latent-space dynamics models that principally handle uncertainty. For example, see [5], which combines a deep neural network encoder with a Gaussian process (GP) latent space. Alternatively, this project could focus on constructing latent spaces using Markovian GPs [6].

Our goal is to match (or improve upon) state-of-the-art performance in high-dimensional control tasks (e.g. deepmind control suite), whilst enabling the model to express what it does and does not know, via uncertainty quantification. This project has multiple exciting (and high-impact) research directions, each with a lot of potential for further work. We are aiming to publish the project's findings at a top-tier conference. This project requires a solid understanding of reinforcement learning, probabilistic methods (Gaussian processes etc.), deep learning and good coding skills.

Minimum requirements:

- knowledge of probabilistic modelling and approximate inference
- knowledge of machine learning
- knowledge of deep learning
- knowledge of reinforcement learning or optimal control
- programming experience in Python + a deep learning library, e.g. TensorFlow, JAX, PyTorch, etc.

Related publications:

[1] Danijar Hafner, Timothy Lillicrap, Ian Fischer, Ruben Villegas, David Ha, Honglak Lee, James Davidson Proceedings of the 36th International Conference on Machine Learning, PMLR 97:2555–2565, 2019.
[2] Hafner, Danijar and Lillicrap, Timothy and Norouzi, Mohammad and Ba, Jimmy (2021). Mastering Atari with Discrete World Models. ICLR 2021.
[3] Raj Ghugare, Homanga Bharadhwaj, Benjamin Eysenbach, Sergey Levine, Ruslan Salakhutdinov (2022). Simplifying Model-based RL: Learning Representations, Latent-space Models, and Policies with One Objective. Arxiv 2022.
[4] Marco Miani, Frederik Warburg, Pablo Moreno-Muñoz, Nicke Skafte Detlefsen and Søren Hauberg (2022). Laplacian Autoencoders for Learning Stochastic Representations. Advances in Neural Information Processing Systems (NeurIPS), 2022.
[5] Yuxin Hou, Juho Kannala, and Arno Solin (2019). Multi-view stereo by temporal nonparametric fusion. In International Conference on Computer Vision (ICCV). Pages 2651–2660. Seoul, Korea.
[6] William Wilkinson, Arno Solin, Vincent Adam (2021). Sparse Algorithms for Markovian Gaussian Processes. Proceedings of The 24th International Conference on Artificial Intelligence and Statistics, 2021.

4116 - Learning Deep Tractable Models

Field of study:	Machine Learning	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Arno Solin	arno.solin@aalto.fi
Academic contact person:	Martin Trapp	martin.trapp@aalto.fi

Deep generative models have gained increasing attention within and outside the machine learning research community. For example, recent techniques can simulate human-like interactions with users or generate high-quality images. However, these approaches fall short in general-purpose applications as they do not allow probabilistic inferences (for example, how likely is it that an AScI student writes a paper about their project and gets it accepted at a machine learning conference?) to be computed efficiently.

Probabilistic circuits (PCs) are a unifying computational framework based on sparsely structured deep neural networks to represent tractable probability distributions. Consequently, PCs allow us to efficiently and exactly answer probabilistic queries like the one mentioned earlier. This is made possible by structural constraints enforced on the sparse deep neural network. Therefore, PCs are increasingly used in general-purpose applications in which probabilistic inference is key. Examples include enforcing algorithmic fairness, anomaly detection, and predictions under missing or noisy data.

This AScI project will aim to contribute to the PC community by investigating some of the pressing research questions in the field. Possible topics include data-driven structure learning with partial prior knowledge, Bayesian parameter and structure learning, and approximate inference with PCs. The concrete topic will be decided together with the student.

The successful student should have good math and programming skills (preferably in Julia or Python) and experience with related machine-learning topics. Prior knowledge in probabilistic circuits and Bayesian learning is a plus but not required. The project will be carried out in person in Helsinki together with members of the research group.

Recommended further readings:

[1] Trapp et al. (2019) Bayesian Learning of Sum-Product Networks. NeurIPS. Pre-print available at: https://arxiv.org/abs/1905.10884

[2] Choi et al. (2020). Probabilistic Circuits: A Unifying Framework for Tractable Probabilistic Models. Pre-print available at http://starai.cs.ucla.edu/papers/ProbCirc20.pdf

4117 - Bayesian workflows for safe iterative model building

Field of study:	Computational Bayesian modeling	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Aki Vehtari	Aki.Vehtari@aalto.fi
Academic contact person:	Aki Vehtari	Aki.Vehtari@aalto.fi

We formalize and develop theory and diagnostics for iterative Bayesian model building. The practical workflow recommendations and diagnostics guide the modeller through the appropriate steps to ensure safe iterative model building, or indicate when the modeler is likely to be in the danger zone.

Required to have knowledge of Bayesian inference methods and programming skills in R or Python.

4118 - Placebo effect of AI technology

Field of study:	Human-Computer interaction/ AI/ Psychology/Engineering Psychology	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Robin Welsch	Robin.welsch@aalto.fi
Academic contact person:	Robin Welsch	Robin.welsch@aalto.fi

Studies evaluating artificial intelligence (AI) technologies could be fundamentally flawed due to the placebo effect, i.e., users experiencing benefits from belief in the effect of a sham treatment. Human-centred AI technologies are designed to support humans and extend human capabilities, raising high expectations for the improvement of people's lives. This research internship will run empirical studies to investigate how the presentation of an AI system can produce placebo effects, i.e., how AI can facilitate task completion in the absence of a functional system.
The main task in this internship are the design, planning, and execution of an empirical user study. This includes the creation of prototypes, the preparation of study materials but also doing research with users in the lab.

Candidates for the intern position should have the following skills:

- knowledge in quantitative user studies and/or AI
- good knowledge of quantitative data analysis
- strong interest in experimental psychology research

You will gain experience in the following areas:

- Artificial intelligence and mental models
- Usability & User Experience
- Conducting User studies
- Application of psychology to human-computer interaction

4119 - Trust-M: Designing Trustworthy Conversational AI Services for Migrants

Field of study:	Human Computer Interaction (HCI), Natural Language Processing (NLP), Human-AI Interaction	
For students currently studying:	Master's preferred	
Number of positions offered:	1-2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Nitin Sawhney	nitin.sawhney@aalto.fi
Academic contact person:	Lucy Truong	lucy.truong@aalto.fi

The Trust-M research project aims to improve the integration of migrants in Finland by devising hybrid and trustworthy digital services based on conversational AI. Finnish public services may not always be accessible, inclusive or trustworthy for all migrants. Improving such services can strengthen social cohesion, resilience of the labor market, and economic vibrance in Finnish Society. The project is a partnership between Aalto University, University of Helsinki, Tampere University, and City of Espoo, supported by the Academy of Finland's Strategic Research Council (SRC) program in Security and Trust in the Age of Algorithms (SHIELD).

Project objectives include: (1) understanding how the socially and culturally constructed notions of trust, inclusion and equality are manifest in present-day digital public sector services, (2) devising alternatives for novel digital public sector services that could nurture trust and respect human rights, particularly considering migrant women, and (3) designing pilot versions of hybrid digital services based on conversational interaction, in conjunction with the City of Espoo.

We are seeking motivated researchers to join the Trust-M team to conduct research and design of novel trustworthy conversational AI systems using multimodal voice-based interaction. Candidates must ideally have interests and expertise in at least 2-3 relevant areas including Human Computer Interaction (HCI), Natural Language Processing (NLP), conversational AI chatbots, speech/voice interaction, rapid prototyping, design research, user evaluation, and ethical/responsible AI. Evidence of prior work or publications in one or more of these areas is highly beneficial. Good interpersonal skills, collaborative research, conducting ethical research studies or participatory design with end users is helpful. Diverse international candidates with multi-lingual backgrounds are encouraged to apply.

You would join the CRAI-CIS research group in the Computer Science department at Aalto University. The transdisciplinary group explores the impact of technology in critical societal contexts, working at the intersection of computational and social sciences engaging HCI and participatory design. More here: https://crai-cis.aalto.fi

4120 - Countering AI-infused Disinformation in the Finnish News Ecosystem

Field of study:	Natural Language Processing (NLP), Machine Learning, Computational Social Science	
For students currently studying:	Master's preferred	
Number of positions offered:	1-2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Nitin Sawhney	nitin.sawhney@aalto.fi
Academic contact person:	Henna Paakki	henna.paakki@aalto.fi

The research aims to examine the increasing emergence of AI-infused disinformation and the challenges faced by news media practitioners and fact-checking organizations. It seeks to devise computational tools, social processes, and cooperative practices that can be used to counter disinformation among the Finnish news ecosystem. While it's clearly a difficult and rapidly changing problem domain, we hope this pilot research will allow us to engage with news media partners in Finland to explore novel socio-technical approaches for information resilience.

We are seeking motivated researchers to conduct research on computational methods for identification of linguistic cues to pre-emptively identify disinformation in news content. You will also fine-tune existing solutions for use with Finnish language content with an aim to develop a prototype (set of tools and methods) that would learn from journalists and media experts who use the tools to annotate and identify disinformation-related content. We will utilize state-of-the art NLP methods including pre-trained large language models for Finnish (e.g. FinBERT), methods that allow training or enhancing models even with very little resources (e.g. using few-shot learning), and smart data selection for human annotation. The qualitative and computational insights from this research has the potential to increase the preparedness of news media practitioners to address the liquid character of disinformation in the future.

You would join the CRAI-CIS research group in the Computer Science department at Aalto University. The transdisciplinary group explores the impact of technology in critical societal contexts, working at the intersection of computational and social sciences engaging HCI and participatory design. More here: https://crai-cis.aalto.fi

4121 - Civic Agency in AI (CAAI): Examining Responsible Practices & Critical Discourses for Public Sector AI

Field of study:	Human Computer Interaction (HCI), Natural Language Processing (NLP), Ethical and Responsible AI	
For students currently studying:	Master's preferred	
Number of positions offered:	1-2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Nitin Sawhney	nitin.sawhney@aalto.fi
Academic contact person:	Karolina Drobotowicz	drobotowicz.karolina@aalto.fi

Algorithmic tools are increasingly being incorporated into public sector services in cities today. The CAAI project aims to understand citizens' algorithmic literacy, agency and participation in the design and development of AI services in the Finnish public sector in order to advance more democratic and citizen-centric digital infrastructures. This new project has the following research objectives: 1) understanding the values, narratives and discourses embedded in public sector data-centric and algorithmic services, 2) understanding citizens' level of literacy and perceived agency with regards to algorithmic public services, 3) empowering citizens to critically engage with algorithmic public services, and 4) transforming design of public sector AI services to ensure civic participation.

Applicants must show a keen interest in this topic and bring a mix of technical and soft skills in at least one of these aspects: programming and rapid prototyping of web-based platforms, using NLP and textual data processing for analysing content and data visualization, and/or conducting interviews and qualitative research with potential participants as part of our team.

You would join the CRAI-CIS research group in the Computer Science department at Aalto University. The transdisciplinary group explores the impact of technology in critical societal contexts, working at the intersection of computational and social sciences engaging HCI and participatory design. More here: https://crai-cis.aalto.fi

4201 - Formalization of mathematics

Field of study:	mathematics (computer formalized)	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	2	
School:	School of Science	
Department:	Department of Mathematics and Systems Analysis	
Professor:	Kalle Kytölä	kalle.kytola@aalto.fi
Academic contact person:	Kalle Kytölä	kalle.kytola@aalto.fi

Formalization of mathematics means writing mathematics in an unambiguous language understood by a computer. This includes formulating both the statements and their proofs. One of the central objectives of formalization is to create a comprehensive, unified, digital library of mathematical knowledge, which has the further virtue of being computer verified for correctness. Among the most successful current libraries of this type is Lean's mathlib <https://github.com/leanprover-community/mathlib>, written in a language called Lean. For some perspective to the current status, one can compare the library to university curricula on the one hand, and current mathematical research on the other hand. There are a few examples of research level results formalized based on mathlib, which indicates that the library has the potential to become a useful resource for mathematicians. Yet, substantial parts of any standard undergraduate curriculum in mathematics are still missing. In particular the library is missing lots of standard probability theory and analysis, although a good amount of measure theory and point set topology exists and can be built on.

These internship projects pertain to the formalization of some aspects of probability theory or analysis in Lean, at the undergraduate or graduate level. Given the speed at which the library is currently developed, the status will inevitably change by the beginning of the summer internship, and it does not make sense to specify the topics of the internships in full detail. Example topics to formalize could be: basic properties of Hilbert-Schmidt operators, classification of states of Markov chains, extreme value statistics, metrizability of convergence in distribution, sequential compactness version of the Banach-Alaoglu theorem, etc. The internship is expected to lead to either successful Lean formalizations or important insights into issues that need to be taken into consideration in the formalization of such topics. The internship may also include testing or minor development of formalization tools for teaching.

Successful candidates should have a solid mathematics background of at least undergraduate level. Some programming skills are needed, and any amount of previous formalization experience in Lean or any other language will be viewed favorably. Please include descriptions and evidence of these in your application.

4202 - Smith form of powers of a matrix

Field of study:	Mathematics	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Mathematics and Systems Analysis	
Professor:	Vanni Noferini	vanni.noferini@aalto.fi
Academic contact person:	Vanni Noferini	vanni.noferini@aalto.fi

The Smith theorem is a result that arises in matrix theory. It has application both to other areas of pure mathematics, e.g., group theory, number theory, algebraic topology, and to mathematical engineering, e.g., control theory, signal processing, systems of differential-algebraic equations. (A special case of) the theorem says the following: Let R be a principal ideal domain. If M is a matrix over R, then M=PSQ where P and Q are unimodular (invertible over R) matrices whereas S is diagonal and satisfies the property that its j-th diagonal element divides the (j+1)-th one, for all j for which the statement makes sense. S is called a Smith form of M; moreover, the diagonal elements of S are uniquely determined by M (up to multiplication by a unit of R), and they are called the invariant factors of M.

If A and B are matrices over R of suitable sizes, then bounds for each of the invariant factors of AB are known in terms of the invariant factors of A and B: see, e.g., the review paper [J.F. Quieró and E. M. Sá, Singular values and invariant factors of matrix sums and products, Linear Algebra Appl. 225, 43-56, 1995] at https://www.sciencedirect.com/science/article/pii/002437959300317S. These bounds are also tight in the sense that, two lists of invariant factors and an element of R that satisfy the k-th such constraint, matrices A and B exist such that the invariant factors of A, B correspond to the two given lists and the k-th invariant factor of AB is the given element. Much less is known about the special case B=A, that is, how the invariant factors of A^2, and more generally of the powers of A, can possibly relate to those of A. The goal of the project is to explore this topic. Obtaining a complete answer is probably very ambitious, but it would already be interesting to investigate some special cases and/or to explore the topic experimentally and to form some conjecture to be proved or disproved in the future.

A successful candidate should have a solid background in mathematics and in particular prior knowledge of matrix theory and/or algebra (esp. ring theory) is very beneficial. Moreover, they should ideally possess programming skills in a suitable mathematical software. Benefits for a student that completes the project include becoming knowledgeable with a research problem, and with the typical tools employed in mathematical research. If significant progress is made, the project might even eventually lead to the writing of a paper in collaboration with the hosting professor: however, this is not necessarily expected.

Concretely, within the project the intern will (likely) need a first reading phase to become familiar with the topic and learn the relevant properties and definitions. In a second phase, the student will start to actively work on the problem, make experiments and, possibly, form conjectures.

4301 - Developing a virtual reality environment to study mental rotation in humans.

Field of study:	Computer Science and Neuroscience (the projected is cross listed in the Department of Computer Science)	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Neuroscience and Biomedical Engineering	
Professor:	Stephane Deny	stephane.deny@aalto.fi
Academic contact person:	Stephane Deny	stephane.deny@aalto.fi

Topic: Mental rotation is the ability that humans have to imagine objects in various poses, allowing them to recognise and compare objects in their everyday life. It is still unknown what algorithms are employed by the brain to perform mental rotation. This project consists in building a virtual reality environment (using the Unity3D framework) in order to study how humans perform mental rotation of 3D objects. Part of the project will consist in developing the 3D environment and part of the project will consist in designing and running pilot experiments to study mental rotation.

About the lab: The 'Bidirectional Research in AI and Neuroscience' (BRAIN) lab is joint between the Department of Neuroscience and Biomedical Engineering and the Department of Computer Science at Aalto University. The objective of the lab is to deliver fundamental advances in our understanding of the brain algorithms, and inspire the next generation of models for AI.

Preferred skills: Some experience in programming. Some interest for the topic.

4401 - Force measurements on living micro-organisms

Field of study:	Physics	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Matilda Backholm	matilda.backholm@aalto.fi
Academic contact person:	Matilda Backholm	matilda.backholm@aalto.fi

Summary: This is an experimental physics project in the general field of soft, living, and fluid materials. We conduct curiosity-driven research on the mechanics, dynamics, and flow of tiny living organisms. The research topic of this project can be tuned based on the skills, experience, and interests of the student. The project will be carried out in the Living Matter group (https://www.aalto.fi/en/living-matter) with Prof. Matilda Backholm acting as the main supervisor. A PhD student or postdoc in the team will also act as an advisor.

Project: We will study forces in living systems, such as the swimming dynamics of microscopic organisms or growth dynamics of tiny plant roots. You will be trained to use the micropipette force sensor technique (M. Backholm et al., Nature Protocols 2019: https://www.nature.com/articles/s41596-018-0110-x), perform hands-on experiments, analyze your data in MATLAB, and present your results during our group meetings.

Necessary skills: We welcome highly motivated MSc students with a strong academic track record in physics and a genuine interest in working in a living matter physics lab. Our work is highly interdisciplinary and collaborative, thus our team members need to be fluent in English and have strong communication skills. Experience in using MATLAB is beneficial.

4402 - Predicting phase transitions in quantum systems

Field of study:	Theoretical physics, Quantum physics, Statistical physics	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Christian Flindt	christian.flindt@aalto.fi
Academic contact person:	Fredrik Brange	fredrik.brange@aalto.fi

Summary

Phase transitions are ubiquitous phenomena in physics, characterized by a swift change in the properties of a system as an external control parameter, such as temperature, is altered. Predicting and understanding the transition between different phases of matter lies at the heart of statistical physics. For conventional equilibrium phase transitions, Lee-Yang theory provides a tool to study the presence of phase transitions. Lee-Yang theory is based on tracking the zeros of the partition function in the complex plane of the control parameter as the system size is increased. For finite system sizes, the zeros are always complex as the partition function is a finite sum of strictly positive exponential functions, with no real zeros. However, in the thermodynamic limit, the zeros may converge to real values of the control parameter, for which a phase transition occurs.

In this project, we will investigate how a similar approach can be utilized to study other kinds of phase transitions in quantum systems, such as quantum trajectory phase transitions. In this case, the phase transition does not occur between different equilibrium phases, but between dynamical phases. More specifically, we will consider the quantum Rabi model, describing a single two-level system coupled to a harmonic oscillator. The project will involve important theoretical concepts such as moment-generating functions, cumulants, the cumulant method, and large-deviation statistics. The student will gain in-depth knowledge in how to describe light-matter interactions, as well as phase transitions in quantum systems with Lee-Yang theory. The project will thus provide the student with a solid background for future studies and research in theoretical physics, quantum transport, and quantum information.

Necessary skills

We look for a highly motivated student in theoretical physics (or related areas), with a strong academic background in quantum physics and/or mathematics. The project will deal with both analytic derivations and numerical calculations. Skills in Mathematica and/or Matlab are an advantage, but not a requirement.

4403 - Generation and detection of entanglement in Cooper pair splitters

Field of study:	Theoretical physics, Quantum transport, Quantum information	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Christian Flindt	christian.flindt@aalto.fi
Academic contact person:	Fredrik Brange	fredrik.brange@aalto.fi

Summary

Entanglement lies at the heart of quantum mechanics, constituting one of the key ingredients to realize quantum information processing. Over the last few decades, Cooper pair splitters have emerged as promising devices to generate spin-entangled electrons in nanoscale systems. In these devices, entangled Cooper pairs existing inside a superconductor are extracted and split by coupling the superconductor to, e.g., two physically separate quantum dots. In this way, it is possible to generate and physically separate pairs of spin-entangled electrons. By controlling the energy levels of the quantum dots, the Cooper pair splitting can be tuned on and off resonance, thus allowing a high degree of control over the timing of the extraction of the entangled electrons. In this project, we will investigate how various feedback protocols, where the tuning of the energy levels depends on the state of the system, may be used to control the Cooper pair splitting in order to extract entangled particles in an efficient way.

The student will gain in-depth knowledge in how to describe quantum transport and entanglement in nanoscale systems. More specifically, the student will get the chance to work with important theoretical concepts such as density matrices, open quantum systems, master equations, full counting statistics, and feedback protocols. The project will thus provide the student with a solid background for future studies and research in theoretical physics, quantum transport, and quantum information.

Necessary skills

We look for a highly motivated student in theoretical physics (or related areas), with a strong academic background in quantum physics and/or mathematics. The project will mainly deal with analytic derivations and calculations, but might also involve some numerical calculations in, e.g., Matlab.

4404 - Machine Learning Strategies for Scientific Data Analysis

Field of study:	Physics	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1-4	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Adam Foster	adam.foster@aalto.fi
Academic contact person:	Adam Foster	adam.foster@aalto.fi

Scientific data can be generated through physical simulations, experimental laboratories and observations from real-world problems. Compared to just a few years ago, the advancement of scientific instruments, digital sensors and computational resources as well as storage devices have created huge collections of scientific data. Unlike traditional statistical analysis, Machine Learning (ML) thrives on growing data sets. The more data fed into an ML system, the more it can learn and apply the results to higher quality predictions and new insights. In this project, we will investigate and implement ML methods (e.g., kernel regression, autoencoders, deep learning) for finding key variables influencing physical phenomena and materials properties. In particular, we will develop and exploit the wealth of materials data available (most of it generated in our research group) and use ML to discover new materials and phenomena linked to them. Examples within the SIN group (http://www.aalto.fi/physics-sin) include interpreting microscopy imaging, identifying exotic quantum phenomena and predicting hydration structures.

The detailed applications and tasks will be tailored according to the background and interests of successful candidates. Applicants should have a basic knowledge of physics, data analysis and statistics. Knowledge of Python would be highly beneficial.

4405 - Ising superconductors

Field of study:	Condensed matter physics	
For students currently studying:	Bachelor's and Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Pertti Hakonen	pertti.hakonen@aalto.fi
Academic contact person:	Alexander Zyuzin	alexander.zyuzin@aalto.fi

Two-dimensional superconductivity has been recently discovered in monolayer transition metal dichalcogenides (for example, $NbSe_2$) [1]. The electronic band structure of this material contains several valleys in which strong spin-orbit interaction pins the spins of electrons to the out-of-plane directions. It's worth mentioning some recent interesting experimental observations for superconducting $NbSe_2$. Such as the increase of the superconducting transition temperature by disorder [2] and observation of anisotropic magnetoresistance in Ising superconductor – magnetic insulator tunnel junctions [3].

Stimulated by recent experiments, in this project, we will theoretically investigate the interplay of superconductivity and magnetism in disordered Ising superconductors. Students interested to learn and apply theoretical techniques to explain recent observations or propose new experiments (such as for Cooper pair splitting) using Ising superconductors are welcome to join the project.

[1] Ugeda et al., Nature Physics 12, 92 (2016).
[2] Zhao et al., Nature Physics 15, 904 (2019).
[3] Kang et al., arxiv. 2101.01327.

4406 - Quantum phase transitions in multiorbital fermion chains

Field of study:	Quantum Materials	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Jose Lado Christian Flindt	jose.lado@aalto.fi christian.flindt@aalto.fi
Academic contact person:	Adolfo Fumega Pascal Vecsei	adolfo.oterofumega@aalto.fi pascal.vecsei@aalto.fi

Summary

This is a project in theoretical condensed matter physics, in particular in the field of quantum magnets. The project can be suitable for a bachelor's thesis, a special assignment, or a master's thesis, and its difficulty can be adjusted to your level. The project will be carried out between the Correlated Quantum Materials group led by Prof. Jose Lado and the Quantum Transport group led by Prof. Christian Flindt. The project will be co-supervised by PhD candidate Pascal Vecsei and Dr. Adolfo O. Fumega.

Background

Quantum many-body systems give rise to exotic phases of matter that cannot occur in classical systems. The recent development of experimental techniques allows now to group atoms forming a desired structure. In particular, atoms can be engineered creating a chain of coupled fermions. Depending on the coupling of these fermions and the energy levels in each of the sites of the chain different quantum phases can emerge.

Matrix product states (MPS) are a widely used method in the study of quantum many-body systems. They provide a convenient way to represent and manipulate the wavefunction of a system, and have been successful in describing the properties of a variety of systems, in particular 1-dimensional systems such as chains. Therefore MPS become the ideal tool to analyze a multilevel fermion chain.

Task

In this project, you will solve a quantum many-body model for a multilevel fermion chain using MPS. You will study the system in different regimes that will be controlled with the different parameters entering the many-body model. From this analysis, your aim will be to get a phase diagram and the physical quantities that characterize each of those phases. Your results will allow to provide the signatures that characterize the different phases that a fermion chain can realize in an experiment.

4407 - Simulating noisy quantum computers

Field of study:	Quantum Computing	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Jose Lado Christian Flindt	jose.lado@aalto.fi christian.flindt@aalto.fi
Academic contact person:	Marcel Niedermeier	marcel.niedermeier@aalto.fi

Summary:

Quantum simulators are crucial tools in the development of quantum algorithms. The most straightforward way of simulating a quantum circuit is to take a representation of the initial state, and to multiply it by the sequence of the desired quantum gates. However, this approach is severely limited by the available memory and computing power, as the number of parameters grows exponentially with the number of simulated qubits. Currently, our group is working on writing a quantum simulator based on tensor-network algorithms, instead of exact state vectors. This makes it possible to circumvent the exponential scaling of the quantum state space and thus to simulate a much higher number of qubits on a classical computer, at the cost of sacrificing some high-entanglement degrees of freedom. Effectively, this approach is analogous to noisy intermediate-scale quantum computation, which can be controlled by a single parameter. Our main goal is to study how well such an approach is suited for the development of noisy intermediate-scale quantum algorithms, in particular with applications in condensed matter physics. Intermediate-scale quantum simulation of condensed matter models are at the forefront of current quantum materials physics research.

There are many different possibilities for summer projects which could be tailored to the candidate's knowledge and interest (with the possibility to turn them into a Bachelor's or Master's thesis, if desired). For instance, we could pick a quantum algorithm and study how it behaves at different bond dimensions of the underlying MPS, which ultimately is equivalent to study the algorithm at different levels of noise. An interesting study at this stage would be to compare the results of the tensor-network simulations with the same calculation performed on a real quantum computer. This may help us to better understand how the simulated noise compares to the noise encountered in a real quantum computation.

Necessary skills:

Knowledge of quantum mechanics at undergrad level (preferably some familiarity with the quantum circuit model) and some programming experience in at least one high-level language (such as Python – for this project, we will use Julia). For certain projects (e.g. at Master's level), familiarity with concepts from quantum information, solid state/condensed matter physics and/or statistical mechanics can be an asset.

4408 - Hamiltonian Inference with Quantum Machine Learning in Materials Science

<table>
<tr><td>Field of study:</td><td colspan="2">Quantum machine learning</td></tr>
<tr><td>For students currently studying:</td><td colspan="2">Bachelor’s or Master’s</td></tr>
<tr><td>Number of positions offered:</td><td colspan="2">1</td></tr>
<tr><td>School:</td><td colspan="2">School of Science</td></tr>
<tr><td>Department:</td><td colspan="2">Department of Applied Physics</td></tr>
<tr><td>Professor:</td><td>Jose Lado
Christian Flindt</td><td>jose.lado@aalto.fi
christian.flindt@aalto.fi</td></tr>
<tr><td>Academic contact person:</td><td>Marcel Niedermeier
Rouven Koch</td><td>marcel.niedermeier@aalto.fi
rouven.koch@aalto.fi</td></tr>
</table>

Summary:

Quantum computing is expected to radically change the way in which certain problems in science are tackled. Especially in the simulation of quantum systems whose degrees of freedom scale exponentially in the system size, or data-driven tasks, the superposition principle of quantum mechanics allows us to greatly reduce the space requirements of the computation. While currently available quantum computers are still prone to errors and decoherences, improved quantum computing processors are developed every year, and a processor with multiple thousands of qubits has been announced by the middle of the decade. Therefore, the interest of the scientific community in the development of quantum algorithms and their performance on NISQ hardware is great, and at the cutting edge of research. In our group, we are amongst others studying the application of quantum computing to condensed matter physics and materials science. So far, we have already developed a quantum simulator based on tensor-networks, which allows us to simulate noisy computers at a much lower cost than necessitated by an exact circuit simulation. Furthermore, we have done research on the interface of machine learning and unsolved problems of quantum-many-body systems, using techniques such as supervised learning for neural networks and generative adversarial networks .

In the present project, we would like to combine these two fields and study quantum machine learning in materials science. Quantum Machine Learning (QML) is a recent field which combines quantum mechanics and technologies with data-driven tasks and big data. QML algorithms can be run on quantum circuits, which can be simulated with tensor-networks or run on experimental platforms as current quantum computers. In general, QML can be applied for classical and quantum data where a combination of classical and quantum algorithms is used (e.g. the neural network is replaced by a quantum circuit but a classical optimization algorithm as stochastic gradient descent is applied to optimize the parameters).

This summer project has several different options to be adapted to the candidate’s prior knowledge about quantum circuits as well as (quantum) machine learning with possible extensions into a Bachelor’s or Master’s thesis, if desired. In particular, we want to train a QML algorithm to perform Hamiltonian inference of dynamical excitations in a complex spin Hamiltonian. The results of the hybrid QM/classical algorithm can be compared with a classical ML algorithm using a neural network instead of a parametrized quantum circuit. In this project, the algorithm will be run on a simulated quantum circuit within the Qiskit package, for instance exploiting and comparing multiple different simulation backends. Time and resources permitting, it will also be possible to perform an actual quantum computation.

Necessary skills:

Knowledge of quantum mechanics at undergrad level (preferably some familiarity with the quantum circuit model) and some programming experience in at least one high-level language (preferably Python). Ideally some background knowledge in Pytorch for ML applications, or some basic knowledge about ML in general.

4409 - Radiation damage in multi-component alloys

Field of study:	Physics	
For students currently studying:	Master's	
Number of positions offered:	2	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Andrea Sand	andrea.sand@aalto.fi
Academic contact person:	Andrea Sand	andrea.sand@aalto.fi

Description: Particle irradiation modifies the physical and mechanical properties of materials, and plays an increasing role in modern technological developments. For example, climate change is driving the need for green energy, with nuclear fusion and next generation fission standing as two of the strongest candidates for efficient and reliable energy production of the future, yet the challenges posed to reactor materials in the high radiation environments are significant. Modelling provides an essential tool for predicting the response of reactor components in future nuclear devices. The damage in materials created by energetic impacting particles is highly sensitive to the mechanisms of dissipation of the impinging particle's kinetic energy.

This summer project involves performing simulations employing a recently developed atomistic model, which accounts for energy dissipation in unprecedented detail, to predict the primary radiation damage in model alloy systems under different incident neutron and ion energies. Focus will be on analysis of the surviving damage, including defect numbers and morphology. The student will gain knowledge of the processes of radiation damage formation in materials, learn the basics of performing molecular dynamics simulations of highly non-equilibrium events, and develop a familiarity with high performance computing environments.

Necessary skills: Experience in programming, e.g. with Python, is highly desirable. The candidate should also have basic knowledge of solid-state physics and computational physics. Previous experience of molecular dynamics or high-performance computing is considered a plus.