Aalto Science Institute (AScI) summer research programme

2022 project list

For more information on the program and how to apply, see https://www.aalto.fi/en/aalto-science-institute/aalto-science-institute-asci-internship-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	
School:	School of Chemical Engineering	
Department:	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 - Applications of CRISPR-mediated genome editing in methanogens

Field of study:	Molecular biology	
For students currently studying:	Master’s	
School:	School of Chemical Engineering	
Department:	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) for the production of methane. On the other hand, they are not good in utilizing or producing multi-carbon substrates or products.

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

Possible tasks for summer students (depends also how the current research is progressing):
- Optimize our current CRISPR toolbox for faster and smarter editing of genomes
- Extend toolbox to other methanogen species
- Explore potential targeting-sites in genome
- Gene expression level test
- 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

School of Electrical Engineering

Department of Communications and Networking

2101 - Bayesian Inference for Computational Cognitive Models		
Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Antti Oulasvirta	antti.oulasvirta@aalto.fi

Description: Computational cognitive models are simulators that make predictions of behaviour in various tasks. They can be very useful in creating intelligent interactive systems that understand their users, but only if the models are correctly specified and their parameters set according to the preferences and abilities of individual users. Correctly parameterized user models can predict behaviour under various conditions, permitting optimisation of user interfaces and anticipation of user responses to task events. Recent advances in reinforcement learning (RL) based cognitive modelling have extended the range of possibilities for simulating task behaviour, as they can predict how adaptive strategies emerge in various task conditions.

The project presents an opportunity to learn about RL based computational modelling and Bayesian parameter inference. It utilises an existing RL based computational model and task data, and utilises an engine for inferring the parameters of the model from different individuals in the data. The project implements the inference framework required to create predictions of users given observed interactive behaviour. [This work is associated with the Finnish Center for AI (fcai.fi).]

Requirements: The applicants are expected to have strong programming skills (Python) and studies in human-computer interaction. In addition, skills in following are preferred but not required: reinforcement learning, Bayesian parameter inference, computational cognitive modelling.

2102 - Intelligent Optimization for User Interface Design

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Niraj Ramesh Dayama	niraj.dayama@aalto.fi

Description: Are you up to the challenge of doing some real hands-on research-based coding for an exciting industry-sponsored project?

Our team is working on computational techniques to design Graphical user interfaces (GUIs). A well-designed GUI becomes a key factor for the success of any app, website or application. We have already developed (and published) a wide array of mathematical and computational tools for GUI design. Several more techniques are currently under development. Our industry sponsors help us identify practical challenges that their designers face during their regular work. We provide novel solutions that help the industry and also contribute to the academic research literature. Would you like to join this journey?

Requirements: The applicants are expected to have strong programming skills (Python). Further, they will need to learn and implement new software packages and programming paradigms. Skills in the following are strongly preferred but not required: Mathematical optimization (such as linear programming), Machine learning, Heuristic algorithms.

2103 - Evaluation of User Interface Designs

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Antti Oulasvirta	antti.oulasvirta@aalto.fi

Description: A great user interface (UI) is always at the heart of a successful app or website. But what is it that makes one UI much nicer and better than the others?

Our research group is working on computational techniques to design Graphical user interfaces (GUIs). We have already developed (and published) a wide array of mathematical and computational tools for GUI design. Several more techniques are currently under development. Our industry sponsors help us identify practical challenges that their designers face during their regular work. We provide novel solutions that help the industry and also contribute to the academic research literature.

We are now starting on a project that requires us to evaluate the qualities of a given UI to objectively state that it is good (or not so). To join this project, we are looking for interns who have had some hands-on design experience with Sketch, Figma (or Adobe) in conjunction with strong programming skills (Python or Java). Further, they should have a drive to learn and implement new software packages and programming paradigms. Skills in the following are strongly preferred but not required: Mathematical optimization (such as linear programming), Machine learning, Heuristic algorithms.

2104 - Color Design AI

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Lena Hegemann	lena.hegemann@aalto.fi

Description: 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.

2105 - Co-design with AI

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Joongi Shin	joongi.shin@aalto.fi

Description: When designing a solution for multiple stakeholders, a key to satisfying all stakeholders is facilitating quality communication between them. How would AI support such knowledge exchange?

Co-design is a design approach that designers invite stakeholders to participate in the process of designing a solution for themselves. Unlike the traditional design approach that designers see users as a mere source of information, the core value of co-design is that stakeholders contribute as the experts in their own domains who actively share their needs, perspectives, and ideas. Throughout a design process, they cooperatively set common goals and design solutions that are satisfying to all. Therefore, how well designers communicate with stakeholders to promote and facilitate knowledge exchange is a key to successful co-design projects.

However, the co-design process is also limited by designers, human beings. Their ability is limited to managing a certain number of stakeholders and interactions, which potentially harms the whole purpose of involving multiple stakeholders in every step of the design process. As a solution, we envision the AI to step in and take some responsibility.

Our goal in this project is to develop a chatbot that moderates co-design activities in supporting designers. In the context of teachers and students designing a course together, we aim to investigate how a chatbot would facilitate conflict resolution. During the internship, we will together develop the UI and interactions of a chatbot that stimulate stakeholders to look at opposing ideas from each other's perspectives and compromise.

Requirements: The applicants are expected to have strong programming skills (Python) and studies in human-computer interaction. In addition, knowledge in the following fields are preferred but not required: NLP, chatbot, co-design

2106 - A Robotic Model for Affordance Perception

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor’s or Master’s	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Yi-Chi Liao	yi-chi.liao@aalto.fi

Description: When you see a button for the first time, how do you know the button can be ″pressed″? Psychologist J. J. Gibson coined the term affordance to solve the mystery. To Gibson, affordances are the possible actions that the environment offers to the animals. For example, a cup offers you ″grasp,″ a ball offers you ″throw,″ and a chair offers you to ″sit.″ Further, the animals can naturally perceive these affordances. However, can we allow robots to have the same ability -- that is, perceiving the possible actions offered by the environment?

The aim of this project is to tackle this grand question. We are building a robotic model that can allow the robots to explore and learn affordance from the interactions with physical objects. The research group has formulated a novel affordance theory based on reinforcement learning, and the project has been accepted to CHI 2022 (the top-tier venue in the Human-Computer Interaction field, see https://chi2022.acm.org/). Currently, we are expanding our model, which is based on the new theory, and looking forward to applying the model to both robots in a simulation environment and in a real-world setup.

During the internship, you will be working with Yi-Chi (a Ph.D. student in User Interfaces, see http://yichiliao.com) to build a reinforcement learning model and apply it to a physical simulation (Mujoco) and a real-world robot. We will also conduct experiments to compare the robot performance against the human baseline.

Requirement: The applicants are expected to have strong programming skills in Python and other programming languages, and sufficient experiences in any of the following subjects - reinforcement learning, meta-learning, robotics, or computer vision.

2107 - Simulation-based Optimization for Physical Interaction Design

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Yi-Chi Liao	yi-chi.liao@aalto.fi

Description: How do we design a physical interface (for example, a push-button)? The traditional approach (also known as User-Centered Design) typically requires iterations of design, implementation, evaluation, and analysis [1]. This workflow is inefficient, biased by the designers, and the results are not promising. It is time for revolution!

The aim of this project is to introduce a novel workflow for designing physical interactions -- that is, Simulation-based Optimization [2]. We are looking into the opportunities where a user model generating synthetic user behaviors interacts with an adaptive user interface. The interaction will automatically derive the optimal design instances. During the internship, you will be working with Yi-Chi (a Ph.D. student in User Interfaces, see http://yichiliao.com) to implement a component for this novel workflow.

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

[1] https://www.interaction-design.org/literature/topics/user-centered-design
[2] https://link.springer.com/content/pdf/10.1007/978-1-4899-7491-4.pdf

2108 - Computational Graphical User Interface Evaluation

Field of study:	Computer Science - Human-Computer Interaction, Machine Learning, and Cognitive Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Department of Communications and Networking	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Markku Laine	markku.laine@aalto.fi

Description:Are you passionate about UI/UX? Keen on learning how to automatically evaluate and fix graphical user interfaces using computational methods, including machine learning?

Graphical user interfaces (GUI) are omnipresent in our everyday life and play an important role in how users interact with various electronic devices. Typically, evaluation of GUIs relies on designers' personal experience (subjective) and empirical user testing (time-consuming), and less so on computational modeling. To address these concerns, we developed Aalto Interface Metrics (AIM), an online web service (https://interfacemetrics.aalto.fi/) and codebase (https://github.com/aalto-ui/aim) for computational evaluation of GUI designs.

The intern will contribute to the further development of AIM and/or its successor system by studying and implementing state of the art metrics and models to them. The intern is expected to have strong programming skills in Python and background in human-computer interaction. In addition, knowledge in different machine learning techniques is preferred but not required.

2201- Intelligent Vertical Farm

Field of study:	Smart agriculture, industry 4.0, artificial intelligence, machine learning	
For students currently studying:	Master's	
School:	School of Electrical Engineering	
Department:	Department of Electrical Engineering and Automation	
Professor:	Valeriy Vyatkin	valeriy.vyatkin@aalto.fi
Academic contact person:	Udayanto Dwi Atmojo Polina Ovsiannikova	udayanto.atmojo@aalto.fi polina.ovsiannikova@aalto.fi

Vertical farming (VF) is one of the approaches to growing greenery in an expanding urban environment. Generally, a vertical farm is a greenhouse with a fully controlled climate and plants growing in vertical trays or columns soilless. This reduces the growing space (due to vertical arrangement), usage of water, nutrients, and enables growing with zero pesticides, making VF an option for growing in extreme conditions such as in the Arctic / Antarctica, or other planets.

The task of this project is to work on one of the challenging parts of such a structure - its automation. Having a testbed functioning according to hydroponic principle, the student's task will be to implement a cloud-connected automation architecture. Data from the plant, its surrounding environment, and other variables of interest in the VF can be collected using OPC-UA-based data collection, and based on the goal, the automation shall make the decisions on adjustments in the state of VF, e.g., lighting, climate control, watering etc. For example, we can consider energy consumption. If the overall demand increases, the farm should be able to use onboard energy storage (batteries) instead of taking energy from the grid or make a decision on where the light is not critical right now and can be dimmed / turned off. Such decisions can be made based on some analytics results based on collected data, which might be carried out by machine learning algorithms running in the cloud or edge.

This vertical farming prototype is housed at Aalto Factory of the Future (https://www.aalto.fi/en/futurefactory). The student will have options to propose which goal and analytics approach to implement.

This project expects the candidate to be a Master (Master's, MEng, …) degree student with a background in control, automation, or mechatronics, with good command of English. Having machine learning or artificial intelligence knowledge is advantageous.

2301 - Organic Materials and Devices

Field of study:	Physics, Applied Physics	
For students currently studying:	Bachelor's or Master's	
School:	School of Electrical Engineering	
Department:	Electronics & Nanoengineering	
Professor:	Caterina Soldano	caterina.soldano@aalto.fi
Academic contact person:	Caterina Soldano	caterina.soldano@aalto.fi

The Organic Electronics Group is looking for a curious and talented student, either at Bachelor's or Master's level, for the Summer 2022, as part of the Aalto Science Institute internship program.

You will contribute to the advance of the field of organic devices; in particular, your role will be to develop thin films, both dielectrics and organic materials, in order to study and improve device performances. Experimental work will include characterization of materials, and fabrication and characterization of devices.

Our group is international, and thus a good command of English is required.

Further information: Prof. Caterina Soldano
www.organicelectronics.aalto.fi (please visit our website for more info)

2401 - Robust machine learning in the Big Data era

Field of study:	Machine Learning, Signal Processing	
For students currently studying:	Master's	
School:	School of Electrical Engineering	
Department:	Department of Signal Processing and Acoustics	
Professor:	Esa Ollila	esa.ollila@aalto.fi
Academic contact person:	Esa Ollila	esa.ollila@aalto.fi

Nowadays, most of engineering applications involve large amount of data. One major issue is that such *Big Data* can be of poor quality. This is because sensors often operate in noisy environments, data contain missing values, or mislabelled data. Furthermore, a new form of data corruption has recently appeared, namely adversarial contamination. Consequently, there is an increasing need for machine learning (ML) techniques that allow to extract meaningful information and patterns reliably from increasingly high-dimensional data, while being robust to outliers, model imperfections, or adversarially doctored data.

The aim of this project is to develop ML/AI methods for solving these issues by capitalizing on novel optimization algorithms and/or data representations such as tensors and graphs. The project employs novel tools and methods from robust statistics. For example, using tensor-valued learning procedures one can better answer questions such as "Can a hyperspectral image of an agricultural region be used to predict the crop type or crop quality accurately?". In this work, the student will work on both theoretical developments and applications of the algorithms.

The prospective candidate should be familiar with topics related machine learning, signal processing or statistics. The student should ideally have some experience with Python and its machine learning and data processing packages.

Reference: Abdelhak M. Zoubir, Visa Koivunen, Esa Ollila, and Michael Muma, "Robust statistics for signal processing," Cambridge University Press, Nov. 2018, 289 pages. https://doi.org/10.1017/9781139084291

School of Engineering

Department of Built Environment

3101 - Integration of mesoscopic and agent-based simulations for mobility		
Field of study:	Transport Engineering	
For students currently studying:	Master's	
School:	School of Engineering	
Department:	Built Environment	
Professor:	Claudio Roncoli	claudio.roncoli@aalto.fi
Academic contact person:	Serio Agriesti	serio.agriesti@aalto.fi

Understanding the impacts of future mobility systems requires novel tools that are capable of capturing travellers' and vehicles' behaviours with an unprecedented level of detail and disaggregation. This internship will focus on transport modelling and simulation, where the objective is the integration of two approaches for demand and supply modelling. Ongoing activities result in the implementation of two separate models, one simulating the travellers' demand in a disaggregated fashion (using the open-source software SimMobility MT) and one simulating the transport supply at mesoscopic (and microscopic) level (using the commercial software Aimsun). The intern is expected, in collaboration with members of the research team, to develop an integrated framework that allows the interaction of the two abovementioned models. The main scientific output would be a modeling framework able to simulate the transport system in each one of its components, from the demand to the supply, exploiting behavioral, routing, and car-following models

The intern will collaborate in designing and developing the framework (including writing code, possibly in Python), executing simulations, exchanging inputs and outputs, and checking for convergence based on the most appropriate measure of error.

The intern is therefore expected to have the following skills:

- Intermediate coding (including ability to exploit the most suitable libraries to maximize computational efficiency). Preferred languages: Python, C++, and R
- Intermediate knowledge in algorithm designing
- Basic to intermediate mathematical and statistical knowledge
- Basic knowledge about transport modeling and transport systems (the academic contact person can share some relevant reading beforehand, to acquire the minimum set of skills expected for this item)

The intern is expected to work at the Built Environment department. The Aimsun software is installed on a workstation located in our premises and cannot be used from any computer.

3102 - Investigating drivers' behavior under social routing nudges

Field of study:	Transport Engineering	
For students currently studying:	Master's	
School:	School of Engineering	
Department:	Built Environment	
Professor:	Claudio Roncoli	claudio.roncoli@aalto.fi
Academic contact person:	Shaya Vosough	shaghayegh.vosough@aalto.fi

Cities are looking for better ways to manage the liveability of urban spaces and an interesting direction involves the development of novel mobility management strategies. However, in order for these strategies to be effective, they should be based on a thorough understanding of travellers' behaviour and their reactions to external inputs. With the goal of improving this knowledge, we aim at investigating the effect of various types of nudges to encourage drivers to choose safer and more sustainable routes to improve urban mobility.
In a joint effort of cities, service providers, and universities, we recently conducted a set of experiments in the cities of Helsinki and Amsterdam, informing drivers about alternative "socially responsible routes", via a navigation app, and recording their choices. For a better understanding of the possible behavioral change and of the factors affecting drivers' decisions, we are going to analyze such data and apply econometrics models.

We are looking for an intern to join us in developing a modeling tool for analyzing drivers' behaviour under various trip information strategies and goals. This process could include data preparation, scenario definition, development and calibration of discrete choice models, and visualization of proper outputs.

The applicant is expected to have a background in statistics and econometrics. (S)he should be familiar with (or interested to learn) topics related to transport and mobility, while, ideally, having experience in statistical modelling software such as Stata, Limdep, or similar.

3201 - Structural analysis and simulation of origami structures

Field of study:	Computational structural engineering, Computational mechanics	
For students currently studying:	Master’s	
School:	School of Engineering	
Department:	Department of Civil Engineering	
Professor:	Assoc. Prof. Jarkko Niiranen	jarkko.niiranen@aalto.fi
Academic contact person:	Assoc. Prof. Jarkko Niiranen	jarkko.niiranen@aalto.fi

Description: This internship project focusing on the structural analysis and simulation of origami structures is a part of a larger research project entitled “FOLD -- Novel folding technology for light-weight design structures and protective packaging”. The FOLD project, accomplished by a multidisciplinary consortium including academic and several industrial partners, combines mathematics, mechanics, materials science, structural and mechanical engineering as well as design and arts for developing novel concepts, models, software and machinery towards origami-based products made of bio-based or recyclable materials for different application fields (e.g., packaging and interior design). Depending on the background and level of the intern, the internship project will move from linear stress and stability analysis of statics to nonlinearities and dynamics.

Requirements: The prospective candidate should have a solid understanding of engineering mathematics and mechanics with excellent study grades, augmented with some experience in finite element analysis of plate and shell structures. Programming skills (e.g., Matlab or Python) are a plus. This internship project can be extended to a Master’s Thesis project.

3301 - Data-driven models for mechanical behavior of materials

Field of study:	Mechanics, materials, machine learning, modeling	
For students currently studying:	Bachelor's or Master's	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Junhe Lian	junhe.lian@aalto.fi
Academic contact person:	Wenqi Liu	wenqi.liu@aalto.fi

The integrated computational materials and engineering (ICME) approach offers the qualitative and/or quantitative description for the microstructure-property relationship, such as crystal plasticity (CP) modeling for the crystal and phase level mechanical properties predications. These models are physical-based rendering all the details and mechanisms of material and deformation; however, they are also extremely expensive. The recent booming development of data-driven approaches is providing an alternative.

In this project, you will learn advanced theories and knowledge on the mechanics of materials with a focus on strength and plasticity. More importantly, you will be trained with 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, mache-learning experience, knowledge on mechanics of materials are highly appreciated.

3302 - Application of Machine Learning in safety assessment of autonomous navigation system

Field of study:	Probabilistic Machine Learning, Bayesian data analysis, quantitative safety assessment	
For students currently studying:	Bachelor's or Master's	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Osiris Valdez Banda	osiris.valdez.banda@aalto.fi
Academic contact person:	Meriam Chaal	meriam.chaal@aalto.fi

Safety is a major concern when shifting the shipping industry towards increased autonomy. The autonomous navigation systems are expected to perform with higher safety levels than human operated system. This claim is still to be proven and supported by quantitative safety assessment. One of the aims of the research project is to cover the answer to this question considering the Digital Line of Sight as a new technology of the autonomous navigation system. The probabilistic quantitative methods offer the possibility to analyze safety and communicate the results adequately, especially that some of the approaches can use either rare events data or abundant sensors data from the modern systems. Thus, the candidate for the open position under this research project should have strong background in probability and statistics and be motivated to work on the project idea. The project implements the bayesian inference framework required to estimate model parameters given the observed data from the sensors. The candidate will contribute to both model specification and practical implementation of the modelling workflow in addition to contributing in drafting a scientific article to dissiminate the results.

Necessary skills:
We are looking for an outstanding and motivated Bachelor's or Master's candidate who has background knowledge about data analysis and machine learning.
With experience in the following:
a) Bayesian statistical methods, e.g. MCMC sampling
b) Strong programming skills in R language
c) Using Stan modelling language is **preferred**
d) Background in signal processing is **preferred** (when dealing with time series data from sensors)

3303 - Development of autonomous ship model

Field of study:	Naval Architecture, Ocean and Marine Engineering, Electrical Engineering, Computer science	
For students currently studying:	Bachelor's or Master's	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Osiris Valdez Banda	osiris.valdez.banda@aalto.fi
Academic contact person:	Victor Bolbot	victor.bolbot@aalto.fi

The autonomous ships are becoming a tangible reality with a number of research projects already testing the full-scale technology. Aalto, as a world leading university should not stay behind in this race and instead should keep one of the leading positions as an education and research institution. To achieve that Aalto university should enhance its educational and research capabilities. To this aim it is necessary to develop a model of autonomous vessel which could be tested by the students and research staff in the already available Aalto ice tank and Laajalahti area.

During the internship an existing ship model available at Aalto university will be used and retrofitted into an autonomous one. For that, open-source electronic prototyping platforms such as Arduino and simple electrical equipment will be employed and the first version of Prototype Ship with limited Autonomy (PROSA) at Aalto premises will be developed. The student will be working under direct supervision from Aalto staff and he will follow a design and project plan developed by senior Aalto members.

The required skills for the intern constitutes

- Good programming skills
- Willingness to learn more about Arduino and other programming languages. Prior knowledge will be considered highly advantageous.
- Ability to adjust to project circumstances and to innovate
- Ability to work under supervision and independently
- Excellent English language skills

3304 - A Review of emerging methods for seakeeping and wave loads analysis

Field of study:	Emerging methods in Ship Seakeeping	
For students currently studying:	Bachelor's or Master's	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Spyros Hirdaris	spyros.hirdaris@aalto.fi
Academic contact person:	Spyros Hirdaris Ghalib Taimuri Aaro Karola Mingyang Zhang	spyros.hirdaris@aalto.fi ghalib.taimuri@aalto.fi aaro.karola@aalto.fi mingyang.0.zhang@aalto.fi

The reliable prediction of the seakeeping behavior of ships in a seaway is a demanding task for naval architects and of great practical interest to ship owners/operators, as it affects both the design and operation of ships. The science base of ship seakeeping in rough weather requires good understanding of ship design and problems involved as well as sound understanding of mathematical assumptions of ship theory and the potential use of emerging technologies (e.g. CFD, nonlinear potential flow hydrodynamics, machine learning methods, neural network theory etc.). The purpose of this placement is to conduct a review (literature survey) of concurrent and emerging methods for use in seakeeping analysis.

Necessary skills: We are looking for an outstanding and motivated Bachelor's or Master's candidate who has background on **ship dynamics, seakeeping and waves** interest in the following :

a) Theoretical background on potential flow theory on ship hydromechanics
b) Understanding of principles in naval architecture
c) Some aprciation of stochasticity
d) Curiosity on the use and implementation of emerging methods (e.g. machine learning and / or CFD for ship seakeeping)

School of Science

Department of Computer Science

4101 - Deep Learning for Extreme Scale Classification		
Field of study:	Machine Learning	
For students currently studying:	Bachelor's or Master's	
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.

[2] Embedding Convolutions for Short Text Extreme Classification with Millions of Labels https://arxiv.org/pdf/2109.07319.pdf

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

4102 - Modern ubiquitous applications: from devices to the cloud

Field of study:	Computer Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Mario Di Francesco	mario.di.francesco@aalto.fi
Academic contact person:	Mario Di Francesco	mario.di.francesco@aalto.fi

Modern applications that are ubiquitous – namely, everywhere – rely on two key components. First, on embedded devices such as mobile phones, wearables and smart objects in the Internet of Things to interact with users and collect information from the physical environment. Second, on a cloud or edge computing infrastructure to support different types of applications requiring a substantial amount of processing and storage, such as those involving machine learning. The major challenges in realizing such applications include efficient resource utilization at both devices and the supporting infrastructure, reliability, and user friendliness. The goal of this project is to investigate some of these aspects in the context of the research carried out in our research group. See also https://users.aalto.fi/~difram1/ for additional details.

Required skills: experience with Android application development or embedded systems programming, solid understanding of data analysis and (or) machine learning techniques.

Desired skills: some knowledge on human computer interaction and (or) computer vision, familiarity with cloud and web technologies.

4103 - Deep Representation Learning – Foundations and New Directions

Field of study:	Machine Learning, Algorithms, Applied Math, Bioinformatics	
For students currently studying:	Bachelor's or Master's	
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

Applications are invited for an internship in deep representation learning, broadly construed. Topics of particular interest include:

(1) 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 Methods, 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) Learning on the edge (i.e., learning under resource constraints)
(11) Applications in physics, computer vision, drug discovery, material design, synthetic biology, quantum chemistry, etc.
(12) Quantum Machine Learning for structured spaces

Representative publications:

(1) John Ingraham, Vikas Garg, Regina Barzilay, and Tommi Jaakkola. Generative Models for Protein Design. NeurIPS (2019).
(2) Vikas Garg, Stefanie Jegelka, and Tommi Jaakkola. Generalization and Representational Limits of Graph Neural Networks. ICML (2020).
(3) Vikas Garg and Tommi Jaakkola. Solving graph compression via Optimal Transport. NeurIPS (2019).
(4) Vikas Garg, Lin Xiao, and Ofer Dekel. Learning small predictors. NeurIPS (2018).
(5) Vikas Garg, Cynthia Rudin, and Tommi Jaakkola. CRAFT: Cluster-specific assorted feature selection. AISTATS (2016).
(6) Vikas Garg, Adam Kalai, Katrina Ligett, and Steven Wu. Probably approximately correct domain generalization.
AISTATS (2021).
(7) Vikas Garg and Tommi Jaakkola. Predicting Deliberative Outcomes. ICML (2020).

An ideal student would have strong mathematical/theoretical/statistical/algorithmic background, and be comfortable programming in a deep learning library (e.g., PyTorch).

4104 - Reproducible accuracy in machine learning

Field of study:	Machine Learning	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Samuel Kaski	samuel.kaski@aalto.fi
Academic contact person:	Samuel Kaski	samuel.kaski@aalto.fi

Improved accuracy is the focus of many ML papers. Yet few even provide any uncertainty estimates on their accuracy results, even though there are numerous sources of variability within the training and testing procedure, from the training and test distribution over parameter priors to the random seed itself. Recht et al (ICML 2019) showed that a benign dataset shift significantly affects the accuracy. In a similar direction, in this project you would systematically study how much accuracy of classical ML models such as LeNet on CIFAR10 varies with changes of the training procedure."Do ImageNet Classifiers Generalize to ImageNet?", Recht et al (ICML 2019)

4105 - ABC assistant for statistics selection

Field of study:	Machine Learning	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Samuel Kaski	samuel.kaski@aalto.fi
Academic contact person:	Samuel Kaski	samuel.kaski@aalto.fi

Likelihood-free inference (LFI) methods are used to fit complex, simulator-based models with intractable likelihood function to data. A popular LFI method is approximate Bayesian computation (ABC), which is used to sample from the approximate posterior of a generative model. ABC relies on computing the discrepancy between summary statistics of the simulated and observed data. Therefore, the choice of summary statistics is crucial for the approximation quality of the ABC posterior. However, selecting appropriate statistics is a non-trivial and tedious task for most practitioners. In this project, we develop interactive AI tools to assist the practitioners in performing statistics selection for ABC. The developed tools can be applied to models from various fields of science chosen to match your interest.

4106 - Investigating Homophily and the Glass Ceiling in Supervisor- and Collaboration-Networks

Field of study:	Computer Science / Data Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Barbara Keller	barbara.keller@aalto.fi
Academic contact person:	Barbara Keller	barbara.keller@aalto.fi

Homophily and the Glass Ceiling are concepts from Sociology: "The glass ceiling is a colloquial term for the social barrier preventing women and members of minority groups from being promoted to top jobs in management" and "Homophily is describing the tendency of individuals to associate and bond with similar others"
In "Homophily and the Glass Ceiling Effect in Social Networks" the authors described a graph evolution model which exhibits a glass ceiling effect under certain parameters. We want to extend this work by investigating additional real-world networks, such as (but not limited to), supervisor- and collaborator-networks.

The tasks involves:
- Finding relevant data sources
- Scraping and cleaning data
- Calculating relevant metrics
- Write-up of the findings

The applicant is interested in Social Networks and their analysis and has sound programming skills, preferably in python.

4107 - Shortest salesman tours and Steiner trees in a geometric setting

Field of study:	Theoretical Computer Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Sándor Kisfaludi-Bak	sandor.kisfaludi-bak@aalto.fi
Academic contact person:	Sándor Kisfaludi-Bak	sandor.kisfaludi-bak@aalto.fi

Variants of the famous Traveling Salesman and the Steiner Tree problems have countless applications in logistics, manufacturing, and network design. While the problems are hard to solve in general, the specific versions arising in applications often have geometric constraints that may help make them more tractable. For example, if we need to find the shortest closed curve containing n given points in the plane that are in convex position, then the boundary of their convex hull is always the right answer, and it can be computed in near-linear time.

The goal of this project is to identify specific geometric settings where finding the optimal or a near-optimal salesman tour or Steiner tree can be done efficiently (in polynomial time).

The applicant should have some mathematical maturity, as well as a good familiarity with the worst-case analysis of algorithms. Some knowledge of computational complexity (polynomial reductions, NP-hardness) and having some background in computational geometry is an advantage.

4108 - Deep generative modeling for precision medicine and clinical trials

Field of study:	Machine learning, bioinformatics	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Harri Lähdesmäki	harri.lahdesmaki@aalto.fi
Academic contact person:	Harri Lähdesmäki	harri.lahdesmaki@aalto.fi

We are looking for a summer intern to develop novel probabilistic machine learning methods for large-scale health datasets from biobanks and clinical trials. This project aims to develop novel deep generative modeling methods to (i) predict adverse drug effects using longitudinal/time-series data from large-scale biobanks and clinical trials, and to (ii) harmonize large-scale health data sets for AI-assisted decision making to revolutionize future clinical trials. Methodologically this project includes e.g. VAEs, GANs, Bayesian NNs, domain adaptation, Gaussian processes and causal analysis. Experience/Studies on (probabilistic) machine learning is expected. Tasks for summer internship can be adapted to fit student's skills. The work will be done in collaboration with research groups from the Finnish Center for Artificial Intelligence, and the novel methods will be tested using unique real-world data sets from our collaborators in university hospitals and big pharma company. Work can be continued after the summer.

Our recent work:
[1] http://proceedings.mlr.press/v130/ramchandran21b.html
[2] http://proceedings.mlr.press/v130/ramchandran21a.html
[3] https://arxiv.org/abs/2111.02019
[4] https://academic.oup.com/bioinformatics/article/37/13/1860/6104850

For more information: https://research.cs.aalto.fi/csb/publications.shtml

4109 - Deep generative modeling for continuous-time dynamical systems

Field of study:	Machine learning	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Harri Lähdesmäki	harri.lahdesmaki@aalto.fi
Academic contact person:	Harri Lähdesmäki	harri.lahdesmaki@aalto.fi

Recent machine learning breakthroughs include black-box modeling methods for differential equations, such as Gaussian process ODEs [1] and neural ODEs. These methods are particularly useful in learning arbitrary continuous-time dynamics from data, either directly in the data space [1] or in a latent space in case of very high-dimensional data [3]. We are looking for a summer intern to join our current efforts to (i) develop efficient yet calibrated Bayesian methods for learning such black-box ODE models, (ii) develop neural ODEs to learn arbitrary dynamics of high-dimensional systems (e.g. in robotics, biology, physics or video applications) using a low-dimensional latent space representation, and (iii) further developing these methods for reinforcement learning and causal analysis. Experience/Studies in (probabilistic) machine learning is expected. Tasks for summer internship can be adapted to fit student's skills. Work can be continued after the summer.

Our recent work:

[1] http://proceedings.mlr.press/v80/heinonen18a.html
[2] http://proceedings.mlr.press/v89/hegde19a.html
[3] https://papers.nips.cc/paper/9497-ode2vae-deep-generative-second-order-odes-with-bayesian-neural-networks
[4] https://openreview.net/forum?id=aUX5Plaq7Oy
[5] https://proceedings.mlr.press/v139/yildiz21a.html
[6] http://arxiv.org/abs/2106.10905

For more information: https://research.cs.aalto.fi/csb/publications.shtml

4110 - Deep generative modeling for single-cell sequencing data analysis

Field of study:	Machine learning, bioinformatics	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Harri Lähdesmäki	harri.lahdesmaki@aalto.fi
Academic contact person:	Harri Lähdesmäki	harri.lahdesmaki@aalto.fi

Single-cell sequencing technologies provide functional genomics data at unprecedented resolution and can help revealing answers to various disease-related questions that could not be answered previously. We are looking for a summer intern to develop novel probabilistic machine learning methods for various tasks in single-cell biology, including e.g. (i) cell type identification, (ii) modeling spatial single-cell data, (iii) predicting immunotherapy treatment response, (iv) analysing single-cell data from cross-sectional studies. Experience/Studies in (probabilistic) machine learning as well as interest/studies in bioinformatics are expected. Tasks for summer internship can be adapted to fit student's skills. Work can be continued after the summer.

For more information: https://research.cs.aalto.fi/csb/publications.shtml

4111 - Developing the vHelix DNA nanostructure design platform

Field of study:	Computer Science / Computational Biology	
For students currently studying:	Bachelor's or Master's	
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 [1] employs DNA as generic building material for assembling nanoscale objects with dimensions in the order of 10-100 nanometres. Our group has been contributing, in collaboration with a biochemistry team from Karolinska Institutet in Stockholm, to the design of a general-purpose design platform "vHelix" for producing in particular 3D wireframe designs folded from a single long DNA strand [2].

A new, user-friendly and extendible version of the vHelix platform has been developed as summer internship projects in 2020 and 2021, and recently piloted in our DNA Nanotechnology course. After the 2015 publication of the DNA strand-routing algorithm [3] implemented in the current vHelix version, several alternative methods have emerged, and the goal of the present project is to implement some of these more recent algorithms as plugins to the new extendible vHelix version, and also to extend the vHelix design support from DNA to RNA nanostructures.

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, please see the research group webpage at http://research.cs.aalto.fi/nc/.

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

[2] http://vhelix.net/

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

4112 - Reconstructing Crisis Narratives: Computational Social Media, Visualization and Platform Design

Field of study:	Machine Learning, NLP, Social Media Analytics, Data Visualization	
For students currently studying:	Master's	
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

This research project jointly being conducted between Aalto University and THL is analyzing and reconstructing crisis narratives using mixed-methods, combining qualitative research for narrative inquiry with computational data analytics of crisis discourses in news and social media. We are seeking two research interns to work with our Computational Social Science team on social media analytics and the Design Research team on devising a web-based platform for visualizing this data in an interactive manner. Applicants should have experience with either machine learning, NLP and social media analytics OR data visualisation, Javascript and web-based programming for rapid prototyping and design.

4113 - Civic Agency in AI? Democratizing Algorithmic Services in the City (CAAI)

Field of study:	Ethical AI, Human Computer Interaction, NLP	
For students currently studying:	Master's	
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.

4114 - Approximate inference in Bayesian deep learning

Field of study:	Approximate inference in Bayesian deep learning	
For students currently studying:	Master’s	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Arno Solin	arno.solin@aalto.fi
Academic contact person:	Martin Trapp Andrea Pilzer	martin.trapp@aalto.fi andrea.pilzer@aalto.fi

Deep architectures like deep neural networks are an integral part of contemporary artificial intelligence. However, when deploying deep learning models to real-world applications we need to pay attention to issues related to data efficiency, robustness, and interpretability. The design choices made in deep models imply strong inductive biases. Realizing this makes it possible to build more data efficient, robust and interpretable deep models.

This project aims to examine recent techniques for uncertainty quantification in Bayesian deep learning. In particular, you will be implementing and evaluating contemporary techniques for approximate Bayesian inference in deep learning models and gaining insights into existing methods' efficacy. Furthermore, we will devise a novel approach for approximate Bayesian inference in deep neural networks based on the gathered knowledge and recent advancements. The applicants should make themselves familiar with the following works:

[1] Laplace Redux -- Effortless Bayesian Deep Learning (https://arxiv.org/abs/2106.14806)
[2] Bayesian Deep Learning and a Probabilistic Perspective of Generalization (https://arxiv.org/pdf/2002.08791.pdf)

The successful candidate should have good math skills, be knowledgeable in either Python or Julia, and have experience with machine learning related topics, e.g. Bayesian inference, deep neural networks, Gaussian processes. The successful candidates will work closely with the group members on the described topic.

4115 - Advancing deep mixtures of Gaussian processes expert models

Field of study:	Machine Learning	
For students currently studying:	Master's	
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

Gaussian processes (GPs) are powerful non-parametric Bayesian regression models that allow exact posterior inference, but exhibit high computational and memory costs. The most common approaches to overcome these limitations are variational approximations to the GP posterior and methods based on local GP experts. Approximations based on local experts use a divide-and-conquer strategy and partition the covariate space (or the data set) into subsets, each modelled with an individual GP expert. Recent work on local GP experts explored deep tractable probabilistic models (sum-product networks) to model the prior over possible partitions and showed that the resulting model class allows exact and efficient posterior inference and has state of the art performance on regression tasks.

This project aims to advance local GP experts by extending work on deep structured mixtures of Gaussian processes. In particular, you will familiarise yourself with the model and existing implementations (Julia or Python), and develop a technique for either non-conjugate likelihoods or learning of the hierarchical partitions. The applicants should make themselves familiar with the following works:

[1] Deep Structured Mixtures of Gaussian Processes (http://proceedings.mlr.press/v108/trapp20a.html)
[2] Scalable Variational Gaussian Process Classification (http://proceedings.mlr.press/v38/hensman15.pdf)
[3] Deep learning with differential Gaussian process flows (https://arxiv.org/pdf/1810.04066.pdf)

The successful candidate should have good math skills, be knowledgeable in either Python or Julia, and have experience with machine learning related topics, e.g. Bayesian inference, deep neural networks, Gaussian processes. The successful candidates will work closely with the group members on one of the topics outlined below. The work will be done in close collaboration with the group members.

4116 - Stationary deep learning models applications for uncertainty quantification in computer vision

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

Deep learning rapidly rose to one of the most accurate and effective AI tools for many tasks. However, this comes at the price of reduced robustness and explainability due to the huge datasets required and to the massive amount of model parameters. A remedy to these issues is Bayesian deep learning, a powerful tool to induce priors in the model or performing probabilistic inference.

In this project, we will focus on inducing priors in deep learning models. Recently, in [1] researchers demonstrated that stationarity, through periodic activation functions of the model classifier, can benefit model out-of-domain data sensitivity. We will push forward this line of research, firstly, by making the full neural network stationary and, secondly, experimenting the viability of such a method for larger computer vision datasets and tasks (e.g., domain adaptation).

[1] Periodic Activation Functions Induce Stationarity,
https://proceedings.neurips.cc/paper/2021/file/0d5a4a5a748611231b945d28436b8ece-Paper.pdf

The successful candidate should have good math skills, be knowledgeable in either Python or Julia, and have experience with machine learning related topics, e.g. Bayesian inference, deep neural networks, Gaussian processes. The successful candidates will work closely with the group members on the described topics.

4117 - Foundations of distributed and parallel computing (*multiple positions*)

Field of study:	Theoretical computer science	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Jukka Suomela	jukka.suomela@aalto.fi
Academic contact person:	Jukka Suomela	jukka.suomela@aalto.fi

The modern world relies on huge computer networks and large-scale computing clusters, and our research group studies the theoretical foundations of such systems. We seek to understand the fundamental limits of what can be solved efficiently in very large networks or with massively parallel computers.

We have got plenty of exciting summer internship opportunities for students with different kinds of backgrounds and interests. Some of our work is similar to what people typically do in mathematics: proving theorems with pen and paper. However, some of us are also making heavy use of computers in our work: we write computer programs that discover algorithms and prove theorems for us. So we have got something exciting to do both for those students who like to do computer programming and for those who work better without touching computers.

We are looking for students who enjoy thinking about mathematical puzzles and who have got good problem-solving skills. We expect you to have some familiarity with algorithm design and analysis, theoretical computer science, and discrete mathematics. Knowing something about graph theory and distributed or parallel computing will be helpful but not necessary.

4118 - Massively Parallel Algorithms for Graph Problems

Field of study:	Computer Science	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Jara Uitto	jara.uitto@aalto.fi
Academic contact person:	Jara Uitto	jara.uitto@aalto.fi

Parallel processing of data and distributed computing are gaining attention and becoming more and more vital as the data sets and networks we want to process are overgrowing the capacity of single processors. To understand the potential of modern parallel computing platforms, many mathematical models have emerged to study the theoretical foundations of parallel and distributed computing. In this project, we study algorithm design in these models with a particular focus on the Massively Parallel Computing (MPC) and Local Computation Algorithms (LCA) models.

The problems we study are often in (but not limited to) the domain of graphs, that serve as a very flexible representation of data. We are interested in, for example, the computational complexities of classic problems such as finding large independent sets, matchings, flows, clustering problems, etc.

The applicant is assumed to have a solid knowledge of mathematics, knowledge on the basics of graph theory, and a good command of English. No prior knowledge in distributed computing is required, although it might be helpful.

4119 - Bayesian workflow

Field of study:	Computational probabilistic modeling	
For students currently studying:	Master's	
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

Background: The task is to take part in development of Bayesian workflow tools and diagnostics. The topic can be selected together with the student. Some example topics are importance sampling diagnostics, diagnosing funnel and banana shaped posteriors, Monte Carlo standard error for arbitrary function, analysis of dynamic Hamiltonian Monte Carlo behavior, analysis of low rank black box variational inference, visualization of results from projective predictive model selection.

Prerequisites: knowledge of Bayesian methods, and R or Python

4201 - Formalization of mathematics related to probability theory

Field of study:	Mathematics (computer formalized)	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Mathematics and Systems Analysis	
Professor:	Kalle Kytölä Jukka Kohonen	kalle.kytola@aalto.fi jukka.kohonen@aalto.fi
Academic contact person:	Kalle Kytölä Jukka Kohonen	kalle.kytola@aalto.fi jukka.kohonen@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 the language called *Lean*. For perspective to the current status, one can compare the library to mathematical research on the one hand and to university curricula 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, large parts of any standard undergraduate curriculum in mathematics are still missing. For instance, the library does not yet have much probability theory, but a good amount of measure theory exists, and it can be used as foundations on which to develop formalization of probability theory.

This internship project pertains to the formalization of some aspects of probability theory in *Lean*, roughly 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 topic of the internship in full detail. Rather, we suggest as example topics to formalize: cumulative distribution functions, specific distributions, extreme value statistics, combinatorial probability, or Markov transition kernels and Markov processes in discrete time. The internship is expected to lead to either successful Lean formalizations or important insights into the aspects of that need to be taken into consideration in the formalization of such topics.

We expect the candidate to 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 - Formalization of mathematics related to analysis

Field of study:	Mathematics (computer formalized)	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Mathematics and Systems Analysis	
Professor:	Kalle Kytölä Jukka Kohonen	kalle.kytola@aalto.fi jukka.kohonen@aalto.fi
Academic contact person:	Kalle Kytölä Jukka Kohonen	kalle.kytola@aalto.fi jukka.kohonen@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 the language called *Lean*. For perspective to the current status, one can compare the library to mathematical research on the one hand and to university curricula 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, large parts of any standard undergraduate curriculum in mathematics are still missing. For instance, the library does not yet have much probability theory, but a good amount of measure theory exists, and it can be used as foundations on which to develop formalization of probability theory.

This internship project pertains to the formalization of some aspects of analysis in *Lean*, roughly 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 topic of the internship in full detail. Rather, we suggest as example topics to formalize: the weak-* topology on the dual of a normed space coincides with the operator norm topology if and only if the normed space is finite-dimensional, that the weak-* topology restricted to bounded sets of the dual of separable normed spaces is metrizable, the Riesz-Markov-Kakutani representation theorem (positive linear functionals on the space of continuous functions as regular Borel measures on the underlying space), or other analysis topics that are used in probability theory. The internship is expected to lead to either successful Lean formalizations or important insights into the aspects of that need to be taken into consideration in the formalization of such topics.

We expect the candidate to 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.

4301 - DNA-origami-based plasmonic assemblies

Field of study:	Nanotechnology, biotechnology, biophysics, plasmonics	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Neuroscience and Biomedical Engineering	
Professor:	Anton Kuzyk	anton.kuzyk@aalto.fi
Academic contact person:	Anton Kuzyk	anton.kuzyk@aalto.fi

The Molecular Nanoengineering group operates at the interface between nanoscience, molecular self-assembly, DNA nanotechnology and nanoplasmonics with particular focus on DNA-based artificial molecular systems with functionalities tailored for biosensing, nanophotonics and biomimetics.

The summer project involves design, fabrication and characterization of DNA-origami-based metal nanostructures. More specifically, you will contribute to the group's efforts on generating reconfigurable chiral plasmonic assemblies with the record high optical activity. Such structures have great promise for development of novel biosensing schemes and biomaterials-based photonics.

Preferred skills: An ideal candidate has a solid background and/or strong interest in biochemistry, applied physics, physical chemistry, bionanotechnology and/or biophysics. Previous experience in molecular self-assembly and nanomicroscopy (AFM, TEM, SEM) is an advantage.

Further information about the group:
https://goo.gl/k9EtLx

4401 - Machine learning, statistical physics and engineering of foams

Field of study:	Physics	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Mikko Alava	mikko.alava@aalto.fi
Academic contact person:	Juha Koivisto	juha.koivisto@aalto.fi

The foam physics problems at our group present different issues that range from basic physics to understanding foam property design by ML to material engineering. One task is to utilize the recently developed machine learning and artificial intelligence algorithms and the second is to study particle-laden foams experimentally.

The candidate is expected to have either some programming experience and a keen interest in computational physics and/or to be interested in working on an experimental materials physics project.

4402 - Simulating Quantum Computers with Matrix Product States

Field of study:	Theoretical physics, quantum computing/quantum information, computational physics, statistical and condensed matter physics	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Christian Flindt Jose Lado	christian.flindt@aalto.fi jose.lado@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 package which manipulates so-called matrix product states 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. Our main goal is to study how well such an approach is suited for the development of intermediate-scale quantum algorithms, in particular with applications in condensed matter physics.

There are many different possibilities for summer projects (with the possibility to turn them into a Bachelor's or Master's thesis, if desired), which can broadly be characterised as *developing* or *applying* our quantum simulator. For instance, you can work on modeling how a given quantum algorithm would run on a *real* quantum processor. Important characteristics to consider here are the qubit topology (i.e. the connectivity pattern of the qubits), (de-)coherence times of single qubits and gate fidelities. Taking this information into account would then allow us to modify a given quantum algorithm – which may already work in theory – such that it performs best on a given quantum machine. In addition, we are interested in improving the performance and fidelity of our quantum simulations, which involves testing different mathematical representations of the qubits in our software. On the other hand, you can study the quantum simulation of models of condensed matter and quantum many-body physics, e.g. their Hamiltonian dynamics, their thermodynamics or properties of their ground states. Not much prior work has been done in the intermediate-scale quantum simulation of condensed matter models, which would place this project at the forefront of current materials physics research. Furthermore, this offers the opportunity to compare and benchmark those results with calculations run on real quantum computers, such as provided by IBM.

Necessary skills:
Knowledge of quantum mechanics at undergrad level (preferably some familiarity with the quantum circuit model), programming experience in at least one high-level language (such as Python, ideally Julia). For certain projects, familiarity with concepts from quantum information and basic notions of tensor networks or matrix product states is an additional asset. Students interested in studying quantum simulations of condensed matter models should have a background in condensed matter/solid state physics and/or statistical mechanics.

4403 - Single photon generation in electron quantum optics

Field of study:	Theoretical physics, quantum optics	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Christian Flindt	christian.flindt@aalto.fi
Academic contact person:	Benjamin Roussel	benjamin.roussel@aalto.fi

Summary

Recent experiments have shown the ability to generate, manipulate and probe electric currents at the level of a single electron. This marked the advent of a novel field of condensed matter called electron quantum optics, where electrons are manipulated in a similar way as photons in quantum optics. Despite many similarities, there is a major difference between photons in a waveguide and electrons in a quantum conductor: electrons, being charged particles, are always surrounded by electromagnetic radiation. Notably, this means it is possible to use electron quantum optics beyond condensed matter, by engineering, through electronic states, interesting states of the electromagnetic field.

During this theoretical internship, we propose to explore the generation a single-photon source based on the decay of an electron-hole pair in a quantum conductor. The student will gain in-depth knowledge of multimode quantum optics and interactions in many-body electronic systems, providing them with a solid expertise for future studies in theoretical physics, quantum optics and quantum technologies.

Necessary skills

We look for a highly-motivated student in theoretical physics (or related areas), with a strong knowledge of quantum physics. This project will mainly deal with analytical derivations and simple numerical evaluations.

4404 - Predicting phase transitions in quantum systems

Field of study:	Theoretical physics, Quantum physics, Statistical physics	
For students currently studying:	Master’s	
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.

4405 - Generation and detection of entanglement in Cooper pair splitters

Field of study:	Theoretical physics, Quantum transport, Quantum information	
For students currently studying:	Master’s	
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.

4406 - Machine Learning Strategies for Scientific Data Analysis

Field of study:	Physics	
For students currently studying:	Bachelor's or Master's	
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 of successful candidates. Applicants should have a basic knowledge of physics, data analysis and statistics. Knowledge of Python would be highly beneficial.

4407 - Preformed Cooper paring and non-Abelian anyons in graphene-based systems

Field of study:	Physics	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Pertti Hakonen	pertti.hakonen@aalto.fi
Academic contact person:	Alexander Zyuzin Manohar Kumar	alexander.zyuzin@aalto.fi manohar.kumar@aalto.fi

The engineered quantum materials set a distinctive platform for emergent quasiparticles with very rich physics. The spectacular properties of these quasiparticles such as, for example, quantum entanglement, quantum coherence, and quantum superposition are forming the frontier in emerging quantum technologies. One such system is magic angle twisted bilayer graphene (MATBG), where unconventional superconductivity was discovered [1, 4]. The physics of superconductivity in MATBG is far from being understood.

It suffices to consider the preformed Cooper pairing mechanism to analyze the origin of the superconductivity in material hosting flat bands such as MATBG [2, 3]. The nearly dispersionless nature of the flat band promotes local Cooper pair formation so that the system can be modelled as an array of superconducting grains. The overall coherence arises due to Andreev scattering between the grains.

On the other side, one can engineer a superlattice of superconducting islands placed on top of graphene, where overall coherence is induced by the Andreev reflection, like preformed Cooper pairs but still a different mechanism. The grain connectivity could be controlled by the playing with the global charge density of graphene. Furthermore, it could be well forming a playground to study the emergence of higher order topological quasiparticles in the presence of high magnetic field. The fractional quantum hall states are created in the graphene at high magnetic field, which in presence of superconductivity might form non-Abelian anyons.

In this project, we propose to study superconductivity in graphene decorated with superconducting islands and in MATBG in the presence of the magnetic field. Though this is a theoretical project, it will be performed in collaboration with an experimental group.

This project will be interesting for the students willing to learn topological phases of matter and one who like to contribute to emerging quantum technologies. This project will form a MS thesis, but could be extended to an experiment-oriented PhD thesis, where one could probe these states in interferometry and microwave settings.

References:

1. Y. Cao *et al.* Nature **556**, 43–50 (2018).
2. M. Randeria *et al.* Phys. Rev. Lett. **69**, 2001–2004 (1992)
3. A. A. Zyuzin *et al.* arXiv: 2109.07520
4. https://en.wikipedia.org/wiki/Twistronics

4408 - Finite Temperature Neural Network Quantum States for Lee-Yang Theory

Field of study:	Theoretical Condensed Matter Physics	
For students currently studying:	Bachelor's or Master's	
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:	Jose Lado Christian Flindt	jose.lado@aalto.fi christian.flindt@aalto.fi

Summary: This is a project in theoretical condensed matter physics, in particular in the field of quantum many-body physics. This project can be suitable as 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 jointly between two groups, the Quantum Transport group led by Prof. Christian Flindt, and the Correlated Quantum Materials group led by Prof. Jose Lado, and co-supervised by PhD candidate Pascal Vecsei.

Background: Phase transitions in quantum many-body systems describe some of the most intriguing features of nature: superconductivity, magnetism, charge order and spin liquids all arise from the collective behaviour of many quantum degrees of freedom. The detection of phase transitions between different phases of matter in such systems poses a significant challenge due to the exponential growth of the size of the Hilbert space with system size. Recent advances, which exploit the properties of Lee-Yang zeros, complex zeros of the partition function, as function of system size, allow for a prediction of the location of the phase transition using high moments of the order parameter in simple model systems for magnets. For this, these high moments are evaluated using numerical methods like tensor networks or exact diagonalization. At the same time, neural networks have become a very promising class of variational states to describe the wave function of quantum many-body systems. They have mainly been used to study the ground state properties of various quantum systems, for example of the spin-1/2 Heisenberg model on the pyrochlore lattice. Recently, these methods have been extended to finite temperature.

Task: In this project, you will implement neural network quantum states to study finite temperature properties of quantum many-body systems. You will calculate the high moments of the order parameter of paradigmatic spin systems, like the quantum Ising model, to estimate the Lee-Yang zeros and thereby uncover their phase diagram.

Necessary skills / prerequisites: Basic knowledge of statistical physics, as well as programming skills, preferably in Python, are required. No prior knowledge of machine learning or neural nets is needed.

4409 - Dynamical excitations in confined quantum spin liquids

Field of study:	Theoretical Quantum Materials	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Jose Lado	jose.lado@aalto.fi
Academic contact person:	Jose Lado	jose.lado@aalto.fi

Summary: This is a project in theoretical condensed matter physics, in particular in the field of fractional quantum magnetism. 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 in the Correlated Quantum Materials group led by Prof. Jose Lado and it will be co-supervised by PhD candidate Guangze Chen and Dr. Adolfo O. Fumega.

Background: Quantum many-body systems give rise to exotic phases of matter that cannot occur in a classical framework. In particular, in the field of magnetic materials, quantum spin liquids represent a paradigmatic example of such exotic phases, featuring fractional excitations and lacking magnetic order even at zero temperature. Despite strong theoretical efforts, the experimental characterization of quantum spin liquids has remained a critical open problem in quantum matter. Interestingly, the recent development of experimental techniques allowing to manipulate magnetic atoms allows creating confined spin liquid states. Ultimately, this confined quantum many-body states offer a versatile platform to design nano-structures that allow probing dynamical fractional spin excitations.

Task: In this project, you will theoretically investigate a quantum many-body model for a confined quantum spin liquid. You will study the confined modes of the quantum spin liquid for different magnetic phases, in particular in the antiferromagnetic and quantum spin liquid regimes, and focusing on its dynamical many-body excitations. This will be performed by solving the many-body Hamiltonian with an exact computational many-body formalism. You will show show to distinguish fractional excitations, providing an observable that could be directly measured in experiments.

Necessary skills / prerequisites: Basic knowledge of quantum physics, as well as programming skills, preferably in Python, are required. No prior knowledge of quantum spin liquid physics is needed.

4410 - Growth and characterization of 2D ferromagnet / ferroelectric heterostructures

Field of study:	Condensed matter physics, materials science	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Peter Liljeroth	peter.liljeroth@aalto.fi
Academic contact person:	Mohammad Amini	mohammad.amini@aalto.fi

In this project, we will use molecular beam epitaxy (MBE) to grow heterostructures of monolayer ferroelectric (SnTe or SnSe) and ferromagnetic (CrBr3) materials on highly oriented pyrolytic graphite (HOPG) substrates. MBE is a powerful tool for growing clean and defect free two-dimensional (2D) layers, which will us to achieve high quality layers and interfaces in the heterostructure. We will characterize the systems using several different techniques such as scanning tunneling microscopy (STM) and X-ray photoelectron spectroscopy (XPS).

The applicant should have some experience on working a lab, prior experience on MBE or surface science tools is a plus.

4411 - MBE growth of transition metal dichalcogenide monolayers

Field of study:	Condensed matter physics, materials science	
For students currently studying:	Bachelor's or Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Peter Liljeroth	peter.liljeroth@aalto.fi
Academic contact person:	Xin Huang	xin.huang@aalto.fi

This project involves growing transition metal dichalcogenide monolayers using molecular-beam epitaxy (MBE) and characterizing them using surface science methods (XPS, STM, AFM) and optical techniques (e.g. micro-Raman). We will focus on tantalum diselenide (1T- and 1H-TaSe2) and the main part of the work is to optimize the MBE growth parameters for obtaining high quality monolayers in the desired crystal phase.

The applicant should have some experience on working a lab, prior experience on MBE or surface science tools is a plus.

4412 - Radiation damage in multi-component alloys

Field of study:	Physics	
For students currently studying:	Master's	
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.

4413 - Emergent phenomena in liquids out of thermodynamic equilibrium (*2 positions*)

Field of study:	Applied physics, applied mathematics	
For students currently studying:	Master's	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Jaakko Timonen	jaakko.timonen@aalto.fi
Academic contact person:	Dr. Nikos Kyriakopoulos Dr. Carlo Rigoni	nikos.kyriakopoulos@aalto.fi carlo.rigoni@aalto.fi

We offer two exciting research projects for talented Master's students to expand our recent discoveries in the fields of electrohydrodynamically driven pattern formation[1] and charging and gradient formation in nonpolar nanocolloids[2]. We welcome applications especially from students with excellent grades and interest in the following topics: experimental physics, mathematical modelling, capillary phenomena, fluid mechanics, statistical physics, advanced optical microscopy, image analysis and electrical characterization techniques.

1. Raju, Kyriakopoulos and Timonen, Science Advances (2021), https://www.science.org/doi/10.1126/sciadv.abh1642 (see also https://www.youtube.com/watch?v=WSjL4jgpJCI)

2. Cherian, Sohrabi, Rigoni, Ikkala and Timonen, Science Advances (in press), https://arxiv.org/abs/2009.12563