Aalto Science Institute (AScI)

International Summer Research Programme

2024 project list

(updated, 22.12.2023)

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

Contents

School of Chemical Engineering

Department of Bioproducts and Biosystems

1101 - Extraction of lignin carbohydrate complexes from biomass – compositional analysis and analysis of hydrodynamic diameter in solutions

Field of study:	Lignocellulose chemistry	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Chemical Engineering	
Department:	Department of Bioproducts and Biosystems	
Professor:	Tiina Nypelö	tiina.nypelo@aalto.fi
Academic contact person:	Chonnipa Palasingh	chonnipa.palasingh@aalto.fi

Biomass processing usually consumes large amount of mechanical, thermal and chemical energy. Our project's objective is to improve energy efficiency by introducing chemical pre-treatments which have potential to cleave lignin-carbohydrate bonding and facilitate biomass disintegration. For establishing the pretreatments, we need the key compounds for testing their reactivity in a laboratory environment. This need will be addressed by three objectives (O): O1 Extracting lignin-carbohydrate complexes from biomass, O2 characterizing their chemical composition and O3 determining their physical solution properties.

The work to achieve the objectives includes tasks (T):

- T1: Extract lignin-carbohydrate complex from wood and non-wood materials
- T2: Determine carbohydrate composition, lignin content (HPAEC), and uronic acid content (GC-FID)
- T3: Determine hydrodynamic diameter/zeta potential of extracted components in solution (DLS)

This internship work provides output to two projects YIPPIE and HELMI that are focused on hydrolysis of ester bonds and resolving intrinsic miscibility of wood components in solution, respectively. The work by the summer trainee will contribute to provide carbohydrate complexes for further chemical treatments to be used in YIPPIE project and contributes to knowledge of wood component properties in solution which are in focus in HELMI. There is a postdoc that contributes to both projects and a doctoral student who contributes to YIPPIE and it is an excellent opportunity to involve junior team members to train them in research thinking and methodology and equip them with analytical and experimental skills.

The prerequisite skills that facilitate to accomplish the internship are some experience and plenty of interest in working in chemistry laboratory, knowledge and interest in biomass, and interest in dynamic light scattering, HPAEC and/or GC analyses.

1102 - Towards renewable liquefied petroleum gas: Purification and in vitro biochemistry of cofactors derived from methanogens

Field of study:	Biochemistry	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Chemical Engineering	
Department:	Department of Bioproducts and Biosystems	
Professor:	Silvan Scheller	silvan.scheller@aalto.fi
Academic contact person:	Maxime Laird	maxime.laird@aalto.fi

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

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

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

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

Preferentially: Experience (or theoretical knowledge) of advanced spectroscopic methods, in particular NMR

1103 - Metabolic engineering of methanogens

Field of study:	Molecular biology	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Chemical Engineering	
Department:	Department of Bioproducts and Biosystems	
Professor:	Silvan Scheller	silvan.scheller@aalto.fi
Academic contact person:	Enrique de Dios Mateos	enrique.dediosmateos@aalto.fi

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

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

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

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

1301 - Process engineering for the circular economy of raw materials

Field of study:	Chemical and Metallurgical Engineering	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	2	
School:	School of Chemical Engineering	
Department:	Department of Chemical and Metallurgical Engineering	
Professor:	Rodrigo Serna	rodrigo.serna@aalto.fi
Academic contact person:	Rodrigo Serna	rodrigo.serna@aalto.fi

One of the major challenges in our modern world is an ever-increasing demand of raw materials. For that reason, the aim of our group is to find technological solutions to address the current needs related to the production of inorganic raw materials, whether from primary or secondary sources.

We are looking for enthusiastic students at Bachelor's or Master's level to support our research projects on raw materials recycling and circular economy engineering. In this role, you may carry out experimental and simulation work on recycling processes to recover the highly valuable active materials. Our work covers aspects form characterization of materials using novel techniques such as electron microscopy and x-ray tomography to bench-scale separation of components using froth flotation.

Ideal candidates would be studying programs in metallurgical engineering, chemical engineering, mineral processing, environmental engineering, materials science or similar. Experience in laboratory work is considered an asset.

School of Electrical Engineering

Department of Electrical Engineering and Automation

2101 - Machine-learning-based modelling of electric machine drives

Field of study:	Control systems, electric drives, electric machines, machine learning	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Electrical Engineering and Automation	
Professor:	Marko Hinkkanen	marko.hinkkanen@aalto.fi
Academic contact person:	Firdausa Ahmed	firdausa.ahmed@aalto.fi

Background:

In high-speed machines, lateral vibrations limit the rated speed and the power density. Our team develops model-based real-time control methods for multiphase electric machines, which can produce controllable electromagnetic radial forces in addition to the electromagnetic torque. These radial forces can subsequently be used to control the lateral vibrations of the machine. The forces could also be used to achieve magnetic levitation of the rotor system. Hence, this kind of electric machines are also called bearingless machines.

Overall goal:

Multiphase bearingless machines exhibit inherent electromagnetic and electromechanical nonlinearities that must be considered while developing control methods and their underlying dynamic models. These nonlinearities can be analyzed computationally by means of finite-element method (FEM) models, which, however, are not suitable for real-time control. In principle, the computed FEM data could be realized in dynamic models and control methods by means of look-up tables. However, in multiphase bearingless machines, this approach has limitations due to high dimensions of the data. Our goal is to explore alternative approaches, implemented via suitable machine-learning methods (e.g., convolutional neural network) to replace multidimensional look-up tables.

Research tasks:

1. Getting familiar with multiphase bearingless machines and their available FEM data.
2. Literature survey of potential machine-learning methods and related tools.
3. Implementation of a multiphase bearingless machine model by means of the selected machine-learning method and the FEM data.
4. Writing a report in the form of a conference paper manuscript.

Prerequisites:

1. Experience in Python.
2. Familiarity with machine-learning methods and libraries.
3. Basic understanding of electric machine drives is a plus.

2102 - Intelligent distributed energy system based on decentralized swarm intelligence with on-the-fly learning

Field of study:	Artificial intelligence, control and automation, energy	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Electrical Engineering and Automation	
Professor:	Valeriy Vyatkin	Valeriy.vyatkin@aalto.fi
Academic contact person:	Udayanto Atmojo	Udayanto.atmojo@aalto.fi

The shift in the energy market landscape and green energy transition, industrial decarbonization push for a transformation on the energy system architecture and infrastructure. The energy grid becomes increasingly intelligent and changing towards the prosumer model where participants in the energy grid may act as both producer and consumer of energy utilizing various energy assets that they have, either electrical energy assets or other such as heating or cooling, or in the future also hydrogen energy asset. Participation and bidding of energy assets in the energy market requires certain threshold in terms of energy volume, often involving a role of aggregator which will pool energy assets to fulfill this threshold requirement. Such aggregation role, and also governance, management of energy assets have been mostly done in centralized manner, however centralized approach is not scalable as the number of energy assets grow, and also their (geographical) locations where they have to be pooled. Following this, decentralized computation approach utilizing cloud and edge computing is more sensible.

To improve scalability, decentralized control and management of energy assets has to account for not only aggregation of the energy assets in light of the participation in the energy market, but also to address demand-side energy management to fulfill the user comfort in buildings or premises where the energy assets are used, and also operational processes enabled by the energy assets. Inspired from the behavior of flock of animals in the nature in reacting upon dynamic, unexpected changes, disruptions in their environment, decentralized swarm intelligence appears to be a promising approach to build the underlying intelligence that complements very well with a decentralized IEC 61499 control standard that governs the energy assets together as a system. This project aims at investigating the potential and benefits of decentralized swarm intelligence to control and manage distributed energy assets. Such intelligence may be embedded as services executed across cloud-edge continuum, with each swarm actor capable to learn and adapt the system on the fly following the dynamics in the environment.
Use cases considered in the project will consider existing activities and testbed setups at Aalto Factory of the Future facility (https://www.aalto.fi/en/futurefactory).

We are looking for a Master student, who has a strong background in applied artificial intelligence in industrial systems, in particular with past experience working on real prototypes of AI deployed/running on edge or field computing devices. Past experience in working with laboratory setup demonstrators with cyber-physical nature is highly advantageous.

2103 - Infrastructure and technology layers for ensuring trust and provenance on information, data across industrial value chain

Field of study:	Computer science, cybersecurity, software systems	
For students currently studying:	Master's	
Number of positions offered:	1	
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	Udayanto.atmojo@aalto.fi

Ambitious sustainability and climate goals issued by the European Commission has led to a deluge of new regulations, to name a few, corporate sustainability directive, ecodesign for sustainable products regulation, EU green claims directive. This has substantially increased the level of scrutiny imposed by the public authorities to companies in various sectors with regard to the data associated to the products they manufacture, processes involved in manufacturing the products, logistics and so on, from the early stage of the value chain (raw materials) going to end of life and further when the product is recycled. Consequently, this introduces strong needs from the companies on having the necessary software infrastructure that can enable better management and governance of such data. In addition, there has to be suitable technology layers that facilitate the integration of both the Operational technology (OT) layer and the Information Technology (IT) layer especially that these data are collected or coming from systems that are located either at the IT or OT layer. An important feature to consider is that there has to be mechanisms that ensure the provenance and trustworthiness of the data involving across systems and companies in the value chain.

This project will attempt to investigate a few aspects related to such systems that can fulfill the above needs and circumstances, e.g., blockchain or distributed ledger technologies (DLTs), IT/OT integration and interoperability enabled by IEC 61499, Module Type Package (MTP), or Open Process Automation Standard (OPAS), and enablers to support interoperable digital product passport (DPP) such as Asset Administration Shell / AAS and OPC UA information model.

We are looking for a Master student with background in computer science, software engineering, cyber-security, or related areas. Practical knowledge in any of the mentioned technologies or standards mentioned and past experience in working with laboratory (hardware) demonstrator is highly preferred.

2104 - Creating human digital twin in the industrial environment

Field of study:	Computer science	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Electrical Engineering and Automation	
Professor:	Valeriy Vyatkin	Valeriy.vyatkin@aalto.fi
Academic contact person:	Udayanto Atmojo	Udayanto.atmojo@aalto.fi

Industry 4.0 has so far boosted global industry sectors to the next level based on digitalization. However, as the European Commission pointed, the Industry 4.0 paradigm has completely neglected the social and environmental aspect of industrial activities. In order to better align with the EU sustainability and climate goals, the European Commission highlighted the Industry 5.0 paradigm, an extension of Industry 4.0 which emphasizes the inclusion of both social (human-centric) and environmental (e.g., carbon footprint) into the existing Industry 4.0-driven industry digital transformation. The human-centric in Industry 5.0 requires that industrial environments, activities, systems have to align with values, needs of human. As such, actors in the industrial systems need to be aware and better anticipate human's intentions, behaviors when they operate in the industrial environments. One of the key pre-requisites for this is to have an accurate human digital twin, which can be used to train intelligent enablers, e.g., artificial intelligence, in the industrial systems or simulate various scenarios with human-in-the-loop setting and assess their impacts. The current body of knowledge has shown various attempts in establishing human digital twin, however they are usually realized as static models and simplistic.

This project aims to investigate how to realize human digital twin. We envisage the use of various sensors to capture several properties associated to human and imprint certain characteristics associated to human in the human model. We look to create a human model which is more dynamic, adaptive, and can incorporate a combination of "types", e.g., physical and cognitive features, etc so it can be used for different types of assessment.

We are looking for a Master student with background in computer science, industrial systems engineering, or related areas, with familiarity in industrial system and environments. Practical knowledge in artificial intelligence is highly advantageous.

2105 - Verifying the safety of AI-enabled automation system

Field of study:	Computer science, control and automation, formal methods	
For students currently studying:	Master's	
Number of positions offered:	1	
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	Udayanto.atmojo@aalto.fi

The advance of computing technology has enabled more demanding computation done on smaller computing platforms. This also enables artificial intelligence to be run on edge computing platforms, and thus potentially running and integrated in the control and automation. For example, it is possible in the IEC 61499 function block based control standard to have a function block which contains an IP-restricted implementation, such as an AI model, which is connected to other basic function blocks which have their logic implemented in state machine, altogether forming a function block network. While typical control and automation application is deterministic based on rule-based logic, artificial intelligence is trained using data to converge to a certain solution and produces output which is probabilistic in nature. Deep learning or generative AI model is trained using massive amount of data and has massive space of output possibilities, it is very challenging to establish real assurance of their correct behavior and especially safety just by testing.

Furthermore, considering the recently formalized EU AI Act, it is becoming more important than before to be able to guarantee the overall trustworthy property, including safety, of AI-enabled system in used in especially high-risk areas. Adversarial testing is an example of current approaches that can be used to evaluate safety through identifying the weakness(es) of the AI-enabled application, however it requires very carefully designed set of test cases and a lot of manual human effort involved to produce such test cases. This project aims to investigate a more formal-based approach, e.g., probabilistic model checking, to verify the safety property of AI-enabled automation system, which include both rule-based control logic and “probabilistic” AI component. The project will study how to formally specify the safety property, the automation system that has both trained AI model and IEC 61499 basic function block with state machine, and method to verify such system based on model checking. An existing example based on automation system at Aalto Factory of the Future facility (https://www.aalto.fi/en/futurefactory) will be considered as a case study.

We are looking for a motivated Master student, with strong background in formal methods, familiarity with probabilistic model checking is a great advantage. Some familarity in artificial intelligence is appreciated, but it’s not an exclusive key requirement. Familiarity with control and automation is a major advantage.

2106 - Approaches for generating accurate simulation model programmable logic control (PLC) platform

Field of study:	Computer science, control and automation	
For students currently studying:	Master's	
Number of positions offered:	1	
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	Udayanto.atmojo@aalto.fi

Safe, reliable, and performant operation of industrial systems can be assessed through simulation. Simulation model of the industrial process can be established when the plant is initially commissioned, and during the early commissioning phase, simulation model can then be used to test control and automation application and overall operation of the plant in a safe (simulated) environment before it is built and run in the real world.
The traditional approach in testing is difficult to scale where it is often impeded by the availability of the real / physical programmable logic controllers (PLCs), the capability to scale horizontally, and replace the PLC at will. In addition, the commissioning phase often involves a large engineering team with members located globally, it often involves long distance project travels where team members must gather to the sites where the hardware or the physical industrial plants are available. This activity consumes not only time and cost, but also generates carbon environmental footprint associated to the travels.

We are interested to investigate an approach where the PLC can be virtualized during the early commissioning phase in order to . As far as PLC virtualization is concerned, part of the prerequisite requires an accurate model of the underlying control hardware platform, in this case in particular, programmable logic controller to deploy the automation application and test it with the PLC simulation model in the loop. This project will investigate amenable modelling approaches that allow the creation of accurate simulation model of PLC platform that runs automation application, particularly those that are used to execute IEC 61499 distributed automation standard. This project may investigate and incorporate white-box, black-box, or hybrid modelling approaches to generate an accurate model of IEC 61499 PLC platform, and assess the relevant metrics, e.g., the fidelity of the simulation model produced by the approach.

We are looking for a Master student with strong background in computer science, computer, or software engineering with familiarity on control and automation to work on this project. Knowledge and practical knowledge on machine learning and artificial intelligence is needed, but not the only necessary skill required.

2201 - Organic Devices: Materials and Interfaces

Field of study:	Physics, Material Science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Electronics and Nanoengineering	
Professor:	Caterina Soldano	caterina.soldano@aalto.fi
Academic contact person:	Amirhossein Azari	amirhossein.azari@aalto.fi

The Organic Electronics Group is looking for the Summer 2024 for a curious and talented student at BSc/MSc level, in the fields of (Applied) Physics, Photonics, Microfabrication, Materials and Device Characterization, or related disciplines.

The field of Organic Electronics exploits organic molecules and their optical and electronic properties to develop functional electronic devices. You will contribute to the advance of organic thin film transistor technology, thus a relevant background in semiconductor physics or similar is highly desired.

Your role will be to develop thin films, both dielectrics and semiconductors to study and improve device performances. Experimental work includes deposition of materials, studies of surfaces, device fabrication and characterization.

2301 - Optimal Perception

Field of study:	Deep Reinforcement Learning	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of lnformation and Communications Engineering	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Antti Oulasvirta	antti.oulasvirta@aalto.fi

In this project, we study how the properties of an RL agent's visual system affects its learning and performance. In practice, we optimize the parameters of its visual system jointly with the architecture of its policy in order to maximize learning gains in a given environment. The goal is to tune the system to optimally exploit the structure of the environment. We apply the results to user simulations developed in the group, such as [1].

Requirements:

- Deep RL theory
- Gymnasium and Stable Baselines3
- Bayesian optimization of black box optimization methods

Reference:

[1] https://dl.acm.org/doi/abs/10.1145/3526113.3545689

2302 - Predicting Eye Movement on Information Visualizations

Field of study:	Human-Computer Interaction, Machine Learning, VIsualization	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of lnformation and Communications Engineering	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Danqing Shi	danqing.shi@aalto.fi

Eye tracking is frequently used in understanding information visualizations and visual analytics, where gaze data provides valuable information about decision-making. However, eye trackers are not always available, and their calibration can be time-consuming. To overcome these limitations, researchers use computational models to predict visual attention. These models do not require eye-tracking equipment and can they can predict the gaze behavior. In this project, we aim to construct a new computational model that represents human visual attention when processing information visualizations and assess its effectiveness.

Tasks: conduct a user study, analyze the data, and build an interactive demo.

Requirements:

1) Programming in Python
2) Experience in conducting user studies and experiments
3) Knowledge in information visualization or visual analysis (Optional)
4) Knowledge in machine learning, with a preference for reinforcement learning (Optional)

References:

[1] Wang, Y. and Bulling, A., 2023. Scanpath prediction on information visualisations. IEEE Transactions on Visualization and Computer Graphics.
[2] K. Todi, J. Jokinen, K. Luyten, and A. Oulasvirta, “Individualising Graphical Layouts with Predictive Visual Search Models,” ACM Transactions on Interactive Intelligent Systems (TiiS), vol. 10, iss. 1, p. 9, 2019.

2303 - Simulating Human Grasping with Reinforcement Learning

Field of study:	Human-Computer Interaction, Machine Learning	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Hee-Seung Moon	hee-seung.moon@aalto.fi

This project studies how to simulate human grasping of everyday objects. We are developing an artificial agent with human-like visual perception and motor capabilities (i.e., human-like kinematics and muscle actuations). Utilizing Reinforcement Learning (RL), we are optimizing this agent's actions to mimic humans' optimal movements in object grasping. This simulation-based approach enables the generation of extensive motion data without the need for expensive human data collection. It allows us to observe how different shapes and sizes of objects affect human grasping. This project includes key applications: 1) synthesizing 3D human grasping motions, and 2) inferring a user's intention in VR, specifically which object they intend to grasp and how.

Possible Tasks for Interns:

- Study and improve the RL training process for our artificial agents, focusing on human-like grasping.
- Work on the visualization and synthesis of agent's movements into established 3D human models (e.g., [2]).
- Develop VR interaction prototypes using simulation-based grasp inference.
- Conduct user studies to evaluate the effectiveness of our RL agents and their applications.
-

Required Skills:

- Strong programming skills in Python, with experience in RL within the MuJoCo environment.
- Experience in 3D modeling of the human body and hands (e.g., [2]) is plus.
- Experience in VR programming (Unity, C#) is also a plus.

References:

[1] https://sites.google.com/view/myosuite/myosuite
[2] https://mano.is.tue.mpg.de/

2304 - Leveraging Large Language Models in User-Centered Design

Field of study:	Human-Computer Interaction, User-centered design, LLMs, Human-AI workflows	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Joongi Shin	joongi.shin@aalto.fi

Research theme:
Creating great solutions starts with defining problems worth addressing. In user-centered design (UCD), trained user researchers define key problems by examining user data (e.g., interview and survey resposnes), which highlights users' pain points and their causes that pertain to their contexts. However, defining problems is a challenging task. Like any other creative activity, it also requires creativity in looking into users' pain points and contexts from diverse perspectives to correctly understand them. In this project, we look into the competence of Large Language Models (LLMs) in generating problem descriptions interactively with designers.

Possible tasks for interns:
- Designing human-LLM workflows for this task.
- Prompt engineering.
- Implementing user interface (UI) for enabling the workflows (Please see the example paper A).
- Conduct user studies for evaluating the system.

Requirements:
- General understanding of user-centered design.
- Knowledge in prompt engineering.
- UI Implementation skills (Python).
- Experience in conducting user study is a plus.

References:
A. LLMs for generating design space: https://arxiv.org/abs/2310.12953
B. Scenario-based design: https://link.springer.com/chapter/10.1007/978-3-642-02806-9_23
C. Human-AI workflow: https://doi.org/10.1145/3596926

2305 - Predicting Gaze Trajectories in GUIs

Field of study:	Human-Computer Interaction, Deep Learning	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Aini Putkonen Yue Jian	aini.putkonen@aalto.fi yue.jiang@aalto.fi

Are you interested in ways eye-tracking data can inform UI design? In this project, we focus on fundamental tasks on UIs: free viewing [1] and visual search. Free viewing involves users looking at a screen without any particular instructions, while visual search consists of finding a target among distractors (e.g., an icon on a crowded desktop). Better understanding of free-viewing and visual search on realistic UIs could help design better UIs and understand how users allocate attention while searching for items. The project focuses on modelling human behaviour based on an eye-tracking dataset.

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

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

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

- Proficiency in Python
- Experience with deep learning methods (e.g., transformers)
- Interest in modelling human behaviour
- Experience in conducting user studies and experiments

Reference:
[1] Yue Jiang, Luis A. Leiva, Hamed Rezazadegan Tavakoli, Paul R. B. Houssel, Julia Kylmälä, and Antti Oulasvirta. 2023. UEyes: Understanding Visual Saliency across User Interface Types. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23).

2306 - LLM assisted Color Exploration

Field of study:	Human-Computer Interaction	
For students currently studying:	Bachelor's (final year) or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Antti Oulasvirta	antti.oulasvirta@aalto.fi
Academic contact person:	Lena Hegemann Joongi Shin	lena.hegemann@aalto.fi joongi.shin@aalto.fi

Color choice is an important and challenging task in visual design. Well-chosen colors support the purpose, aesthetics, functionalities, and messages intended by the designer. However, color design is a challenging task because, initially, the exact requirements are often under-defined. Therefore, color design is an explorative process that aims to clarify the requirements while arriving at a matching color choice. Extending on our prior work on AI-assisted coloring [1], this project aims to explore ways of using Large Language Models to assist designers in exploring color design solutions and enhance their creativity to generate high-quality visual design.

Possible tasks for interns:

- Designing color design assistant interaction
- Implementing user interface (e.g. Figma plugin) for the color design assistant
- Conducting user study evaluating the color design assistant

Requirements:

- Programming skills (preferably Python and Javascript)
- Interest in design processes

Additional skills in at least one of the following:

- User Interface Design
- Machine Learning, Large Language Models or Image processing
- Conducting User Studies

Reference:

[1] Hegemann, L., Dayama, N. R., Iyer, A., Farhadi, E., Marchenko, E., & Oulasvirta, A. (2023, March). CoColor: Interactive Exploration of Color Designs. In Proceedings of the 28th International Conference on Intelligent User Interfaces (pp. 106-127). https://userinterfaces.aalto.fi/cocolor/

2307 - Extraction of RSS and Phase from RFID

Field of study:	Electrical Engineering	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Stephan Sigg	stephan.sigg@aalto.fi
Academic contact person:	Stephan Sigg	stephan.sigg@aalto.fi

In the frame of this intern project, the intern student will, in collaboration with other researchers in the group, work on the extraction of RSS (Received signal Strength) and Phase from signals reflected off RFID tags. Particularly, we will use a commercial reader system and interpret the signals observed at its Rx antenna.

Necessary skills: none
Prerequisites: none

2308 - Pose recognition from video

Field of study:	Electrical Engineering	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Stephan Sigg	stephan.sigg@aalto.fi
Academic contact person:	Stephan Sigg	stephan.sigg@aalto.fi

In the frame of this intern project, the intern student will, in collaboration with other researchers in the group, work on pose recognition from video. Particularly, we have in prior work proposed a system to extract a secure authentication key from the contour of a handwriting signature. In this work we attempt to apply this algorithm on a sequence of contours of a person conducting gesture/poses.

Necessary skills: none
Prerequisites: none

2309 - Prediction of missing sensor data

Field of study:	Electrical Engineering	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Stephan Sigg	stephan.sigg@aalto.fi
Academic contact person:	Stephan Sigg	stephan.sigg@aalto.fi

In the frame of this intern project, the intern student will, in collaboration with other researchers in the group, work on the prediction/interpolation of sensor data readings, which are missing from a collection of sensors (e.g. sensor disabled, not attached or not available for other reason). This also includes the prediction across different sensor modalities.

Necessary skills: none
Prerequisites: none

2310 - Approaches to creativity in AI

Field of study:	Electrical Engineering	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Stephan Sigg	stephan.sigg@aalto.fi
Academic contact person:	Stephan Sigg	stephan.sigg@aalto.fi

In the frame of this intern project, the intern student will, in collaboration with other researchers in the group, work on creativity in AI. Particularly, the student will investigate several mechanisms to achieve suggestions that can be considered as creative by a human observer. This may include the use of Neural Architecture search, in order to extend the search space of the machine learning algorithm, but also other approaches will be considered.

Necessary skills: none
Prerequisites: none

2311 - Gesture recognition based on RFID

Field of study:	Electrical Engineering	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Electrical Engineering	
Department:	Department of Information and Communications Engineering	
Professor:	Stephan Sigg	stephan.sigg@aalto.fi
Academic contact person:	stephan sigg	stephan.sigg@aalto.fi

Gesture recognition based on radio frequency identification (RFID) has attracted much research attention in recent years. Basically, different sensing indicators exist such as time of arrival (ToA), received signal strength (RSS), phase of arrival (PoA), and phase difference of arrival (PDoA). UHF RFID operates in 860-960 MHz frequency range which cannot offer high bandwidth. Thus, ToA estimation has considerable error and will not help in RFID-based sensing scenarios. Furthermore, RSS is highly influenced by fading and multipath effects. Although phase values are more sensitive to slight motions than the other types of information, they are also relatively analogous for complex gestures. In this regard, angular measurements such as Angle of Arrival (AoA) in receiver would be promising way to distinguish different gestures specially if they were fused with RSS or phase. AoA in receiver provides information about the direction of the incoming signals that is advantageous. That is because while one is performing gesture, the AoA of the backscattered signals continuously changes. Accordingly, we build the baseband received signals based on the RSS and phase of the backscattered signals provided by an RFID reader. Finally, we estimate the AoA of the incident signals via the MUSIC algorithm.

Necessary skills: none
Prerequisites: none

School of Engineering

Department of Built Environment

3101 - Implementation of an incentive scheme in Helsinki transportation network for traffic management

Field of study:	Transport Engineering	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Built Environment	
Professor:	Claudio Roncoli	claudio.roncoli@aalto.fi
Academic contact person:	Shaya Vosough	shaghayegh.vosough@aalto.fi

Cities are actively seeking innovative mobility management strategies to enhance the efficiency of urban transportation networks. In order to support the design of suitable strategies, involving, for example, pricing or incentivizing, accurate representation of the road users' behavioural response is paramount. Furthermore, when considering actions aimed at redistributing vehicles throughout the traffic network with incentives, it should be considered that the budget is limited since municipalities and transportation authorities face financial constraints and resources. Therefore, a system optimum solution that models the interaction arising between network supply, traffic demand, and users' route choices can significantly contribute to the efficient allocation of incentives within a limited budget.

To tackle this problem, we have developed an optimal methodology aimed at maximizing the efficiency of path-based incentive schemes within the constraints of a limited budget and solved it by employing an innovative column generation algorithm. As part of a national project funded by the Academy of Finland, we aim to implement this approach, coded in GAMS, to the Helsinki transportation network developed in SUMO.

We are looking for an intern to contribute to the development of a tool for applying the proposed method to a real-world network and analysing the impact of various incentive schemes on a large-scale network. This process could include coding, development, and calibration of the assignment models, visualization of proper outputs, and preparing reports, possibly in the form of scientific papers.

The applicant is expected to have a background in transportation and/or computer science. (S)he should be familiar with (or interested to learn) topics related to traffic assignment, while, ideally, having experience in programming languages such as C++ or similar. Knowledge of tools such as SUMO and GAMS would be advantageous.

3201 - Hydro-Mechanical assessment of thermally insulated precast cementitious blocks ingrained with residue carbon from green hydrogen production

Field of study:	Cementitious materials, waste valorization	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Civil Engineering	
Professor:	Sanandam Bordoloi	sanandam.bordoloi@aalto.fi
Academic contact person:	Seppänen Merja	merja.seppanen@aalto.fi

Significance of research project in relation to current knowledge: The European Commission through RePowerEU communication calls for an EU production target of 10 million tons of clean hydrogen by 2030 (EU RePowerEU 2023). For every ton of green hydrogen 4 tons of carbonaceous residue is emitted that would need proper disposal or utilization. One of the high value applications of this burgeoning waste can be in the construction industry as thermally insulated cementitious materials. The European Commission targets a net reduction in greenhouse gases by 55% before 2030 and ultimately achieve net-zero CO_2 emissions by 2050 (Wang et al. 2021). Reaching this goal is only possible with new technologies that can lower the OPC content in mix design significantly and substitute it with suitable materials. **The overarching aim of the 12-week project is to test the uniaxial compressive strength, CO_2 adsorption potential and thermal conductivity of pre-cast low-CO_2 intensive cementitious mix (≤% 50 lower than OPC based) using a blend of green hydrogen carbon residue (CR), OPC, and Ag tailings using CO_2 mineralization.**

Practical steps taken for successful completion of the test in the duration of internship: The Professor in charge is currently characterizing different green hydrogen-based carbon residue from a local supplier. Detailed morphological and chemical study for execution of the internship work has been laid out. The civil engineering lab is well equipped to conduct the tests provided in the workplan.

Expected research results and their anticipated scientific impact: The project will result in contributing to a novel methodology that maximizes CO_2 assimilation within cementitious mixes using green hydrogen-based carbon and locally available Ag tailing. We intend to publish one journal paper based on the results of the study and possibly apply for an ERC startup grant in 2024 from the current findings for a holistic and detailed study of a range of green hydrogen residue composites.

Necessary skills to conduct tests:
The candidate must have basic skills in conducting the following tests on developed composites.

Properties	Methodology	Standards	Insights for mixes
Compressive strength	Ingstron Machine	EN 12390-3	Indicative of strength
CO_2↑	Thermogravimetric analysis (TGA)	Chen et al. 2022a	Quantitative CaCO3 mineralized
Thermal conductivity	Thermal conductivity sensors	EN 1992-1-2	Usability as building and pipeline insulators

Overarching contributions of the project: The project directly advances three SDGs by developing technologies for low CO_2 intensive materials. The project contributes to developing sustainable cities (SDG 11 -Sustainable Cities and Communities), reduce greenhouse gas emissions (SDG 13 - climate action), and promotes reutilization mine tailings, coal residue, and organic waste in construction industry (SDG12 -Responsible consumption and production). The quantitative and overarching aim will be to develop a range of cementitious building composites that emit zero CO_2-eq (kg ton-1).

Major references:
Chen, T., Zhao, L., and Qin, L., 2022a. Modification of carbonation-cured cement mortar using biochar and its environmental evaluation. Cement and Concrete Composites, 134, p.104764
EU RePowerEU 2023 communication (https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen_en)

3202 - Digitization of construction - Digital twins

Field of study:	Construction management/Computer science	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Civil Engineering	
Professor:	Olli Seppänen	olli.seppanen@aalto.fi
Academic contact person:	Olli Seppänen	olli.seppanen@aalto.fi

Description: Digital twins are an emerging concept which has drawn attention in manufacturing as well as construction industry. The digital twins of construction process are a digital replica of the construction process which can be used to model, simulate, compare, and evaluate the performance of processes. Accurate digital twins will be helpful in streamlining the process of construction to reduce delays and cost overruns associated with construction projects. This will not only be helpful in the economy of a nation but also reduce carbon footprints as wastage related to construction will be reduced.

The intern will participate in the work package of the project that is related to modeling and simulation. The aim of the project is to provide real-time implementation of site situations to analyze and predict the behaviors and activities for the construction workers.

We expect the following skills from the intern:

- Knowledge and experience in Agent-Based modeling and simulation
- Knowledge of Anylogic: Simulation Modeling Software
- Experience in Java programing
- Creative and intelligent mind to develop unique algorithms.
- Good writing and verbal communication skills
- Interactive and collaborative problem solver

The intern is expected to work at the Department of Civil Engineering in the research group of Building design and construction management.

3203 - Digital twins in construction

Field of study:	Construction management/Computer science	
For students currently studying:	Master's	
Number of positions offered:	1	
School:	School of Engineering	
Department:	Department of Civil Engineering	
Professor:	Olli Seppänen	olli.seppanen@aalto.fi
Academic contact person:	Olli Seppänen	olli.seppanen@aalto.fi

Description: Digital twins are an emerging concept which has drawn attention in manufacturing as well as construction industry. The digital twins of construction process are a digital replica of the construction process which can be used to model, simulate, compare, and evaluate the performance of processes. Accurate digital twins will be helpful in streamlining the process of construction to reduce delays and cost overruns associated with construction projects. This will not only be helpful in the economy of a nation but also reduce carbon footprints as wastage related to construction will be reduced. One of the ways of achieving accurate digital twins is automating data capturing and interpretation techniques. The methods employed in automation of interpretation in the field of construction require some further research before they can be completely utilized for converting real site data to digital information of the under-construction infrastructure. The aim of this project is to explore such methods on the real construction data to convert them into meaningful information for purposes including planning or managing a construction process.

The intern will collaborate in designing and developing the framework for point cloud processing for construction related data interpretation.

The intern is therefore expected to have the following skills:

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

The intern is expected to work at the Department of Civil Engineering in the research group of Building design and construction management.

3301 - Does accuracy of winter navigation decision making depend on the source of the ice data?

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

Ice information is important for winter navigation in the Baltic Sea. It effects the traffic safety and efficiency. The existence of ice plays a significant role in ship route planning and shipping traffic arrangement. For example, if the ice condition is severe for merchant vessels entering the Baltic, icebreaker assistance would be needed to help merchant vessel to go through the ice-covered waters. Otherwise, the merchant vessel could get stuck in ice, or the ship hull could be damaged. Therefore, accurate ice information plays an important role in maintaining efficient and safe winter navigation.

This project aims to analyze and compare two different ice data sources for winter navigation decision making. One source comes from hindcast model, which is stored in three-dimensional NetCDF format. Another source come from ice chart which is an open-source data, see example here https://www.smhi.se/oceanografi/istjanst/produkter/arkiv/sstcolor/sstcolor_20230128.pdf.

The working contents of the intern position:

1. NetCDF data processing and data management
2. Data extraction from images
3. Data processing with different spatio-temporal resolution
4. Statistical analysis

Necessary skills:

1. Ability to work independently and in a team.
2. Programming skills. Python is preferable.
3. Data processing and management.

3303 - Machine-learning-based modelling for hydrogen-material interaction for future hydrogen storage and transport applications

Field of study:	Mechanics, materials, machine learning, modeling	
For students currently studying:	Bachelor's and Master's	
Number of positions offered:	1-2	
School:	School of Engineering	
Department:	Department of Mechanical Engineering	
Professor:	Junhe Lian	junhe.lian@aalto.fi
Academic contact person:	Rongfei Juan	rongfei.juan@aalto.fi

One of the most promising decarbonizing solutions is hydrogen technologies, which are capable of cleanly and sustainably matching the needs of modern society. However, regardless of the position in the hydrogen production and usage chain, components must operate safely in the hydrogen environment, which has been one of the most concerning challenges for hydrogen technologies. This is unique because the excellent mechanical properties of metallic materials drastically deteriorate in a hydrogen environment and catastrophic and unpredictable failure of metals could occur caused by hydrogen, known as hydrogen embrittlement. This eventually hinders the efficiency and accuracy of developing better hydrogen-tolerant materials and further assessment of the performance of materials and components used in a hydrogen-sensitive environment and ultimately delays hydrogen technology adoption.

In this project, we aim to develop a digital and novel data-physics integrated approach for designing newly graded hydrogen-tolerant metals and assessing the feasibility of materials in hydrogen storage and distribution applications. This project will focus on the further development of hydrogen-metal interaction in a multiscale manner, including finite element level, crystal plasticity level, and molecular dynamic level, incorporating machine-learning-based approaches. It will also explore parameterization by using various optimization algorithms (e.g., genetic algorithm, Bayesian algorithm, etc.) or machine-learning models. The development and optimization will be extensively conducted on the Finnish supercomputer platform (CSC).

In this project, you will learn advanced theories and knowledge on the mechanics of materials with a focus on strength and failure, as well as hydrogen-related new applications. More importantly, you will be trained with various optimization algorithms and modern data-driven models based on deep learning, such as ANN and LSTM. Finally, you will have the chance to apply these models and 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: coding with Python or MATLAB, experience with finite element simulation, crystal plasticity simulation, molecular dynamics modeling, optimization algorithms, machine-learning modeling, and knowledge of the mechanics of materials are highly appreciated.

School of Science

Department of Applied Physics

4101 - Edge states in confined geometry

Field of study:	Physics	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Pertti Hakonen	pertti.hakonen@aalto.fi
Academic contact person:	Manohar Kumar	manohar.kumar@aalto.fi

Graphene-based hybrid quantum material being atomically thin and with the combination of unique dielectric environments makes it an ideal platform for the realization of non-Abelian anyons. These anyons will be pivotal for topological qubits. In this setting, non-Abelian anyons like fractional quantum Hall states ν = 5/2 with much higher gap energy could be realized. A quantum point contact (QPC) is much necessitated component to realize topological qubits. However, graphene being a semi-metal i.e., the lack of bandgap makes the QPC a non-conventional structure. Our group is presently developing QPCs in graphene. The transport measurement on the Hall bar with a QPC geometry has shown clear signatures of the quantized plateaus in conductance. However, the quantized steps are heavily influenced by the several equilibration processes of the edge states in the QPC. The understanding of the scattering process in the QPC region is still evolving. PIs at Aalto are developing with Prof. Tworzydlo a better theoretical model for the QPC in graphene. The calculation requires going beyond the simple scattering matrix formalism for the conventional QPC conceived in semiconducting GaAs/AlGaAs heterostructure.

We would like to investigate theoretically quantum transport in the confined geometry of graphene using quantum tight-binding models. The formalism developed will replicate the quantum conductance via a quantum point contact. Furthermore, a GUI will be developed to simulate the transport in Hall bar geometry. These models could be further engineered to design better electronic interferometers in the quantum Hall regime. A two QPCs construction i.e., Fabry-Pérot interferometer will be a basic building block for the topological qubit.

This work will be part of ongoing long-term activities in the Nano group (Aalto University) of which Prof. Tworzydlo, University of Warsaw, Poland provides theoretical support. We are looking for a highly motivated student with, preferably, a strong background in tight-binding calculation. Interested candidates are asked to get in touch with the Academic contact person or the professor in charge for further details.

The following references illuminate the background of the project well:

1. PhysRevB.82.205412 (aps.org)
2. Phys. Rev. B 105, L241409 (2022) - Positioning of edge states in a quantum Hall graphene pn junction (aps.org)

4102 - Fractionalization in zero magnetic fields a.k.a. Fractional Chern Insulator

Field of study:	Physics	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Applied Physics	
Professor:	Pertti Hakonen	pertti.hakonen@aalto.fi
Academic contact person:	Manohar Kumar	manohar.kumar@aalto.fi

Fractionalization is one of the most celebrated phenomena in many-body physics, observed in different materials irrespective of their characteristics, impurities, geometrical configuration, and electron densities. It becomes even more intriguing to see the quantization of Hall plateaus at certain fractional multiples of e^2/h with unprecedented precision, indicating the topological origin of this quantization. The fractional quantum Hall (FQH) states observed in solid state systems at extreme experimental conditions: high magnetic field, and low cryogenic temperatures is one such example. Very recently, a new member was added to this family: Fractional Chern Insulator (FCI). These are lattice analogs of the FQH system, where fractional excitations are formed at zero magnetic fields. FCI in higher Chern bands are expected to carry non-Abelian excitations, allowing to storage of quantum information non-locally. Thus, the low-energy excitations of FCI could be a potential candidate for topological quantum computing. In the NANO group, we are investigating such emerging excitations in multilayer graphene and twisted moiré superlattice of transition metal dichalcogenides. These van der Waals (vdW) heterostructure forms an exciting platform for exploring the emergent electronic correlations in the presence of non-trivial band topology.

We are looking for highly motivated and hard-working students to join our small team comprised of a PhD and a Postdoc. The candidate is expected to exfoliate multilayer graphene in a controlled environment and identify the 4-6 layers by standard RAMAN and AFM techniques. The identified flakes will be encapsulated with insulating 2-D crystals h-BN to form h-BN/m-G/h-BN heterostructure. With the help of the PhD student, the candidate will fabricate the ohmic contacted Hall bar devices. This device will be further characterized in a cryogenic environment and low magnetic field.

This project will be interesting for students willing to learn the topological phases of matter and contribute to emerging quantum technologies. This project will form an MS thesis but could be extended to a PhD thesis, where one could probe these states in microwave settings. Highly motivated BSc students are also welcome.

We encourage interested candidates to contact the academic contact person or the professor in charge for further information.

4103 - Quantum Many-Body Physics on a Simulated Quantum Computer

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

Understanding the behaviour of many-body quantum systems is one of the most important tasks in condensed matter physics. However, only few cases can be solved exactly, and one must otherwise resort to numerical approximations. Quantum computers, on the other hand, are expected to greatly advance the simulation of complex quantum systems, as the quantum states of interest can be directly created and manipulated in the quantum register.

This project is about using a quantum computer, simulated by a tensor network algorithm developed in our research group, to understand the behaviour of many-body quantum models. You will learn how to use quantum computers to solve questions related to the behaviour of quantum systems of many spins, which will provide a model of the properties of many realistic materials.

The main tool in this project is the Julia programming language, and it is therefore well suited for students with an interest in coding. No prior knowledge of Julia is required, but a successful candidate should be comfortable with either Python or C++, or similar. While we can adjust the project to different levels of difficulty, a background in quantum computing/information, statistical physics and condensed matter physics will be helpful and considered an advantage.

4104 - Radiation damage in multi-component alloys

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

Description:
Particle irradiation modifies the physical and mechanical properties of materials, and plays an increasing role in modern technological developments. For example, climate change is driving the need for green energy, with nuclear fusion and next generation fission standing as two of the strongest candidates for efficient and reliable energy production of the future, yet the challenges posed to reactor materials in the high radiation environments are significant. Modelling provides an essential tool for predicting the response of reactor components in future nuclear devices. The damage in materials created by energetic impacting particles is highly sensitive to the mechanisms of dissipation of the impinging particle's kinetic energy. This summer project involves performing simulations employing a recently developed atomistic model, which accounts for energy dissipation in unprecedented detail, to predict the primary radiation damage in model alloy systems under different incident neutron and ion energies. Focus will be on analysis of the surviving damage, including defect numbers and morphology. The student will gain knowledge of the processes of radiation damage formation in materials, learn the basics of performing molecular dynamics simulations of highly non-equilibrium events, and develop a familiarity with high performance computing environments.

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

4201 - Machine Learning: Foundations and New Frontiers

Field of study:	All areas of Machine Learning, including, but not restricted to Generative Models, Geometric learning, Representation Learning, Reinforcement Learning, Neural ODEs, Physics Informed Learning, Deep Learning, Computational Biology, NLP, (Applied) Math, and Quantum ML.	
For students currently studying:	Bachelor's or Master's or PhD	
Number of positions offered:	5 (approx)	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Vikas Garg	vgarg@csail.mit.edu;
Academic contact person:	Vikas Garg	vikas.garg@aalto.fi

Applications are invited for various internship positions in our group, see e.g., (1-10) below about our contributions to representation learning, graph neural networks, generative models, etc. An ideal student would be eager to push the frontiers of science; have strong mathematical, theoretical, statistical, or algorithmic background; and be comfortable with programming in Deep Learning. **We particularly invite students with strong Pure, Applied Math, Bioinformatics, or Physics backgrounds to apply.** We also value diversity and encourage candidates from underrepresented backgrounds to apply.

Interns in our group from previous years have produced stellar research, including, a publication accepted with Oral presentation at NeurIPS 2023 (0).

Topics of particular interest include but are not limited to:

(1) Generative Models
(2) (Temporal) Graph Neural Networks, Topological Deep Learning, Topological Data Analysis (e.g., Persistent Homology)
(3) Neural ODEs/PDEs/SDEs, Deep Equilibrium Models, Implicit Models
(4) Differential Geometry/Information Geometry/Algebraic/Spectral Methods for Deep Learning
(5) Learning under limited data, distributional shift, and/or uncertainty; Conformal Prediction
(6) (Approximate) Equivariant and Invariant models
(7) Fair, interpretable, or explainable methods
(8) Off-policy reinforcement learning, inverse reinforcement learning, and causal inference
(9) Multiagent systems and AI-assisted human-guided models
(10) Compression and learning on the edge (i.e., resource constrained settings such as IoT devices)
(11) Applications in large language models, drug discovery, material design, synthetic biology, quantum chemistry, etc.
(12) Quantum Machine Learning

Representative publications:

(0) J. Immonen(*), A. Souza (*), and V. Garg. Going beyond persistent homology using persistent homology. NeurIPS (2023).
(1) J. Ingraham, V. Garg, R. Barzilay, and T. Jaakkola. Generative Models for Protein Design. NeurIPS (2019).
(2) V. Garg, S. Jegelka, and T. Jaakkola. Generalization and Representational Limits of Graph Neural Networks. ICML (2020).
(3) V. Garg and T. Jaakkola. Solving graph compression via Optimal Transport. NeurIPS (2019).
(4) V. Garg, L. Xiao, and O. Dekel. Learning small predictors. NeurIPS (2018).
(5) T. Garipov et al. Compositional Sculpting of Iterative Generative Processes. NeurIPS (2023).
(6) Y. Verma, M. Heinonen, and V. Garg. AbODE: Ab initio antibody design using conjoined ODEs, ICML (2023).
(7) A. Souza, D. Mesquita, S. Kaski, and V. Garg. Provably expressive temporal graph networks. NeurIPS (2022).
(8) G. Mercatali, A. Freitas, and V. Garg. Symmetry induced disentanglement on graphs. NeurIPS (2022).
(9) D. Alvarez-Melis(*), V. Garg(*), and A. Kalai(*). Are GANs overkill for NLP? NeurIPS (2022).
(10) V. Garg and T. Pichkhadze. Online Markov Decoding: Lower Bounds and Near-Optimal Approximation Algorithms. NeurIPS (2019).

4202 - Dual active learning for Human-AI teaming

Field of study:	Collaborative decision-making and design with AI	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Samuel Kaski	samuel.kaski@aalto.fi
Academic contact person:	Ali Khoshvishkaie	ali.khoshvishkaie@aalto.fi

Dual learning [1, 2] is a machine learning paradigm involving training two primal and dual models together. The tasks hold a specific connection so that the output of each serves as the input of the other, creating a loop. Jointly training of the two models can further improve them by providing valuable signals in various ways, for instance, by labelling the output of the other. In this project, we aim to actively involve a human expert inside this loop.
The idea is to engage the expert to provide data for a primal task, which we care about, by actively performing the dual one, which is easier. For instance, generating a molecule holding particular properties (primal task) might be too tricky for chemists; however, recognising the properties of a given molecule (dual task) would be easier. By using active dual learning in this specific setting, we leverage human knowledge to improve a difficult task by performing a less complicated one.

We are looking for students with good programming skills (PyTorch) and a background in machine learning. Knowledge of active learning is considered a plus.

Keywords: active learning, dual learning, knowledge elicitation

References:
[1] He, D., Xia, Y., Qin, T., Wang, L., Yu, N., Liu, T. Y., & Ma, W. Y. (2016). Dual learning for machine translation. Advances in neural information processing systems, 29.
[2] Qin, Tao. Dual learning. Singapore:: Springer, 2020.

4203 - Efficient methods for uncertainty in Deep learning

Field of study:	Bayesian deep learning	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Samuel Kaski	samuel.kaski@aalto.fi
Academic contact person:	Trung Trinh	trung.trinh@aalto.fi

Bayesian neural networks (BNNs) are neural networks (NNs) whose weights are represented by a distribution. Compared to a deterministic NN, BNNs theoretically can produce more accurate and better calibrated predictions. However, due to the sheer amounts of parameters in modern NNs, BNNs are difficult to train and require massive amounts of computation. Methods have been proposed to improve the efficiency of BNNs, for instance by performing inference in the node space [1] or in the depth space [2].

In this project, we will survey the methods and applications of efficient BNNs, as well as whether or not these methods can be combine together to obtain better performance.

Relevant skills: Python programming, Deep learning frameworks (Pytorch, JAX), knowledges of deep learning and Bayesian methods.

References:

[1] https://arxiv.org/pdf/2005.07186.pdf
[2] https://arxiv.org/pdf/2006.08437.pdf

4204 - Investigating Homophily and the Glass Ceiling in Supervisor- and Collaboration-Networks

Field of study:	Computer science and sociology	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
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.

4205 - Intragroup and intergroup dynamics on Reddit

Field of study:	Computational social science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Barbara Keller	barbara.keller@aalto.fi
Academic contact person:	Barbara Keller	barbara.keller@aalto.fi

In this computational social science project we analyse real world social media. Specifically, we study discussion dynamics within and between groups (e.g., fan groups, pro/anti groups of a certain topic) by analyzing Reddit data. This position is suitable for someone who has interest in the topic, solid coding skills (preferrably in Python), familiarity with the Reddit platform, and some knowledge of social media data analysis methods. Experience with analyzing social media data (especially Reddit data) will be a plus.

4206 - Algorithms for tree-like geometric structures

Field of study:	Theoretical Computer Science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1-2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Sándor Kisfaludi-Bak	sandor.kisfaludi-bak@aalto.fi
Academic contact person:	Sándor Kisfaludi-Bak	sandor.kisfaludi-bak@aalto.fi

Tree-like geometric structures are common and they often lead to algorithmic benefits. For example, treewidth is a highly successful graph parameter measuring the tree-likeness of a graph; hyperbolicity, a parameter for metric spaces also has algorithmic benefits. The goal of the internship is to look at some geometric problem and design an algorithm that works best in tree-like metric spaces, or prove structural properties that rely on metric tree-likeness.

Prerequisites: Strong background in algorithm theory and discrete mathematics, lots of experience in writing formal proofs, interest in geometric algorithms/computational geometry.

4207 - Stochastic algorithms for testing (un)knottedness

Field of study:	Computer Science / Computational Biology	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
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

Mathematically speaking, a knot is an embedding of the 1-dimensional circle into 3-dimensional Euclidean space [1], and two knots are equivalent (or ambient isotopic) if they can be continuously deformed to each other. A knot is trivial or the unknot if it is equivalent to the round circle in 3-space. It is a notoriously difficult open question whether an efficient algorithm for testing (un)knottedness exists, although some remarkable advances have been achieved recently [2]. The task can nevertheless be approached in many ways that yield partial results, one of which is trying to find a good sequence of Reidemeister moves [3] for unknotting a given knot diagram.

In the present context, the challenge of (un)knottedness arises in our work on the browser-based tool DNAforge [4] for designing 3D wireframe DNA nanostructures. Here the fundamental technique of DNA origami [5,6] builds on folding a long cyclical scaffold strand into an outline or "routing" of the desired target shape, guided by a large number of short staple strands. If the targeted strand routing is nontrivially knotted, then the physical folding cannot take place, and one should be aware of this in the design phase.

The task of this internship project is to adapt and test stochastic search techniques, such as Simulated Annealing [7], towards the goal of searching for a good Reidemeister sequence that unknots a given scaffold strand routing. If no such sequence can be found in a reasonable time, then the given routing is labelled as being at risk of being knotted. As part of the project, the selected method will be integrated into the DNAforge tool.

The project requires familiarity with basic algorithm design techniques, facility with combinatorial thinking, and good programming skills. Knowledge of biomolecules is not necessary, but familiarity with Javascript (or willingness to learn) is a prerequisite. For further information about our work, please see the research group webpage at https://research.cs.aalto.fi/nc/.

References:

[1] https://en.wikipedia.org/wiki/Knot_(mathematics)
[2] https://www.maths.ox.ac.uk/node/38304
[3] https://en.wikipedia.org/wiki/Reidemeister_move
[4] https://dnaforge.org/
[5] https://doi.org/10.1038/nature04586
[6] https://doi.org/10.1038/nature14586
[7] https://en.wikipedia.org/wiki/Simulated_annealing

4208 - Designing Tools and Practices for Responsible AI for Public Services

Field of study:	Computer Science	
For students currently studying:	Master's preferred	
Number of positions offered:	2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Nitin Sawhney	nitin.sawhney@aalto.fi
Academic contact person:	Kaisla Kajava Ana Paula Gonzalez Torres	kaisla.kajava@aalto.fi ana.gonzaleztorres@aalto.fi

With the emerging adoption of algorithmic decision-making and generative AI across societal sectors, there is a need for supportive AI policies and regulations (e.g., the European Union's Artificial Intelligence Act), which creates many socio-technical challenges for responsible and trustworthy AI.

We are seeking to hire a summer researcher to work in applied governance frameworks for trustworthy/responsible AI which include the application of experimental frameworks for regulation and potential implementation of Machine Learning Operations (MLOps) to support transparency, accountability, and auditability.

The research is part of the Civic Agency in AI (CAAI) project being conducted in collaboration with providers of AI-based public services in Finland. 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.

Applicants must show a keen interest in proposed research topics and bring a mix of technical and qualitative skills and/or interest in one or more of these aspects: trustworthy AI, programming MLOps pipelines, data science and/or Natural Language Processing (NLP), AI policy, societal impact of AI-based systems, and AI discourses.

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

4209 - Probabilistic machine learning for multi-modal data

Field of study:	Computer Science, Machine Learning	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Arno Solin	arno.solin@aalto.fi
Academic contact person:	Marcus Klasson	marcus.klasson@aalto.fi

We are seeking motivated and talented interns to join our current research projects focused on probabilistic machine learning with positions in tractable modelling, uncertainty quantification in deep learning, and multi-modal (computer vision + language) modelling. This project is part of our broader initiative in multi-modal modelling, aiming to advance the frontiers of understanding and methods in the field of machine learning. More specifically, the research interests are in uncertainty quantification in large-scale vision/language models, as well as combining semantic understanding with scene reconstruction (Gaussian splatting / NeRF models).

Interns will have the opportunity to work on cutting-edge research problems, including uncertainty quantification in neural networks and the development of innovative inference methods. Our team values creativity, analytical skills, and a collaborative spirit. A successful candidate is expected to have knowledge of probabilistic modelling and approximate inference, and general machine learning methods as well as experience with programming in Python (e.g., TensorFlow, JAX, PyTorch, etc.).

This internship presents a unique opportunity to contribute to significant research in a dynamic and supportive environment. We encourage students who are enthusiastic about probabilistic modelling and have a keen interest in language models and computer vision to apply. Highlight your specific skills and interests in your application to align with our team's needs.

See the supervisor's home page for representative publications: https://arno.solin.fi

4210 - Machine learning for sensor fusion and vision

Field of study:	Computer Science, Machine Learning	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Arno Solin	arno.solin@aalto.fi
Academic contact person:	Marcus Klasson	marcus.klasson@aalto.fi

We are seeking motivated and talented interns to join our research team to work on an applied data capture and real-time analysis application in computer vision. The intern will have the opportunity to work with the Luxonis RAE (https://shop.luxonis.com/products/rae) robot and Luxonis cameras for data capture and scene reconstruction and analysis. The applications relate to Gaussian splatting / NeRF modelling as well as general-purpose segmentation models.

Our team values creativity, analytical skills, and a collaborative spirit. A successful candidate is expected to know about general machine learning, have some tinkering background, and experience with programming in C++ and Python (e.g., TensorFlow, JAX, PyTorch, etc.). This internship presents a unique opportunity to contribute to significant research in a dynamic and supportive environment. We encourage students who are enthusiastic about machine learning and interested in real-time modelling and computer vision to apply. Highlight your specific skills and interests in your application to align with our team's needs.

See the supervisor's home page for representative publications: https://arno.solin.fi

4211 - Theory of distributed and parallel computing

Field of study:	Theoretical computer science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Jukka Suomela	jukka.suomela@aalto.fi
Academic contact person:	Jukka Suomela	jukka.suomela@aalto.fi

Our research group "Distributed Algorithms" is looking for a summer intern to help us with our research related to the theoretical foundations of distributed and parallel computing. We expect a good understanding of mathematics (especially in discrete math and graph theory) and algorithms and theoretical computer science. We also often try to outsource our work to computers, so if you have good programming skills and/or some knowledge of e.g. SAT solvers or proof assistants, it is a plus. We have also exciting opportunities for those who are interested in quantum computation in the distributed setting.

For more information, see https://research.cs.aalto.fi/da/

4212 - Bayesian workflow

Field of study:	Bayesian computational modeling	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Aki Vehtari	aki.vehtari@aalto.fi
Academic contact person:	Andrew Johnson	andrew.r.johnson@aalto.fi

You will take part in developing computational diagnostic tools for different parts of Bayesian workflow (see, e.g., https://arxiv.org/abs/2011.01808).

Prerequisites: Bayesian inference and MCMC.

4213 - The psychology of cooperation in Human-AI interaction

Field of study:	Human-Computer Interaction, AI, Psychology	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1-2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Robin Welsch	robin.welsch@aalto.fi
Academic contact person:	Robin Welsch	robin.welsch@aalto.fi

Artificial intelligence (AI) technologies fundamentally affect our every-day lives. Human-centred AI technologies are designed to support humans and extend human capabilities, raising high expectations concerning our AI-augmented abilities. This research internship will run empirical studies to investigate how the use of AI system affect how humans cooperate with each other.

The main task in this internship are the design, planning, and execution of an empirical user study. This includes the creation of prototypes, the preparation of study materials but also doing research with user's in the lab. For a testimonial of last years interns see: http://human-ai-interaction.com/allgemein/summer-is-over-and-our-foreign-students-are-leaving/

Candidates for the intern position should have the following skills:

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

You will gain experience in the following areas:

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

4214 - Scalable reinforcement learning systems for training LLMs

Field of study:	Deep Learning, Reinforcement Learning, Distributed systems, Machine learning systems	
For students currently studying:	Master's	
Number of positions offered:	2	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Bo Zhao	bo.zhao@aalto.fi
Academic contact person:	Bo Zhao	bo.zhao@aalto.fi

Topic: Machine learning (ML) systems translate data into value for decision making. Recent breakthroughs in large language models (GPT 4, Llama 2, ChatGPT, Gemini) and remarkable outcomes of reinforcement learning (RL) in real-world settings (AlphaGo, AlphaFold, reinforcement-learning-from-human-feedback) have shown that scalable model training on large GPU/TPU clusters is critical to obtain state-of-the-art performance.

This summer research project aims to answer the question "how to co-design multiple layers of the software/system stack to improve the scalability and performance of RL/RLHF systems". Specifically, it addresses the challenges to build:

(1) flexible distributed RL systems to accelerate and parallelize the RL and RLHF training loop,
(2) statement management libraries to transparently change the GPU device allocation and multi-dimensional parallelism (i.e., data/model/pipeline parallelism) without affecting the training result and
(3) Holistic end-to-end training pipeline of RLHF training loop for LLMs.

The project aims at building open-source software and/or publishing at top-tier conferences.

About the lab: Aalto Data-Intensive System group (ADIS) conduct research on efficient data-intensive systems that translate data into value for decision making. The scope of our research spans across multiple subfields, from scalable data-centric machine learning systems to distributed data stream management systems, as well as code optimization techniques. Students have the chance to experience world-class research environment including the group-exclusive GPU cluster, Aalto HPC cluster Triton (200 GPUs) and the access to Europe's fastest (world's 5th fastest) supercomputer LUMI equipped with quantum computing capacity. Students also have opportunities to collaborate with other world-leading research groups and industry labs within our international network (e.g., Imperial College, TUM, MPI-SWS, HU Berlin, NUS, Uni Edinburgh, AWS, etc).

Necessary skills:

- Solid knowledge of computer systems (e.g., distributed systems, data management systems, compilers)
- Familiar with machine learning frameworks (e.g., PyTorch, TensorFlow, Megatron-LM, DeepSpeed)
- Knowledge of distributed ML training (e.g., training across multiple GPUs or multiple nodes)
- Solid programming capability of C++, Python, Go and/or Rust, etc.
- Strong analytical thinking skills
- Excellent scientific communication and writing skills
- Comprehensive interest in scientific problems and the ability to work independently and within a larger team

Preferred skills:

- Hands-on experience of distributed ML training (e.g., model training across multiple GPUs or multiple nodes)

4215 - Large Language Models for Extreme Multi-label Classification

Field of study:	Computer Science	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Computer Science	
Professor:	Rohit Babbar	rohit.babbar@aalto.fi
Academic contact person:	Rohit Babbar	rohit.babbar@aalto.fi

With its applications in various domains such as recommendation and search, there is a surge in the study of supervised learning problems with large number of output class labels. In this domain, also referred to as Extreme Classification, we aim to address the computational challenges of employing Large Language Models in the deep learning pipelines for large output spaces. Going beyond the conventional problem setting with textual datasets, the research project will also focus on Multi-modal datasets and zero-shot learning settings. More information about our recent work in this domain can be found at : https://sites.google.com/site/rohitbabbar/

Prerequisites : Background in Deep Learning, Excellent Programming skills in python, and experience with deep learning frameworks such as Pytorch

References :

1. CascadeXML: Rethinking Transformers for End-to-end Multi-resolution Training in Extreme Multi-label Classification, NeurIPS 2022
2. Multi-modal Extreme Classification, CVPR 2022

4301 - Formalization of mathematics

Field of study:	Mathematics (computer formalized)	
For students currently studying:	Bachelor's or Master's	
Number of positions offered:	1	
School:	School of Science	
Department:	Department of Mathematics and Systems Analysis	
Professor:	Kalle Kytölä	kalle.kytola@aalto.fi
Academic contact person:	Kalle Kytölä	kalle.kytola@aalto.fi

Formalization of mathematics means writing mathematics in an unambiguous language understood by a computer. This includes formulating both the statements and their proofs. One of the central objectives of formalization is to create a comprehensive, unified, digital library of mathematical knowledge, which has the further virtue of being computer verified for correctness. Among the most successful current libraries of this type is Lean's Mathlib <https://github.com/leanprovercommunity/mathlib4>, written in a language called Lean. There are a few examples of research level mathematical results that have been successfully formalized, building on Mathlib, which indicates that the library has the potential to become a useful resource for mathematicians. Yet, substantial parts of a standard undergraduate curriculum in mathematics are still missing. In particular the library is missing lots of standard probability theory, analysis, and algebra.

This internship project pertains to the formalization of some aspects of probability theory or analysis or algebra in Lean, at the undergraduate or graduate level. Given the speed at which the library is currently developed, the status will inevitably change by the beginning of the summer internship, and it does not make sense to specify the topic of the internship in full detail. Example topics to formalize could be: sequential compactness version of the Banach-Alaoglu theorem, metrizability of convergence in distribution, tightness and Prokhorov's theorem, correlation inequalities and existence of infinite volume limits in statistical mechanics, Lévy's inversion theorem of characteristic functions, area theorem in complex analysis, representation theory of the symmetric groups, central extensions of Lie algebras, etc. The internship is expected to lead to either successful Lean formalizations or important insights into issues that need to be taken into consideration in the formalization of such topics. The internship may also include some small scale development of specific-purpose proof automation by metaprogramming, and/or development and testing of some tools for teaching.

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

4302 - Similarity of integer matrices

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

Suppose that A and B are two square integer matrices. We say that they are similar over Z if there is a third integer matrix C,whose determinant is +1 or -1, such that AC=CB. And we say that they are similar over Q if there is an invertible rational matrix X such that AX=XB.

Clearly, similarity over Z implies similarity over Q, but the opposite is not true. While similarity over Q is very well understood and can be reduced to the study of the Frobenius canonical form, the situation is much more subtle for similarity over Z. The goal of the project is to study similarity over Z, reviewing scattered results on it that exist in the literature and summarising their content in a written report.

The project lies at the intersection of matrix theory, algebra (especially ring theory and module theory), and number theory. Students having some background in the those branches of mathematics are especially invited to apply.