Projektvalskatalog för EF112X kandidatexamensarbete inom elektroteknik (15 hp) våren 2021

I denna katalog kan du hitta information om alla valbara projekt inom kursen EF112X kandidat-examensarbete inom elektroteknik (15 hp) som erbjuds våren 2021. Kursen EF112X pågår hela vårterminen från mitten av januari till slutet av maj. Projekten utförs i grupper om två. Omfattningen får erbjuder vi 69 projekt inom ramen av 17 olika kontext:

Kontext inom: Systemteknik och robotik

- Kontext A: Automatic car following and platooning (*Jonas Mårtensson, 5 projekt*)
- Kontext B: Autonomous robotic systems (*Dimos Dimarogonas, 3 projekt*)
- Kontext C: Learning in Dynamical Systems (*Cristian Rojas, 5 projekt*)

Kontext inom: Elkraftteknik

- Kontext D: The CO2-free power system (*Mikael Amelin, 3 projekt*)
- Kontext E: HVDC grids (*Ilka Jahn, 3 projekt*)
- Kontext F: Kraftsystemstyrning (*Lars Nordström, 3 projekt*)

Kontext inom: Elektromagnetism, fusion och rymdteknik

- Kontext G: Fusion - solens energikälla på jorden (*Thomas Jonsson, 3 projekt*)
- Kontext H: Observations in Space (*Lorenz Roth, 3 projekt*)
- Kontext I: Suborbital Free Flyer for Near-Earth Space Research (*N. Ivchenko, 5 projekt*)
- Kontext J: Design/testing of novel microwave/antenna technologies(*Quevedo-Teruel,4 proj*)
- Kontext K: Electrotechnical multiphysics simulation (*Marley Becerra, 4 projekt*)

Kontext inom: Information och nätverksteknik

- Kontext L: AIoT: Artificial Intelligence and the Internet of Things (*Carlo Fischione, 9 projekt*)
- Kontext M: Information Engineering: Big Data & AI (*Tobias Oechtering, 7 projekt*)

Kontext inom: Datavetenskap och maskininlärning

- Kontext N: Automatic bug fixing (*Martin Monperrus, 3 projekt*)
- Kontext O: Computational brain modelling & brain-like computing (*Pawel Herman,3 projekt*)
- Kontext P: Artificial Intelligence (*Mika Cohen, 3 projekt*)
- Kontext Q: Big Graphs of Software Packages (*Benoit Baudry, 3 projekt*)

Kontext inom: Embedded systems

- Kontext R: Embedded systems (*Elena Dubrova, 4 projekt*)

Viktiga datum

- **Informationsmöte om projektvalet: Torsdag, 8 okt 2020**, kl 13:15-16:00
  Mötet sker online via zoom: https://kth-se.zoom.us/j/66931733336
- **Projektval: 27-30 nov 2020** (fysik- och farkoststudenter väljer 1-15 nov 2020)
- **Kursstart: vecka 3, 2021** (uppstart-infomöte, sedan första träff med handledaren)
- **Kursslut: vecka 20, 2021** (heldag presentationsdag)

Kurs-PM

All information om kursens uppbyggnad finns i kurs-PM. En preliminär version kommer att läggas ut senast den 2 november 2020 på kurshemsidan i KTH social (www.kth.se/social/course/EF112X/)

Tillgängliga projekt 2021

Alla projekt som erbjuds vårterminen 2021 finns beskrivna i denna pdf-fil. Läs igenom projektbeskrivningarna noggrant. I valet markerar ni vilka projekt ni helst vill göra. Obs, inom ramen av denna kurs kan man inte "skräddarsy" sitt eget projekt tillsammans med en handledare. Du måste välja ett av de tillgängliga projekten som finns beskrivna i denna katalog.

Val av projekt

När sker valet?

Valet av kandidatexjobbet görs under perioden 27-30 november 2020. Undantaget är fysik- och farkoststudenter som väljer 1-15 november, 2020. Resultatet påverkas ej av när du väljer under valperioden.

Projektgruppen

Kandidatexjobbsprojektet utförs i grupper om två studenter. Om du inte lyckas hitta en projektpartner, tilldelas du en partner med liknande projektönskemål som du.

Gör ditt val

Anmälan görs på på kurshemsidan i KTH social (www.kth.se/social/course/EF112X/). Välj de sju mest intressanta projekten ur denna projektvalskatalog. Du kommer kunna ange din prioriteringsordning när du väljer (prio 1= det projektet du helst vill ha).

Om du redan har hittat en projektpartner, fyll i bådas namn, e-mail och program i samma anmälan. Gör endast **en** anmälan per grupp. Om du inte har en projektpartner än, anmäl dig ensam (du kommer sedan tilldelas en projektpartnern).

Tilldelning av projekt

Studievägledaren gör en behörighetskontroll (minst 104 poäng i början av period 2), därefter fördelas projekten. Valresultatet kommer att anslås på kursens hemsida i Canvas innan jul.

Lycka till!

Anita Kullen (kullen@kth.se)
Kursledare för EF112X kandidatexamen inom elektroteknik, EECS, KTH

Context A
Automated car following and platooning

Context coordinator: Jonas Mårtensson, Division of Decision and Control Systems, jonas1@kth.se

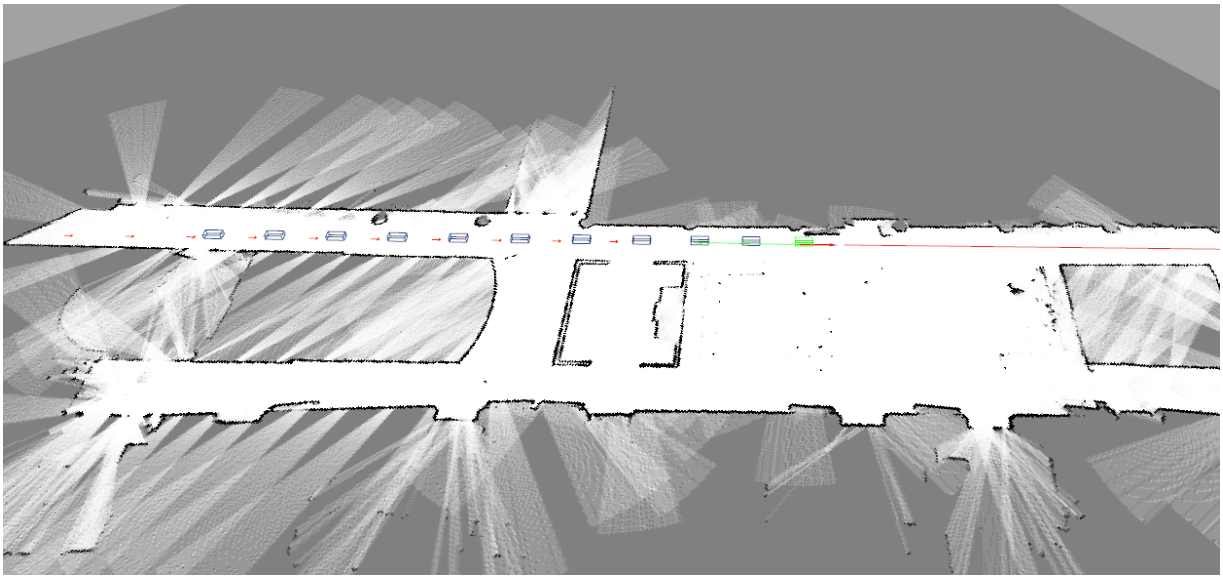
The vision of our future transportation system is that we are able to radically improve the accessibility, efficiency and safety by developing new vehicles, functions and services that take advantage of the rapid advances in sensor, information, and communication technologies. In particular we foresee huge benefits from increased use of real-time management, planning, control and AI.

In this context we will study various aspects of automated car following and platooning. Adaptive cruise control is already standard in all heavy vehicles and in upper segments of passenger cars. However, more sophisticated use cases such as cooperative systems, truck platooning and fully automated highway driving is still under active development with many remaining research challenges. The hope is that safety, transport efficiency, fuel economy and traffic congestion can be greatly improved by intelligent collaborative automated vehicle systems.

Here we will study several interesting problems, dealing with diverse but still related topics: vehicle motion control that compensate for tire slip, vision-based sensing for car-following control, vehicle interactions at highway ramps, traffic congestion control by automated vehicles, and optimal platoon formation algorithms.

Project A1: Vision-based platooning

Supervisior: Frank Jiang, Decision and Control Systems, frankji@kth.se



One of the most important next steps for automated transportation is platooning. Platooning is when a group of vehicles drive closely together in a line. In many cases, engineers assume that platooning vehicles will broadcast their position data to other vehicles in their platoon, so each vehicle can drive at the correct speed and maintain the correct distance from their neighbor vehicles. However, in modern designs of automated vehicles, the vehicles often have cameras on-board that can perform many real-time tasks. In this project, students will investigate the use of cameras for platooning. Specifically, in this project, students will:

1. Modify and develop a platooning controller to include distances generated from ArUco markers and off-the-shelf robotics software
2. Design a protocol for when the vehicles use the camera or when the vehicles communicate with each other
3. Implement this design on a fleet of small RC vehicles and show them platooning using vision.

Project A2: Platooning at highway ramps: splitting and merging

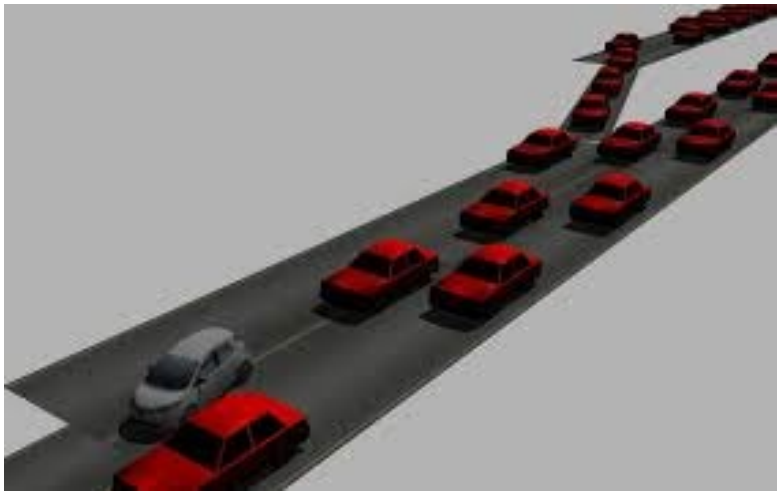
Supervisor: Xiao Chen, Decision and Control Systems, xiao2@kth.se

One of the most important next steps for automated transportation is platooning. Platooning is when a group of vehicles drive closely together in a line. Many of the benefits of platooning, such as decreased cognitive and workload for drivers, reduced fuel consumption, and improved safety are well-studied by researchers. However, there are some new problems to solve in order to make platooning a reality. In this project, students will solve one of these problems: if a platoon blocks a highway entrance or exit, how does the platoon help a vehicle that needs to get on or off? Specifically, in this project, students will:

1. Design a conceptual platoon splitting protocol, to safely allow vehicles enter and exit highways
2. Develop the path-planning and control algorithms for performing platoon splitting
3. Modify an existing, working platooning experimental platform with small RC cars to use the developed platoon splitting protocol

Project A3: Controlling traffic with moving bottlenecks

Supervisor: Matthieu Barreau, Division of Decision and Control Systems, barreau@kth.se



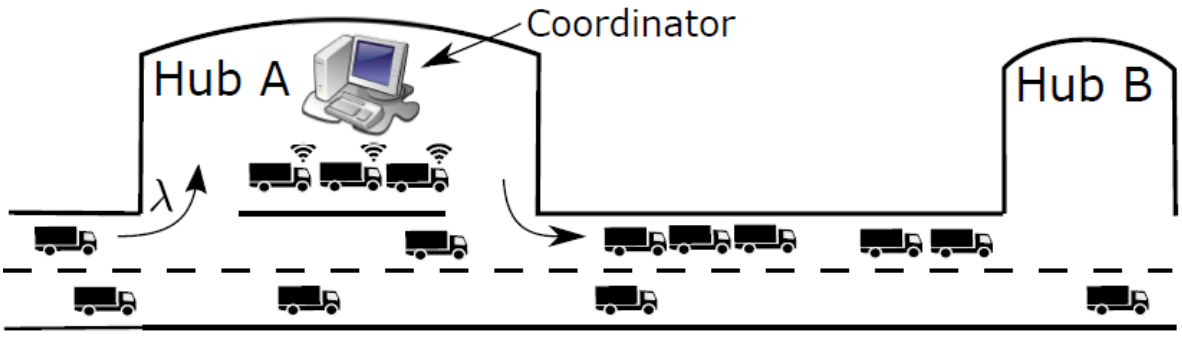
Who has never experienced traffic congestion? This is annoying since it wastes time, energy and it decreases the safety of all users. During the last decade, researchers derived some control solutions to this problem. Most of them rely on traffic lights at the in-ramp or variable speed limits. We have taken a different reasoning and we focus on using autonomous vehicles to tackle this issue. Indeed, by controlling the speed of some sparse vehicles, since the other cars will adapt their speed to the controlled ones, the jam dissipates and even, sometimes, just does not appear. This is a modern point of view and a very recent area of research so not much work has been conducted in this direction. Moreover, most of the results today only focus on a macroscopic model (made up of partial differential equations) and this is not a concrete approach. The main idea behind this project is to convert the control law obtained with the macroscopic model to an equivalent one in the microscopic domain (using ordinary differential equations). Thus, it is possible to use SUMO, a high-fidelity microsimulator, to observe the effectiveness of the control schemes.

The project can be split into 4 parts:

- Interface Python with the simulator;
- Derive the microscopic control law and assess its effectiveness;
- Derive an observer to rely only on autonomous vehicles measurements;
- Enhance the observer-based control law by using some cool and advanced control strategies such as event-triggered observations and decentralized control.

Project A4: Hub-based platoon coordination

Supervisor: Alexander Johansson, Decision and Control Systems, alexjoha@kth.se



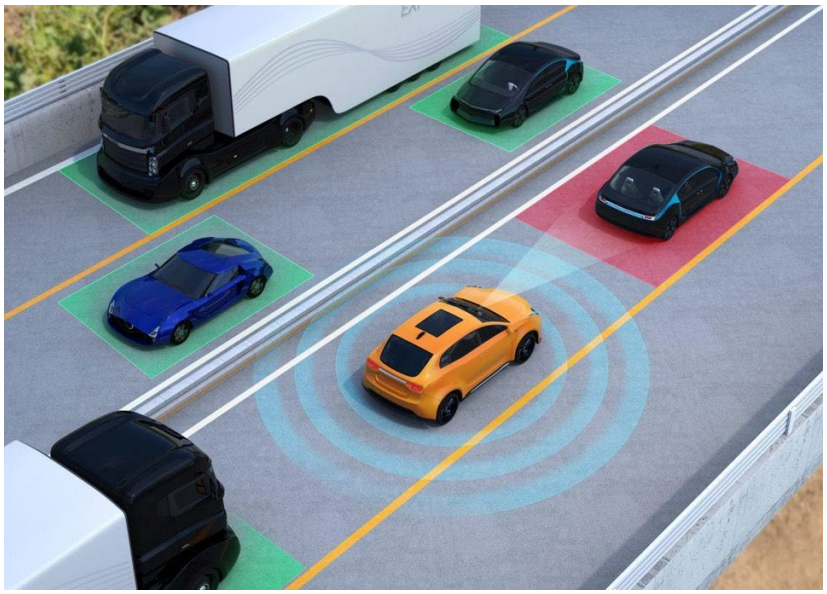
A platoon is a group of vehicles that drive on the road with small inter-vehicular distances and the follower vehicles are automated. Platooning is an emerging technology with many environmental and economic benefits, for example, reduced fuel consumption, reduced workload of the drivers, increased road capacity, and safer driving. In order to boost the benefits from platooning on a system level, it is important to group vehicles that will form platoons in an optimal way. In this project, we will consider the platoon coordination problem at a transport hub to which vehicles arrive according to a statistical arrival process, and a coordinator decides, at each time step, whether to release the vehicles at the hub in form of a platoon or wait for more vehicles to arrive.

The student of this project will have the following tasks:

- Formulate the optimal platoon release time problem as an optimal stopping time problem.
- Develop and study algorithms for the platoon release time problem.
- Collect transport data and use it to approximate the statistical arrival process.
- Test the algorithms in a case study with real transport data.

Project A5: Adaptive Cruise Control with Tire Slip Awareness

Supervisor: Jonas Mårtensson (KTH, Decision and Control Systems) jonas1@kth.se



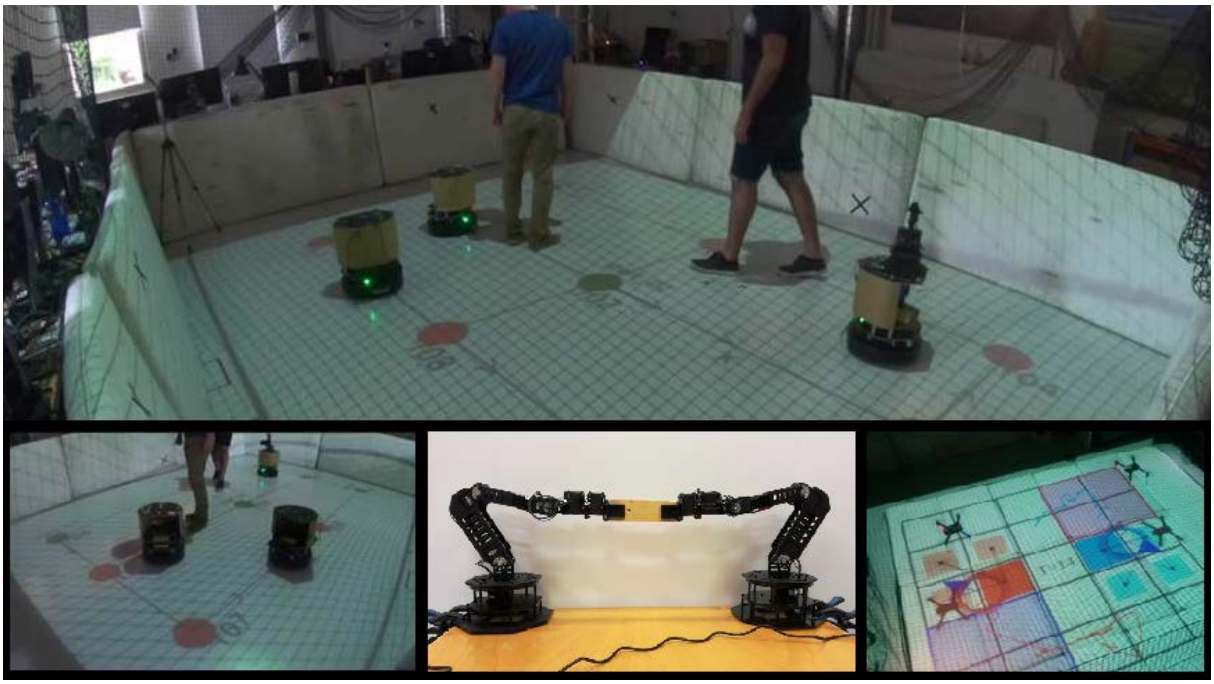
Adaptive cruise control (ACC) systems play a key role for safety of platooning scenarios. However, a vehicle's tire slip condition, which significantly affects not only safe braking distance, but also vehicle maneuverability, is overlooked in the existing ACC or cooperative-ACC (CACC) solutions. This results in that the ACC may request control actuation that is not attainable based on the local slip condition and wheel states, and to discrepancies between the networked control inputs and the local slip control systems. However, the tire slip can be estimated locally in the vehicle and including that in the whole control system design will improve safety by being proactive in brake and acceleration scenarios. This project aims to augment ACC systems by including slip information into the vehicular network control system.

This project aims to develop an augmented adaptive cruise control system by considering vehicle slip information, which is communicated through V2V communication. You will first model the vehicle's longitudinal dynamics and form a second-order consensus process for a connected vehicular system by considering relative speed and inter-vehicular distance. Then, you will include the information about the slip and/or wheel dynamics communicated through V2V and you will investigate how this augmentation affects the platooning performance. Further challenges that need to be addressed are uncertainties in tire slip estimation, limited transfer rate, latency and loss of data in V2V communications.

This project is co-supervised by Prof. Ehsan Hashemi who works at University of Waterloo in Canada.

Context B
Autonomous robotic systems

Context Responsible: Dimos Dimarogonas (dimos@kth.se)



Autonomous artefacts, such as self-driving cars, unmanned aerial and marine vehicles, and smart robots, are rapidly entering mainstream focus from scientific, societal, technological and industrial perspectives. Additionally, large-scale systems and systems of system, e.g., infrastructure systems, are increasingly automated and self-organizing, with the possibility to make intelligent decisions on the basis of continuous, heterogeneous, multi-source data.

Autonomous systems must be capable of planning and executing complex functions as intended, with limited human intervention, operating in uncertain and unstructured physical and/or information environments, and managing unexpected external or internal events, e.g., faults. This distinguishes them from mere automated systems, which also are able to execute complex functions, but which mostly assume structured environments, have limited capacity to learn and adapt to unexpected events.

In the most tangible instantiations of autonomy, such as robotics and automated driving, the main focus for autonomy is to replace or complement the human's capacity to manage complexity, namely, to analyze and make decisions based on vast amounts of, possibly uncertain, data and information in varying forms, under real-time constraints. Autonomous systems will also need to cooperate with humans and each other to solve complex tasks, and thus we see collaboration and interaction as another major trend in the science of autonomous systems.

There are now numerous industrial examples showing the tremendous potential and positive impact of technologies arising from the use of autonomous systems and their integration in informational environments. Most of these technologies are still in their infancy but are believed to have potentially huge impact in the near future.

Project B1: Motion Planning for Aggressive Flights of an Unmanned Aerial Vehicle

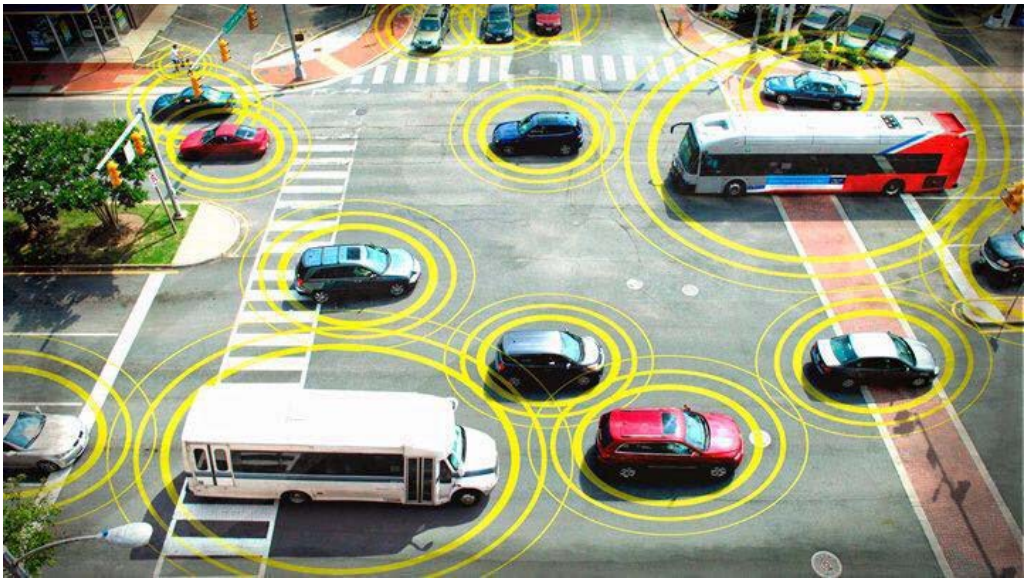
Supervisor: Xiao Tan <xiaotan@kth.se>

The use of autonomous robots for real life missions is increasing and becoming essential in many everyday situations. Robots allow performing search and rescue missions, surveillance and security monitoring of buildings and cities. Especially, the use of small Unmanned Air Vehicles (UAVs) is becoming popular due to their highly flexibility to fly in the obstacle-cluttered environments. While the spherical/ single point model of the UAVs is widely used in the motion planning community, it may ignore trajectories whose feasibility depends on the robot shape. In this project, the aim is to develop a general framework that generates a collision-avoidance, dynamically feasible trajectory by taking the robot shape into account.

The following items should be addressed:
• Study the modelling, planning and control of a quadrotor UAV.
• Develop a motion planning algorithm to navigate UAV in an obstacle-cluttered environment.
• Test the algorithm both in simulation and real platforms.

Project B2: Cooperative Control of Autonomous Ground Vehicles

Supervisor: Fei Chen <fchen@kth.se>



Autonomous ground vehicles (AGVs) are becoming the subject of intense research. For instance, recent studies for autonomous vehicles include autonomous driving, robots search and rescue, and recon missions, among others. Autonomous vehicles will drive in partial or total autonomy by network control algorithms. For large-scale or physically distributed systems, such as a team of AGVs, wherein the control loops are closed through a communication network, one has to deal with the problem of how to design the cooperative control strategy to achieve the tasks like reference tracking, consensus or certain formation. In addition, for safety-critical reasons, the collision avoidance among the vehicles and the obstacles in the workspace cannot be ignored. Hence, there is a need to understand the fundamental knowledge of how the vehicles interact with each other.

In this project, the aim is to study how to coordinate a team of AGVs to perform group tasks under space constraints and the following aspects should be addressed:

- Perform reference tracking for the team of AGVs.
- Study formation control for the AGV team to maintain a predetermined geometric pattern.
- Collision avoidance is an essential topic for AGVs to navigate in complex environment. Therefore, propose a methodology for the AGVs to avoid collisions and obstacles while maintaining the formation.

Project B3: Multi-Robot Motion Planning under High Level Task Specifications

Supervisor: Maria Charitidou <mariacha@kth.se>

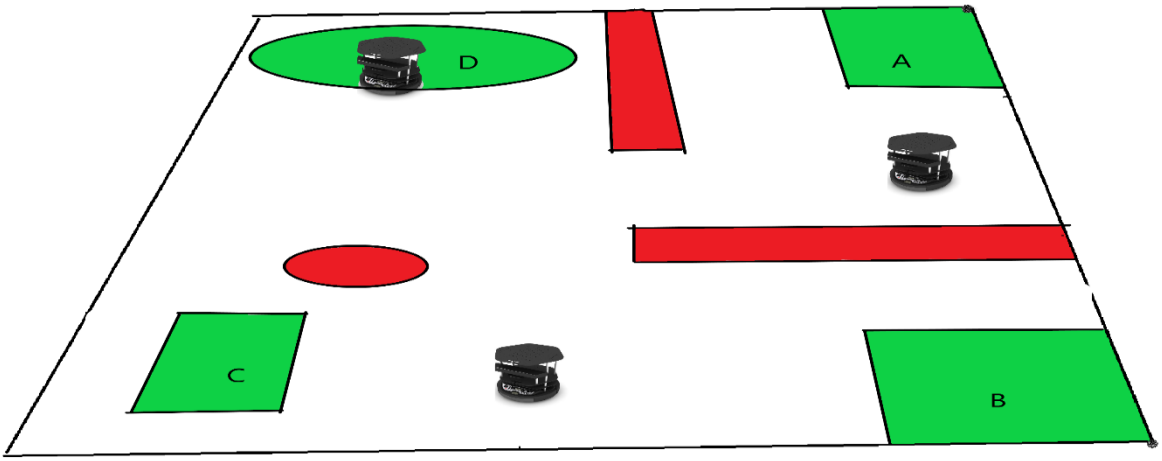


Figure 1: The robots needs to avoid the red areas, and meet up at the green areas. The order in which they visit the green areas is determined by the system to optimize the completion time.

Over the last decades, multiple robots have been used in several applications, examples of which are surveillance, package delivery or assembly. In these applications each robot in the team needs to perform a variety of complex tasks within a specific and often tight time interval. Contrary to single agent scenarios these tasks may often involve the cooperation of different robots. Examples of such tasks are: “visit area A within 10 sec”, “wait robot 2 for 5 sec in area A” and “move together to area C within 8 sec”. Even in these simple scenarios, when multiple robots are considered the behavior of one might affect the performance of the whole team. This calls for a new control framework that takes into consideration inter-agent relations.

In this project you will design a motion plan for each robot in the team such that a set of known time-constrained tasks is satisfied. This motion plan should be collision-free, i.e., each agent should avoid collisions with its peers and any known obstacle in the area. One possible way to approach this problem is by using Signal Temporal Logic (STL) to express the tasks under consideration and Control Barrier Functions (CBFs) for the control design. However, you are free to choose any other solution approach you like.

Your work should address the following:
• Define the workspace and the dynamics of the robots in addition to the desired tasks agents should perform.
• Suggest a method for designing a plan that guarantees the satisfaction of the tasks within pre-determined time intervals. The proposed control laws should be optimal with respect to some costs, e.g. minimizing energy consumption, and should ensure that agents stay within the workspace at all times.

Context C
Learning in Dynamical Systems

Powerful computers, new sensors and high efficiency communication technology have opened the door to the design of technological systems that can learn by themselves. You have probably seen for example how Google's self-taught AlphaGo defeated some years ago the world champion of Go. The advantage of self-learning systems is that they can adjust themselves according to the behavior they observe from their environments. The development towards such self-learning systems is happening on many fronts, including factories, smart buildings and autonomous vehicles among others. In most of these applications, physical systems or humans interact with a computer system, and the computer is based on a mathematical model of their environment. A complicating factor is that physical bodies and humans have dynamics, that is, their behaviors depend on what has happened before.

In this theme, the projects offered are meant to explore several aspects of the problem of learning dynamical systems. For example, how is it possible to learn from observed data the collective behavior of a large number of independent agents? what have self-learning systems actually learned from their interaction with the world around them? how can one implement efficient self-learning systems, either as single entities or as collaborative autonomous robots learning independently of each other? These questions are considered within important applications such as finance, computer gaming and autonomous robotics, using state-of-the-art machine learning tools.

Project C1: Predicting patterns in financial markets

Supervisor: Cristian R. Rojas, Decision and Control Systems, crro@kth.se

Today's financial markets are highly complex systems, involving the interaction of a very large number of types of stocks and agents buying and selling large volumes of stocks and derivatives at a high frequency (sometimes in the order of milliseconds or less). According to standard financial theory, ideal markets are arbitrage-free, which means that it is not possible to make a guaranteed risk-free profit. However, external influences (such as changes in oil prices, interest rates, government policies, …) can have a significant influence on the behavior of the observed prices, so having the ability to analyze and predict those factors can lead to potential opportunities for investments. A reasonable assumption is that these factors do not change very often, so the expected returns and the volatility (variability) of the observed prices should change only sporadically. Based on this assumption, the goal of this project is to use modern machine learning techniques for learning and predicting patterns in the price data of financial markets.

In particular, the project should address the following:

1. Make a mathematical model of the financial data.

2. Evaluate the assumptions of sporadic change of behavior of the stock prices on real observed data.

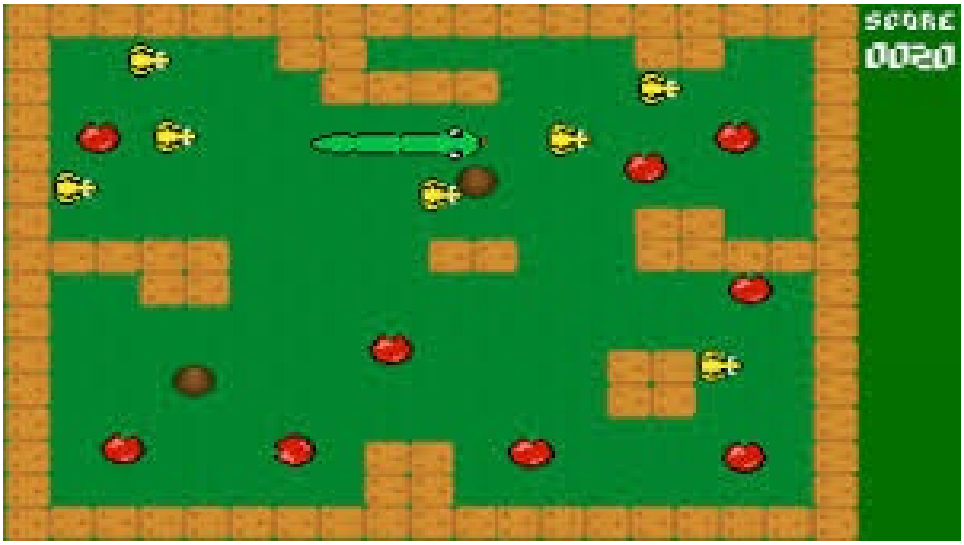
3. Propose algorithms for learning and predicting the patterns of financial data based on the stated assumptions.

4. Evaluate the computational and statistical performance of the proposed methods.

5. Reflect on the advantages and limitations on the proposed methods, and on the limitations of the assumptions imposed on the behavior of the financial market.

Project C2: Deep Reinforcement Learning for Games

Supervisor: Alexandre Proutiere, Decision and Control Systems, alepro@kth.se



Reinforcement Learning (RL) addresses the problem of controlling a dynamical system so as to maximize a notion of reward cumulated over time. At each time (or round), the agent selects an action, and as a result, the system state evolves. The agent observes the new state and collects a reward associated with the state transition, before deciding on the next action. Unlike classical control tasks where typically the system dynamics are completely predictable, RL is concerned with systems whose dynamics have to be *learnt* or with systems interacting with an uncertain environment. As time evolves, the agent gathers more data, and may improve her knowledge about the system dynamics to make better-informed decisions. RL has found numerous applications, ranging from robotics, control, online services and game playing, and has received an increasing attention. Very recently, RL has solved problems in situations approaching real-world complexity, e.g., in learning human-level control for playing video games. These progresses are mainly due to the use of deep neural networks to speed up classical learning algorithms.

This project aims at developing and implementing reinforcement algorithms to learn to play simple video games optimally. More specifically the main tasks of the project are:

1. Propose a game.

2. Create a mathematical model and a succinct representation and encoding of the game snake.

3. Propose and implement deep reinforcement algorithms.

4. Evaluate the speed at which the algorithms learn optimal moves, depending on the size of the chosen neural network.

Project C3: Distributed Optimization through Deep Reinforcement Learning

Supervisor: Alexandre Proutiere, Decision and Control Systems, alepro@kth.se

Reinforcement Learning (RL) has recently gained popularity through its use in learning to play video and board games. The program AlphaGo developed by Google Deep Mind outperformed the best professional go player and received a lot of media attention. The state-of-the-art algorithms in RL combine classical learning techniques, such as Q-learning, with deep neural networks used to get a succinct representation of the system state and of the reward function. RL algorithms are typically implemented in a single agent whose objective is to optimally interact with her environment. This project is concerned with multiple agents cooperating to learn to interact and to accomplish some tasks optimally. We will focus on a simple warehouse example where multiple robots have to learn to interact with each other (avoid collisions) while repeatedly transporting items from one point to another. These points differ for the various robots, but to perform their tasks, robots must move along common paths. Each robot is assumed to know at any time the positions and velocities of the other robots.

The main tasks of the project include:

1. Model the warehouse and encode the tasks robots have to accomplish.

2. Develop and implement in each robot a deep RL algorithm.

3. Simulate the resulting complex dynamical system.

Project C4: Inverse portfolio selection

Supervisor: Cristian R. Rojas, Decision and Control Systems, crro@kth.se

In order to provide a safe investment, mutual funds and other actively managed investment enterprises traditionally distribute their funding among a large range of assets, with different expected returns and volatility, to distribute the risk (i.e., avoid putting all eggs on the same basket). The design of this distribution, called portfolio selection, has to be performed by carefully trading off the promised rewards against the risk of losing part of the investment. There is a large literature on techniques for "optimal portfolio selection", most of which require a statistical model of the behavior of the asset prices in the market.

In this project, the goal is to reverse engineer the models used by some actively managed funds, to understand how they work, and whether they are correctly capturing the behavior of the financial market, since any model mismatch may lead to imperfections in the market, which could potentially be exploited for low-risk investment. Specifically, the project includes the following tasks:

1. Create a mathematical formulation of the inverse portfolio selection problem, by starting with a strategy such as the Markowitz model.

2. Propose a method for inverse portfolio selection, based on the previous formulation.

3. Evaluate the performance of the designed method on simulated data.

4. Apply the method to real price data.

5. Discuss and reflect on the advantages and limitations of the proposed solution.

Project C5: Robust/Adversarial Deep Reinforcement Learning

Supervisor: Alexandre Proutiere, Decision and Control Systems, alepro@kth.se

Reinforcement Learning (RL) addresses the problem of controlling a system so as to maximize a notion of reward cumulated over time. Unlike classical control tasks, RL is concerned with systems whose dynamics have to be learnt or with systems interacting with an uncertain environment. This project will focus on the problem of controlling *unknown systems* that are under *adversarial attacks*. Specifically, we will consider a two-player game, where the first player (or main agent) is the one that tries to control the system, and the second agent (or adversary) is an agent that tries to disrupt operations of the first player. In particular, this project will cover modeling of the adversary, modeling of the main agent, implementation of RL algorithms using Deep learning and simulations of two-player interaction.

The project aims at developing and implementing robust reinforcement algorithms. More specifically, the main tasks of the project include:

1. Propose a system model
2. Model the adversary's objective
3. Formulate a defense, and find the optimal strategy for both the adversary and the main agent using Deep learning
4. Simulate the resulting interaction between adversary and main agent

Context D
The CO_2-free power system

According to Intergovernmental Panel on Climate Change IPCC, at least 80% of the world's electricity consumption must be from low-carbon or carbon-free sources by 2050 to keep the world within 2°C of warming [1]. It is therefore desirable to replace electricity production based on fossil fuels with renewable electricity. Around the world, a number of policies have sought to directly and indirectly increase the penetration of wind generation, solar energy and other continuously varying generation technologies.

This context will study the fictitious power system in Land. Currently Land is supplied by hydro power, nuclear power and coal condensing, but the parliament of Land has decided that the coal condensing should be phased out and replaced by for example wind power, solar energy or biofuels. Each of the alternatives result in technical and economical challenges which needs to be solved.

- Wind power resources are usually available in remote areas, which may not have sufficient connections to the main centres. Moreover, wind power generation do not contribute to keeping the balance between production and consumption in the same way as conventional generators.

- Solar energy can be located anywhere, but the generation is only available during daytime and is significantly lower during the winter compared to the summer. As for wind power, solar energy does not contribute to keeping the balance between production and consumption.

- Biofuels can be used in conventional power plants, although investments are needed to produce the biofuel and to convert coal condensing units or gas turbines for burning other than fossil fuels.

Each project in the context will study different challenges. The overall objective of the context is to provide a recommendation about the way forward for the power system in Land considering costs and other relevant factors for different options.

[1] IPCC, 2014: Climate Change 2014: Mitigation of Climate Change, http://mitigation2014.org/report/publication/

Project D1: Voltage

Supervisors: Lennart Söder, lsod@kth.se, Electric Power and Energy Systems, Evelin Blom, evelinb@kth.se, Electric Power and Energy Systems

The voltage in a power system must be kept within specific limits. Building wind farms in remote areas with weak interconnections to the load centres of the system might cause voltage problems. Those problems can be solved by building new transmission lines or by investing in compensators that boost the voltage where needed. Thus, a less favourable wind farm placement when considering wind speeds might actually be preferable to a windier site if the latter requires additional investments in the transmission system.

The objective of this project is to investigate if voltage and current limits can be maintained for different placements of wind power and solar energy in Land. The project also includes investigating the costs of necessary reinforcements in the transmission system.

The main mathematical tool in the project will be load flow analysis, which is an application of numerical methods for solving non-linear systems of equations.

Project D2: Capacity

Supervisors: Mohammad Reza Hesamzadeh, mrhesamzadeh@ee.kth.se, Electric Power and Energy Systems

Wind power, solar energy, hydro power and nuclear power all have low variable costs, but high fixed costs. The electricity market in Land uses marginal pricing, i.e., it is the variable cost of the most expensive unit currently in use that sets the price. The CO_2 free power system in Land will thus generally have low electricity prices. It can therefore be difficult for the power plants to recover their fixed costs only from selling electric energy (MWh). One solution to this problem is to set up a capacity market, where power plants also are paid for providing the generation capacity (MW).

Moreover, the generation wind power and solar energy are continuously varying; however, power must be available when there is a demand (regardless of weather conditions). Thus, there must be sufficient reserves in the system to provide power when demand is high or wind and solar generation is low. These reserves might rarely be used and can therefore also require capacity payments in order to be profitable.

The aim of this project is to study the need for a capacity market in Land and to compare different ways to set up the capacity market.

The work will involve setting up simulation models of the capacity market, which requires skills in optimisation theory and computer programming.

Project D3: Hydro power

Supervisors: Mikael Amelin, amelin@kth.se, Electric Power and Energy Systems, Charlotta Ahlfors, ahlfo@kth.se, Electric Power and Energy Systems

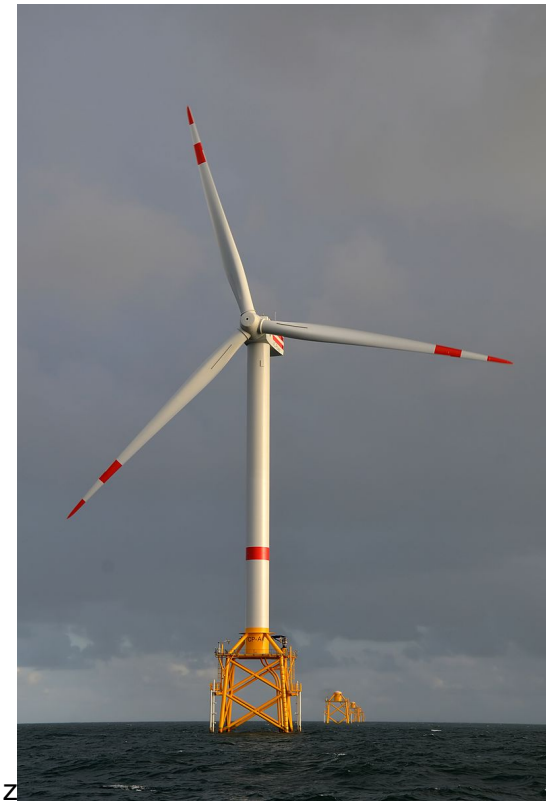
Most large hydro power plants have reservoirs which allow hydro power generation to follow the power demand rather than the water flow in the river. However, the reservoirs have limited capacity and the inflow is not evenly distributed over the year. Moreover, demand, wind power generation and solar generation are also varying over the year. Hence, careful planning is necessary to utilise the available water at the right time and to avoid spilling water or having empty reservoirs when the demand is high.

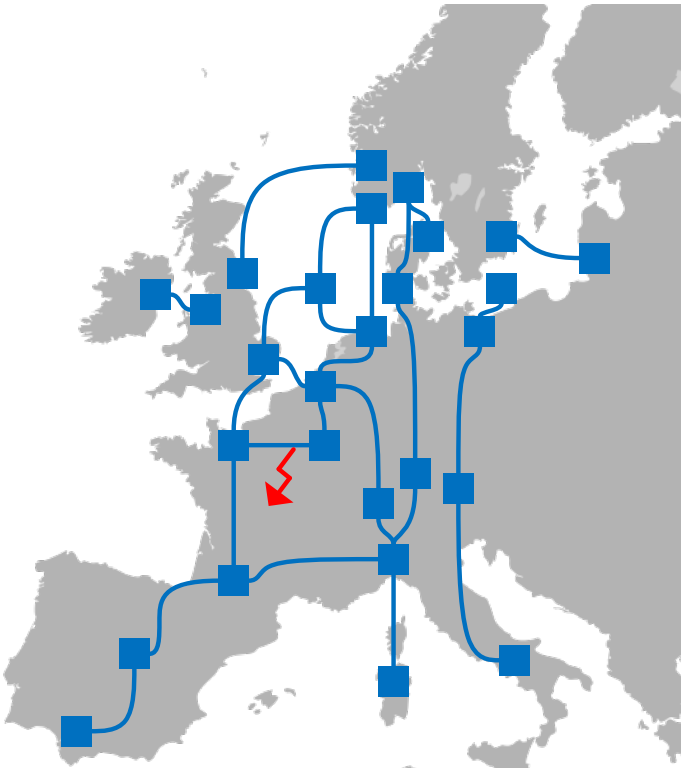
This project will study methods to plan the operation of the hydro power plants in Land, while taking into account different possible locations of new generation capacity, the limitations of the transmission system, etc.

The project is about applied optimisation theory. Computer software such as Matlab or GAMS will be used for solving the optimisation problems.

Context E

HVDC grids





Figur 1: Exempel på ett europeiskt HVDC nät för transport av vindenergi (photo: wikipedia).

Den ökade efterfrågan på förnybar energi har ställt nya krav på transmissionssystemens flexibilitet. Dessa krav tillsammans med tekniska framsteg för högspänd likström (high-voltage direct current, HVDC) har resulterat i ambitionen att bygga storskaliga multiterminala HVDC-nät.

HVDC-tekniken har etablerats som ett värdefullt komplement till det befintliga växelströmssystemet. De inneboende egenskaperna hos DC möjliggör långa kablar med låga förluster. Anledningen till att likström inte än används i stor skala, trots de lägre förlusterna, är att när kraftsystemen byggdes ut på 1800-talet var det komplicerat, nästan omöjligt, att transformera likspänning. Med dagens moderna HVDC -omvandlare är det dock möjligt att bygga HVDC-nät.

Idag är HVDC en vanlig teknik för att ansluta till exempel storskaliga vindkraftparker, eftersom HVDC kan erbjuda konstant spänning, frekvens och fasvinkel på AC-sidan. Efterfrågan på förnybar kraftproduktion i Europa har resulterat i en planerad kapacitet på över 100 GW i Nordsjön. Eftersom elgenereringen från vindkraftparker beror på vindförhållandena, utnyttjas de existerande punkt-till-punkt-HVDC-anslutningarna endast fullt ut under korta tidsperioder. Om en vindkraftpark skulle anslutas till flera växelspänningssystem med flera HVDC-länkar, kan dessa HVDC-länkar möjliggöra elhandel under perioder då vindkraftparken inte arbetar med full effekt.

Viktiga aspekter i ett HVDC-nät är nätregleringen, omvandlare och skyddsfrågor. De studenter som följer denna kontext ska teoretiskt undersöka dessa aspekter i HVDC-nät med PSCAD-simuleringar.

Projekt E1: Operation and control of HVDC converters

Supervisor: Baris Ciftci, bacif@kth.se, avdelningen för elkraftteknik

In an HVDC network, the power conversion between ac and dc grids shall be done efficient and compliant to the related regulations on power quality. In state-of-the-art power converters such as modular multilevel converter, the efficiency exceeds 99 % and they can comply with the power quality regulations on their own without external harmonic filters. The converter topology, its modulation and control play a key role in this context. This project aims at identifying the proper modulation and control methods for various power converter topologies in an HVDC network in terms of efficiency and power quality. Computer simulations of converters are to be conducted with regard to modulation and control, and the results should be evaluated for performance comparisons.

The work contain

1. Literature study around HVDC converters and their control.
2. Design of requirements specification. Applicable norms and standards.
3. Choice of conversion topology and dimensioning.
4. Simulation work for modulation and control of converters.
5. Evaluation of results and report.

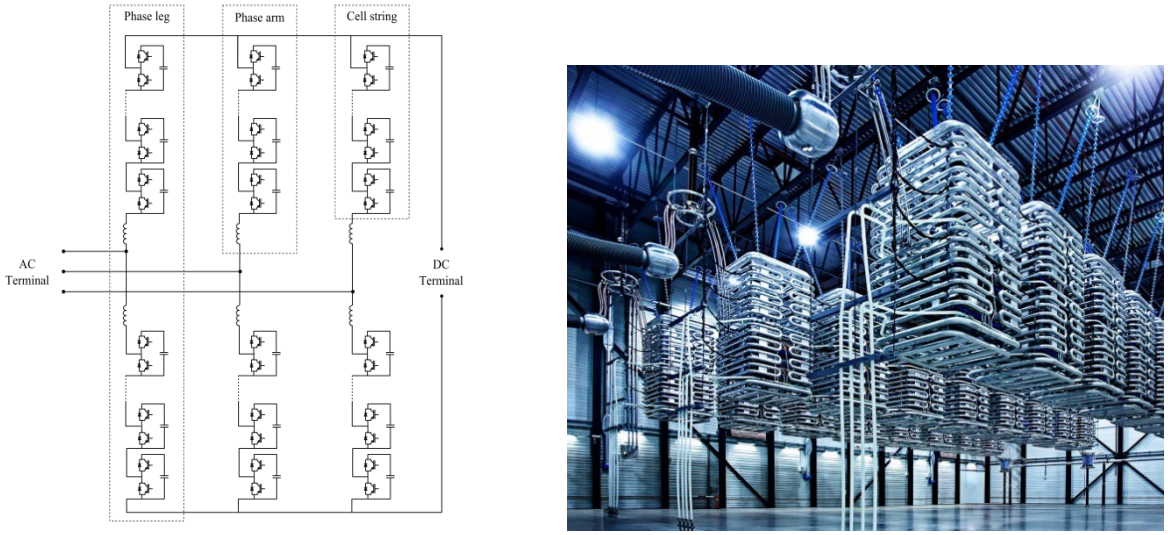


Figure: MMC-based HVDC converter. Left: circuit schematic. Right: photo of an actual converter

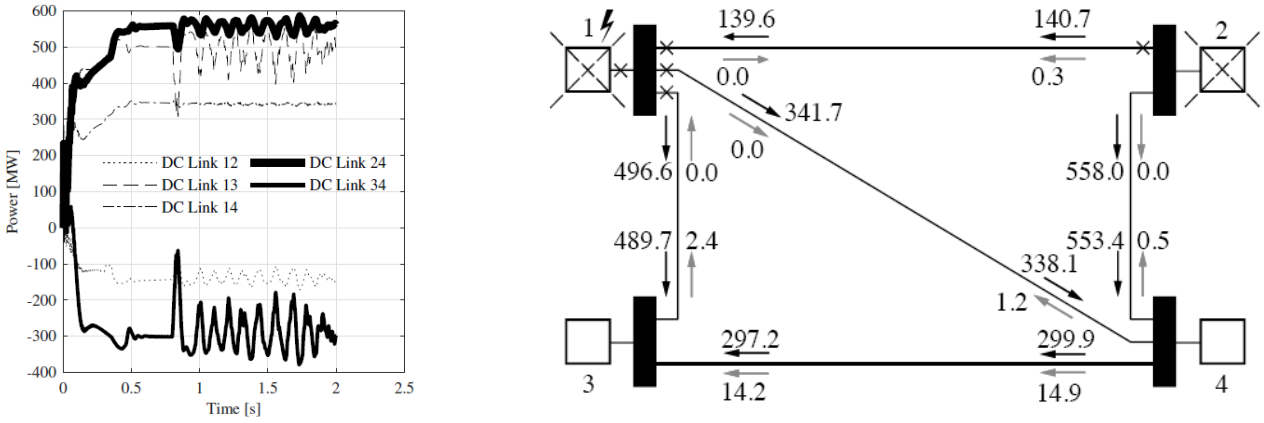
Projekt E2: Protection of HVDC grids against blackouts (simulation)

Supervisor: Ilka Jahn, ilka@kth.se, avdelningen för elkraftteknik

Faults can always occur in electricity grids and a protection system needs to take care of protecting the grid and minimizing disturbances. Without protection system a fault in future European HVDC grid can result in a European blackout.

This project aims at studying the behavior of a simulated HVDC grid subjected to faults. Such a fault could in reality originate from a ship throwing its anchor on a subsea cable. A fault will result in a short circuit with high currents and a voltage collapse. The converters have to be protected against high currents in order not to damage the equipment. For this, the fault needs to be detected which is done by an algorithm which examines the voltage collapse and current rise. Depending on the location and properties of the fault, the voltage collapse and current rise differ, but still a fault needs to be detected by the algorithm. In this project, the students will learn about different algorithms to detect grid short circuits, and test, compare and analyse different algorithms in a simulation setup. In general, a basic understanding of how a future HVDC grid can be protected against blackouts should be developed.

Additionally, hands-on experience with PSCAD simulation software will be gained. PSCAD is a software widely used in power system industry.



Figur 2: Simulation results from last year's student work.

Arbetsgång

1. Literature study of HVDC grid protection and fault detection algorithms
2. Familiarization with the simulation setup
3. Simulation study of different fault detection algorithms
4. Comparison and evaluation of results
5. Report

KEX-jobbet utförs på Engelska eller Svenska.

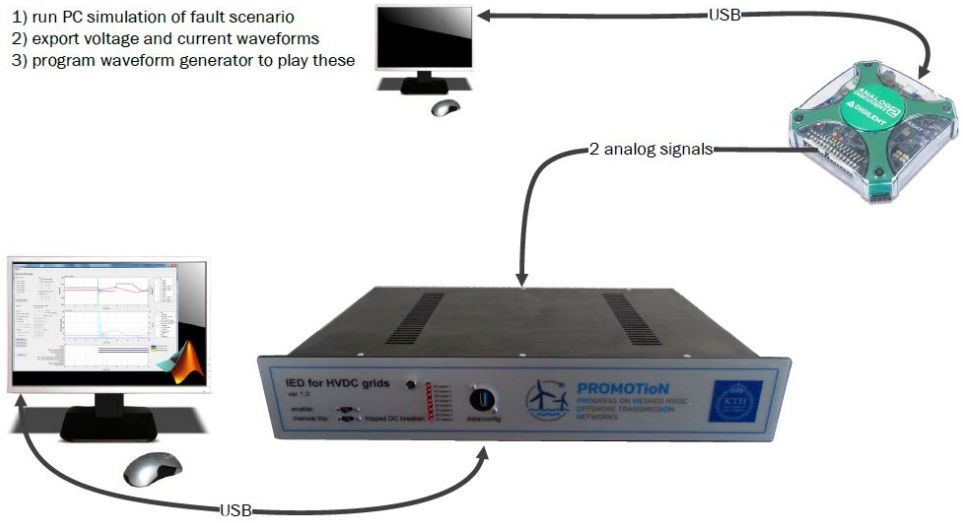
Projekt E3: Protection of HVDC grids against blackouts (laboratory work)

Supervisor: Ilka Jahn, ilka@kth.se, avdelningen för elkraftteknik

Faults can always occur in electricity grids and a protection system needs to take care of protecting the grid and minimizing disturbances. Without protection system a fault in future European HVDC grid can result in a European blackout.

This project aims at studying the behavior of a prototype intelligent electronic device (IED) that is used for correct fault detection in an HVDC grid. The students will learn about different algorithms to detect grid short circuits, and test, compare and analyse different algorithms in a laboratory setup. In general, a basic understanding of how a future HVDC grid can be protected against blackouts should be developed.

Additionally, hands-on experience with laboratory setups will be gained. The prototype to be investigated has previously been used in an international industrial research project[1]. Depending on the students' background, the project can be adapted to include development of new advanced algorithms in C-language or VHDL.



Figur 3: Schematic of the laboratory setup to be used.

Arbetsgång

1. Literature study of HVDC grid protection and fault detection algorithms
2. Familiarization with the lab setup
3. Test of different fault detection algorithms
4. Comparison and evaluation of results
5. Report

KEX-jobbet utförs på Engelska eller Svenska.

[1] https://www.hvdccentre.com/demonstration-of-dc-grid-protection-promotion-wp9-13-may-2020/

Kontext F

Kraftsystemstyrning

Framtidens kraftsystem ställer helt nya krav på mätning, automation och styrning

På svenska

Som ett svar på utmaningen med klimatförändringarna elektrifieras allt fler delar av samhället, och elproduktionen ställs om till att inkludera stora mängder förnybar och delvis distribuerad kraftproduktion. Dessa nya kraftkällor t.ex. vind och solkraft ersätter de större centrala produktionsenheter som tidigare utgjort ryggraden i systemet. Detta ställer nya krav på elkraftsystemet dels eftersom vindkraft och solkraft inte är i lika hög grad styrbart och därför kan påverka systemets stabilitet på nytt sätt. Dessutom är de förnybara kraftkällorna inte lokaliserade i närheten av stora last-centra, exvis. städer, vilket gör att kraven på överföring av elenergi förändras. De senaste åren har dessa frågor blivit alltmer aktualiserat i samhällsdebatten
De nya kraven finns både på transmissions och distributionsnivå. Det inkluderar nya gränser för stabilitet i systemet på grund av minskad roterande massa i generatorer och ökade variationer gällande spänning, effektflöden och frekvens. Dessa nya krav möts effektivast med nya kontroll och automationssystem och även nya styrbara kraftsystemkomponenter, vilka blir allt viktigare för ett välfungerande elkraftsystem. För att dessa kontrollsystem ska fungera krävs mer omfattande mätning och insamling mätvärden från större delar av systemet.

Detta kontext behandlar nya metoder och tekniker för styrning av elkraftsystem med stora mängder förnybar kraftproduktion. Projekten i kontexten inkluderar både traditionella elkrafttekniska frågor såväl som utmaningar inom automation och reglerteknik samt de informations och kommunikationssystem som är nödvändiga för denna automation.

In English

For several reasons, the power system is currently developing to include large amounts of renewable and distributed generation that in part replaces the large central production units that previously formed the backbone of the system. These new distributed power sources, place new demands on the power system partly because they are not equally controllable - but also because they are not always located in the vicinity of large loads.

These changes place new demands on the power system, both at transmission and distribution level. These new demands include new limits on the stability of the system due to reduced rotating mass of generators and increased variations of voltage, power flow and frequency. These new requirements are in turn met most efficiently with new control and automation systems and new controllable power system components, which are becoming increasingly important for an efficient power systems.

This context deals with new methods and techniques for the control of power systems with large amounts of renewable power generation. The projects in the context includes both the traditional electric power issues as well as challenges in automation and control technology and information and communication systems necessary for this automation.

Project F1: Inertia

Supervisors: Mehrdad Ghandhari, mehrdad@kth.se, Electric Power and Energy Systems,
Danilo Obradovic, daniloo@kth.se, Electric Power and Energy Systems

The electrical power injected to a power system must always match the electrical load. Whenever the load is increasing (or if the generation in varying renewable power sources such as wind power is decreasing) the electric power increase is taken from the kinetic energy stored in the synchronous machines of the system. Similarly, if the load is decreasing (or varying renewable generation is increasing) the surplus power will be stored as kinetic energy in the synchronous machines. The ability of the synchronous machines to store or discharge kinetic energy without large changes in rotational speed is referred to as the *inertia* of the system. If the inertia is insufficient, a large frequency deviation may occur due to a disturbance. Too large reductions of the frequency can trigger protection system which may result in system separation, loss of load and costumer outages, since a lot of equipment in a power system, for example power supply systems, do not tolerate too low frequencies.

This project will examine the inertia of the power system in Land and compare the results for different options including using different technical solutions to create artificial inertia if wind power or solar energy is used to replace coal condensing. The costs of the different technical solutions should also be investigated.

The study is mostly about applied control theory and the work will mainly be performed using Matlab/Simulink.

The objective of the project is organized in following tasks:

1. Provide theoretical background of primary frequency control problem of Frequency Containment Reserves for Disturbances (FCR-D)

    a. Understanding the use of governor control in generators units
    b. Understanding the purpose and importance of hydro, nuclear and wind generation in FCR-D
    c. The most important properties of frequency response: IFD, ROCOF, SSFD

2. Run simulations for given Simulink model related to FCR-D. Present and explain the frequency behavior and importance of inertia.

3. Provide theoretical background and understanding of possibilities and limitations of involving batteries into FCR-D based on the given literature

4. Include the battery model into FCR-D in Simulink. Based on defined goals for frequency improvement provide an appropriate battery parameters and conclusions from performed simulations.

The students will be provided with appropriate literature and Simulink model.

Project F2: Damping of Power System Oscillations

Supervisors: Mehrdad Ghandhari, mehrdad@kth.se, Electric Power and Energy Systems, Angel Clark, angcla@kth.se, Electric Power and Energy Systems

The small signal stability of a power system refers to the behavior and ability of a power system to remain stable when subject to small disturbances such as minimal deviations in load or generation. Small signal stability analysis is important because it can yield valuable insight into whether or not the system is inherently stable or unstable. When subject to small disturbances that move the operating point of the system to a small degree, *power system oscillations* can arise at varying frequencies. If the system is stable, these oscillations will be damped out over some time period. However, if the system is small signal unstable these oscillations can be sustained or even increase over time eventually leading to instability. These characteristics of the system can be identified and improved through small signal stability analysis. By linearizing the system around its initial operating point, the potential unstable modes of the system can be identified. Synchronous generators contain excitations systems that help maintain their voltage. However, the exciter of an excitation system can often introduce instability and lead to poor damping of power system oscillations. Therefore, a supplementary form of excitation control is utilized to damp out the oscillations of the unstable mode.

This project will analyze a two generator system in Matlab/Simulink. The system will be linearized to find the corresponding system matrices and eigenvalues to identify the unstable mode. After these results are verified, a supplementary excitation control will be tuned based on the previous results. Additionally, the differences between system matrices for the continuous and discrete domain (solver) in Simulink and their corresponding systems will be investigated.

This study will involve control theory and its application to power system stability and the work will be performed in Matlab/Simulink.

Project F3: Design of a future residential microgrid

Supervisors: Qianwen Xu, qianwenx@kth.se, Electric Power and Energy Systems

Driven by environmental concern and sustainable requirement, development of residential microgrids attracts much attention around the world, as a forward step towards future carbon-neutral society. A residential microgrid is a small power system for a house/building, which consists of a solar photovoltaic (PV) source, a battery storage and residential loads, and can operate either in isolation or in connection to the main grid. In the daylight, the solar PV source can generate electricity to supply the loads, and the extra electricity can be stored in the battery to be used in the evening, or even sold back to the main grid. Thus a residential microgrid can reduce the energy cost and reduce CO2 emission. To make it works, each component of the microgrid should be properly designed and they should be controlled in a coordinated manner to provide stable and sustainable electricity

This project will develop a residential microgrid and its control scheme to achieve stable and sustainable electricity supply. The PV converter system will be designed to maximize its power generation in the daylight; the battery converter system will be designed to be charged when there is surplus electricity, and discharged when there is insufficient electricity. A coordinated control scheme will be developed for the whole system with high reliability and stability. The microgrid system will be developed in Matlab/Simulink as a demonstration of this project.

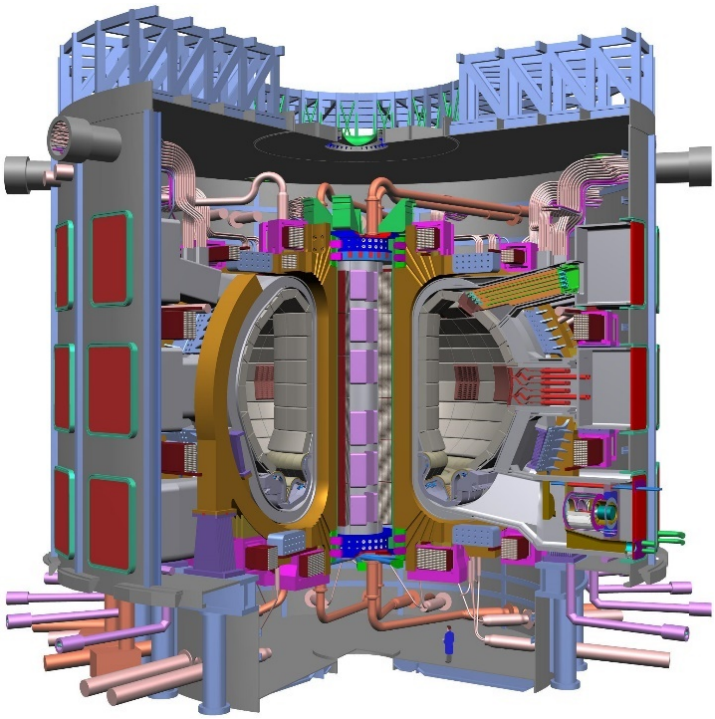
The students will be provided with appropriate literature and some basic Matlab/Simulink models as a start.

Kontext G

Fusion solens energikälla på jorden

Introduktion

Fusionsforskningen arbetar för att kunna konstruera ett kraftverk som genererar energi från kärnreaktioner mellan olika väteisotoper. Dessa fusionsreaktioner avger ungefär en miljon gånger mer energi än kemiska reaktioner och är den process som värmer solen. Om fusionskraften kan bemästras på jorden har vi en i princip i outtömlig energikälla utan växthuseffekter och med relativt lite radioaktiva restprodukter. Dessa reaktioner sker dagligen i fusionsexperiment världen över, men man har aldrig lyckats producera mer än 65% av den inmatade effekten. För att producera netto energi krävs större experiment och just nu byggs en experimentanläggning, ITER, i södra Frankrike som väntas producera tio gånger mer energi än vad man stoppar in. ITER är det andra mest påkostade vetenskapliga projektet i mänsklighetens historia efter The International Space Station. Men om fusion fungerar, som många forskare tror, kan det ha stor betydelse för vår framtida energiförsörjning.



Den 73m höga fusionsreaktorn ITER som nu byggs i södra Frankrike och som ska stå klar 2020. ITER väntas kunna producera 10 gånger mer energi än den förbrukar.

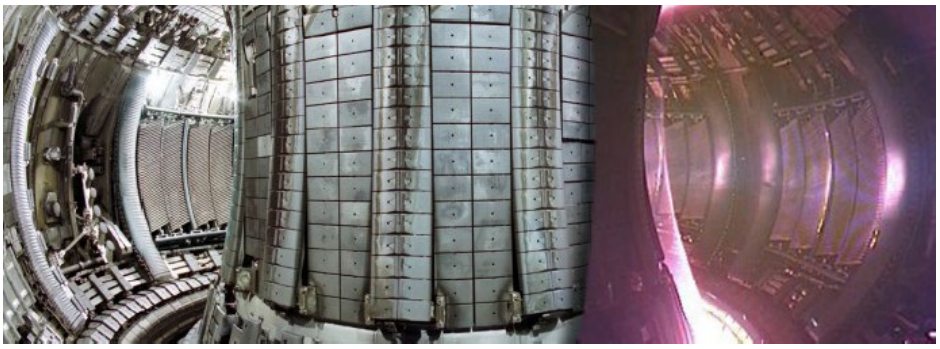
Varför behövs så stora experiment? För att fusionsreaktionen ska komma igång måste man uppnå en temperatur på över 200 miljoner grader, samtidigt som man behöver en tillräckligt hög täthet (~10^{20} m^{-3}), vilket är svårt att åstadkomma i mindre maskiner. Så hur kan man bygga en reaktor som innesluter en 200 miljoner grader varm gas (eller plasma som gasen kallas vid dessa temperaturer)? Det finns inga material som klarar att värmas till över 3 000 grader utan att smälta, så i en fusionsreaktor måste det varma plasmat hållas borta från väggarna. Detta sker med hjälp av magnetfält. Men även med starka magnetfält "läcker" värmen ut, och väggarna i en fusionsreaktor utsätts för stora påfrestningar. Dessutom måste plasmat ständigt värmas upp för att kompensera för värmeförluster till väggen. Denna uppvärmning kommer dels från fusionsreaktionerna, dels från injektion av radiovågor och av högenergetiska partiklar, samt resistiv uppvärmning.

Projekten i den här kontexten ingår både experimentella och teoretiska projekt. Här får man möta forskning vid frontlinjen och man får en inblick i möjligheterna och utmaningarna kring fusionskraften. Dessutom ska vi besöka fusionsexperimentet Extrap-T2R på KTH, samt diskutera etiska och politiska frågor kring vår framtida elförsörjning.

Projekt G1: Data processing in accelerator-based analysis of wall materials from controlled fusion devices

Supervisor: Per Petersson, per.petersson@ee.kth.se, FPP, Laura Dittrich, lauradi@kth.se, FPP

Under conditions that apply on Earth (gravity, air pressure etc.), hot fusion plasmas must be surrounded by the walls of a vacuum vessel and confined by strong external forces, as it is realized in tokamaks (e.g. JET), stellarators (e.g. W7-X) and reversed field pinches (e.g. Extrap-T2R device at KTH). The heat necessary for fusion reactions poses very severe requirements on the selection of plasma-facing materials for a thermonuclear fusion reactor. In future reactor devices, such as International Thermonuclear Experimental Reactor (ITER), the interaction of the plasma with surrounding materials in the vacuum vessel constitutes one of the main remaining engineering problems.



JET tokamak in Culham, England - with and without plasma.

The main goal of this project is to understand the applied ion beam analysis techniques on materials from controlled fusion devices and their limitation with regard to roughness. The entire analysis process can be enhanced by combining measurements focused on rough surfaces with numerical simulations and by the optimization the software for data processing. The concentration of hydrogen isotopes (the main constituent of the plasma) will be investigated by ion beam analysis techniques. The results can then be compared with previously measured data by similar and other methods.

The work will be of interdisciplinary character with elements of material science, data processing, numerical simulations, atomic physics and plasma physics. Depending on the interests and selection of samples the project may be developed in several directions.

Introductory Part

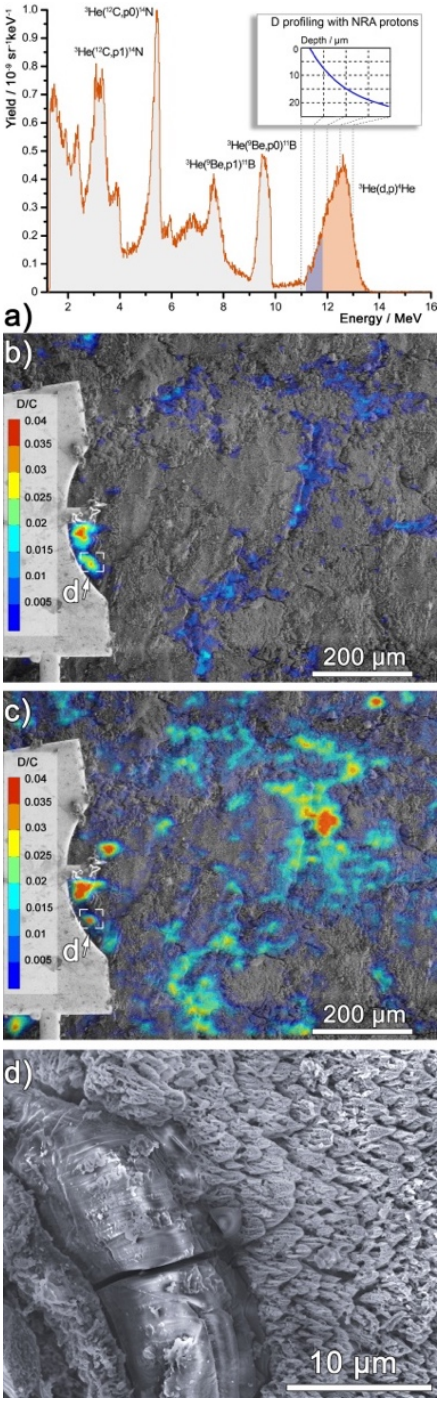
1. Introduction to fusion devices and plasma wall interaction; visit to the Extrap-T2R device.
2. Visit to the Tandem Accelerator Laboratory of Uppsala University and introduction to accelerator-based material analysis techniques.

Main Tasks

1. Selection of materials for studies
2. Surface studies of the plasma-exposed components at the Tandem Laboratory.
3. Computer analysis of experimental data.
4. Enhancement of analysis process with possible integration of simulated data.
5. Report and presentation

Projekt G2: Tool for numerical handling of 3D surface analysis data for fusion applications

Supervisor: Henric Bergsåker, henricb@kth.se



The ITER tokamak will have beryllium wall in most of the vessel but tungsten tiles in the so called divertor. An important plasma-surface interaction issue is how much hydrogen fuel (tritium and deuterium) will get trapped at the surfaces. Another issue is how beryllium mixes at a microscopic scale with tungsten and with carbon and other impurities. To study this, a nuclear reaction analysis method is used, where a finely focused beam of $^3He^{++}$ ions is scanned over the surface and the energy spectrum of the protons emitted from the $^3He(d,p)^4He$ nuclear reaction as well as from Be, C etc. provides depth information. The figures show an example of a proton spectrum and maps of superficial and more deeply buried deuterium at surface. The information on concentration profiles can be derived from the proton spectra through the known energy dependencies of the reaction probability and the rate of slowing down of the ^3He ions. The accessible depth and sensitivity depend on the initial ion energy. Find a way to combine the information from spectra with different ion energy, develop attractive ways of presentation and analyze the statistical problems involved.

The task is to produce software tools, preferably in MATLAB, which extract the 3D information from the raw data and allow to make illustrative graphs and presentations.

- Familiarize yourself with the physics of the method.
- Learn how to extract the 3D information from the data files.
- Consider the statistical uncertainties appropriately.
- Find a way to combine data from different spectra.
- Find attractive ways to present the results.
- Make some example calculations and illustrations for examples of existing datasets and produce a report on the methods used, which also makes it easy for another user to apply the software.

Emphasis can be focused on specific parts of the task, depending on interests.

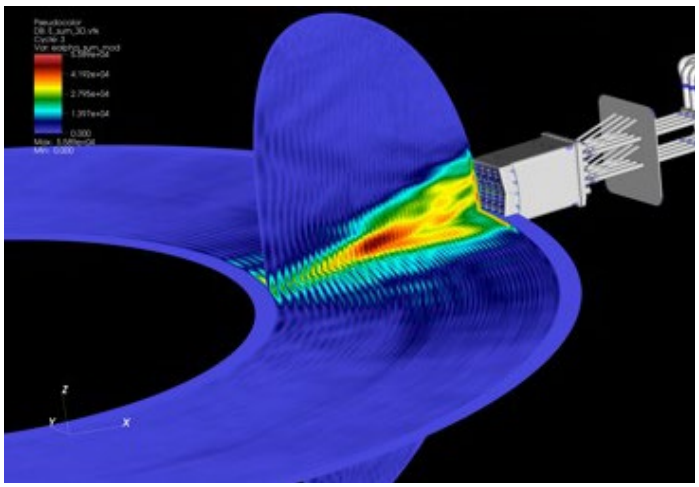
Figure 1: *a) Proton spectrum from a scanned area on carbonfibre surface from JET, with deuterium and beryllium present, both at the surface and in depth. b) Lateral distribution of deuterium near the surface (based on the low energy part of the energy distribution of protons originating from deuterium).The distribution is shown superimposed on a scanning electron (SEM) image of the surface. c) Lateral distribution of more deeply buried deuterium (based on the highest energy part of the proton spectrum).d) Detail from image c, showing a half buried particle, which has a high deuterium content*

Projekt G3: Modellering av radiovågsuppvärmning i tokamaken JET

Supervisor: Thomas Jonsson, johnso@kth.se, FPP
Björn Ljungberg, bjoljung@kth.se, FPP

Fusionsreaktioner kräver mycket höga temperaturer. För att producera stora mängder energi i ett fusionskraftverk krävs temperaturer kring 200 miljoner grader, temperaturer som kan skapas med hjälp av radiovågsuppvärmning. I detta projekt kommer vi att studera uppvärmning på världens största fusionsanläggning, JET, i England. I vår studie kommer vi utföra simuleringar med koden FEMIC (baserad på COMSOL och MATLAB). Projektet är nära knutet till pågående forskning vid KTH kring dispersion hos radiovågor i fusionsplasma och går ut på att kvantifiera dessa effekter.

Dispersion är ett fenomen som uppkommer när olika våglängder har olika brytningsindex. För radiovågor är ett fusionsplasma kraftigt dispersivt, vilket är en stor utmaning vid matematisk och numerisk modellering. I detta projekt kommer ska vi köra ett antal FEMIC simuleringar med olika våglängder och försöka kvantifiera och förstå våglängdsberoendet. Av speciellt intresse är en singularitet i ekvationerna för brytningsindexet och i detta projekt kommer vi studera vad som händer när man närmar sig denna singularitet. Fundamentalt i projektet är att vågor kan beskrivas som en summa av linjärt oberoende termer. För att illustrera detta ska vi använda en serie av relativt enkla 2D simuleringar för att återskapa ett relativt komplext 3D elektriskt fält.



Elektrisk fältstyrka från en numerisk simulering av radiovågsuppvärmning i ett fusionsplasma.

Målen med detta projekt är:

1. Läsa relevant litteratur om radiovågsuppvärmning och plasmafysik.
2. Lära sig att använda FEMIC-koden och COMSOL Multiphysics.
3. Bygga mindre analysverktyg för att analysera data från FEMIC-koden.
4. Designa och utföra simuleringar av uppvärmning i JET.
5. Att beskriva kvalitativt hur en radiovåg kan exciteras från en antenn och sen propagera i plasmat, där det till slut absorberas. Kvalitativt, hur fungerar absorptionen?
6. Att finna lämpliga kvalitetsparametrar för att kvantifiera de dispersiva effekterna.
7. En kvalitativ och kvantitativ analys av simuleringsresultaten som besvarar frågorna;
    a. Identifiera var i plasmat dispersiva effekter är mer eller mindre viktiga.
    b. Hur stora är variationerna i vågornas uppvärmningsförmåga – mätt med de mått som tagits fram i 6?
    c. Hur påverkas vågorna av den singularitet som uppkommer när det så kallade parallella vågtalet går mot noll?
8. Beräkna ett 3D elektriskt fält som en summa av 2D simuleringar med FEMIC.

Skriva en rapport och en presentation av resultaten.

Context H
Observations in Space Physics

Introduction

Space Physics encompasses the physics of the open space, mainly the environments of the Earth, other planets, and the Sun. The neutral gas and plasma (charged gas) environments of the Sun, the planets (including Earth's magnetosphere) and smaller bodies like moons and asteroids can be studied either by space probes that are in high-altitude orbit around the Earth or visit other planets, or through remote telescope observations. The space physics research at KTH is involved in various projects that utilize both remote telescope observations and direct in-situ measurement by space probes.

Two offered projects are based on data from NASA's Magnetospheric Multiscale Mission (MMS). MMS consists of four identical spacecraft with science instruments that can take more precise measurements of the mircophysics of plasma (charged gas) than any space probe before. Another project utilizes original data from NASA's famous Hubble Space Telescope, which regularly observes the environment of our largest planet in the Solar System, Jupiter, and its four large planet-sized moons.

Projekt H1: Magnetosheath Region Classification using Machine Learning

Supervisor: Savvas Raptis, savvra@kth.se, Space and Plasma Physics

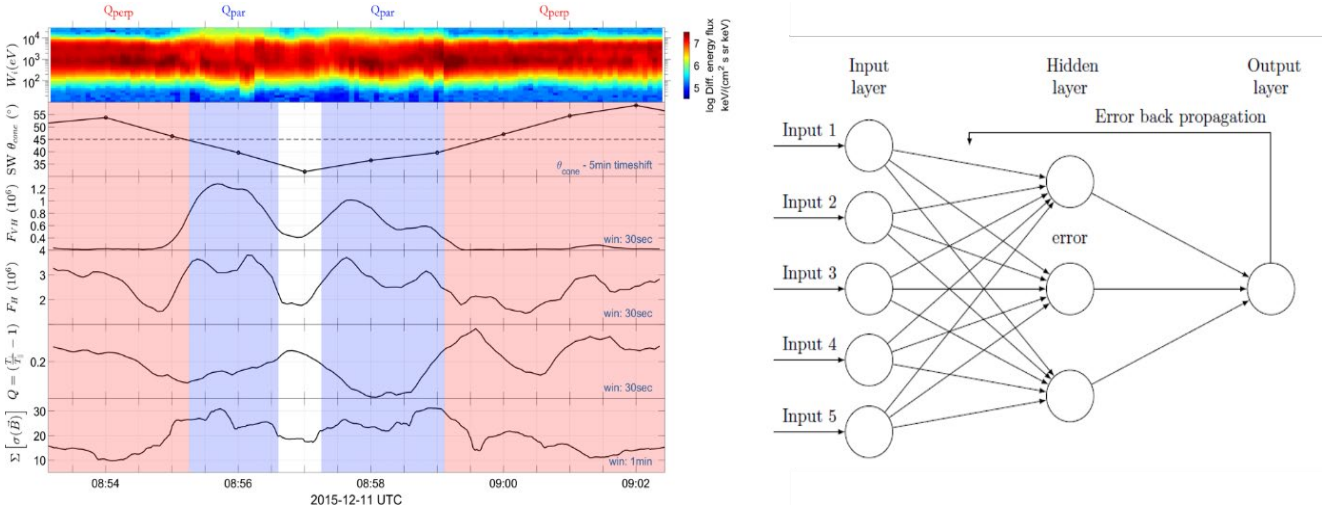


*Figure 1. **[Left]**: Different regions of magnetosheath getting classified between Quasi-parallel (blue) and Quasi-perpendicular (red). **[Right]**: A standard Neural Network (NN) structure showing how back propagation works in a training procedure*

One of the biggest challenges faced when using real time space data is to analyze their properties and characteristics with standard statistical techniques. Machine Learning tools however, such as neural networks (Figure 1 [Right]), can take advantage of the abundance of measurements and allow computers to learn from them, giving us the opportunity to solve problems that were previously thought to be impossible to tackle.

Solar wind particles travel at supersonic speeds towards the Earth. When they reach us, they interact with the magnetic field of the Earth, forming a shock. After these particles interact with the shock, two different regions are created behind the shock, the quasi-parallel and the quasi-perpendicular magnetosheath (Figure 1 [Left]).

The goal of this project is to find out if machine learning can be used to distinguish between these two different regions. To do that, students will develop their own algorithms to combine machine learning coding with real observation data from NASA's MMS satellite.

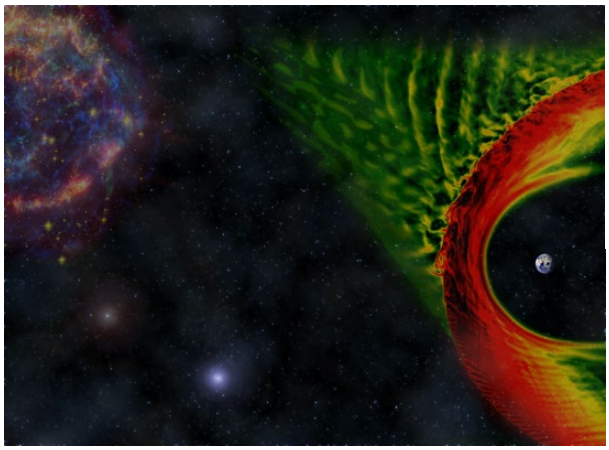
This work includes the following tasks:

- Download and use real satellite data from **NASA's Magnetospheric Multiscale (MMS)** Mission
- Learn about different regions in **Earth's magnetospheric environment**
- Use state-of-the-art **machine learning** techniques, using **Python** and **Tesnorflow/Keras** to classify the regions into different categories based on their properties

Through this project students will develop an understanding of Earth's magnetosphere and use real in-situ measurements to try to solve a classification problem. Doing so, they will familiarize with the most widely used machine learning techniques and coding libraries in Python.

Projekt H2: Electron acceleration at Earth bow shock

Supervisor: Andris Vaivads, vaivads@kth.se, Space and Plasma Physics



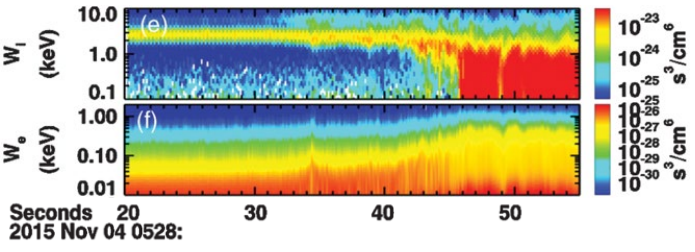


Figure 2. [left]: *Illustration of a supernova remnant shock and the Earth bow shock.*

[right] *MMS observations of ions (top) and electrons (bottom) as MMS crosses the Earth bow shock.*

Shocks forming at the interfaces of fast moving plasmas in Universe are among the most efficient plasma heating and energetic particle generation sites. There are shocks in front of planetary magnetospheres, termination shocks of stellar winds, supernovae shocks and others. Energetic electrons generated by shocks can generate radio waves, X-rays that allow to observe astrophysical shocks remotely. The Earth bow shock is the closest astrophysical shock and satellites crossing it allow direct observations of the physical processes inside shocks. With the launch 2015 of the NASA MMS mission, consisting of four spacecraft, we finally have very high spatial and temporal resolution electron observations from the Earth bow shock region. It allows us to directly probe the electron acceleration processes in the shock.

In this project the students will analyze all the Earth bow shock crossings by MMS spacecraft and look for the most energetic electron acceleration events relating those to the upstream solar wind conditions.

The tasks in this project are:

- Learn MMS data reading and plotting.
- Construct a database of all the bow shock crossings to be studied.
- Define the best method to look for electron acceleration.
- Analyze all crossings and make the list of most energetic acceleration events.
- Correlate the obtained list with the upstream solar wind conditions.

The students will acquire knowledge about space plasma and physical processes of particle acceleration in plasma. In addition the students will learn about spacecraft payload, spacecraft operations, spacecraft data. The data analysis will be done in MATLAB. The results of the work will be of high importance for further studies by the KTH scientists.

Projekt H3: Search for water plumes on Jupiter's moon Europa

Supervisor: Lorenz Roth, lorenzr@kth.se, Space and Plasma Physics

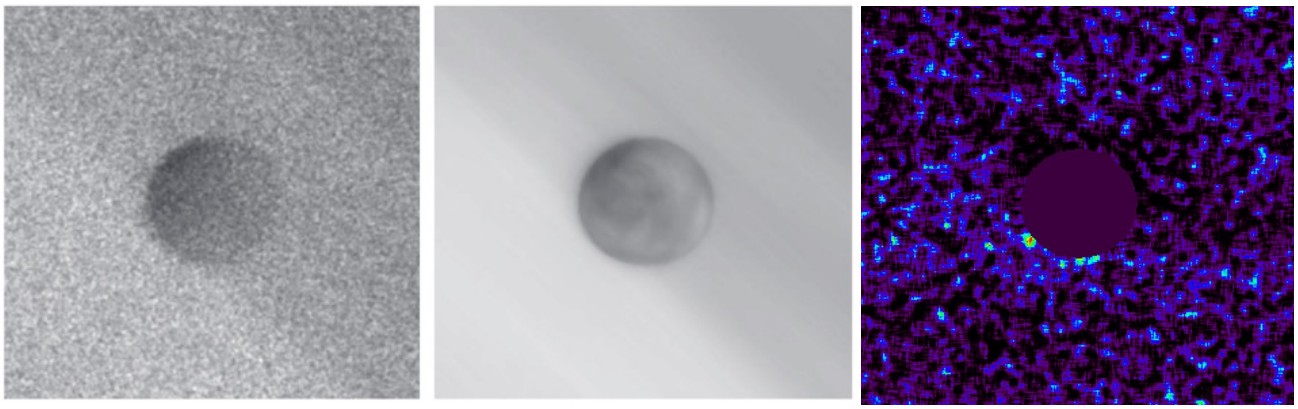


Figure 3. Left: *Europa in transit in front of Jupiter as observed by HST.* ***Middle:*** *Modelled observation of the transit.* ***Right****: Map of the outliers' statistical significance.*

Jupiter's moon Europa is known for its icy surface with a subsurface liquid water ocean possibly able to sustain life. This makes Europa one of the most interesting planetary object in the solar system, and the recent detections of water plumes emitted from the moon's surface fueled the interest for further exploration of the moon by an orbital probe. Some of these detections were made by the Hubble Space Telescope (HST) and rely on the absorption of the solar UV light reflected off Jupiter, which then passes through the plume as Europa transits in front of the planet. Detecting water plumes from these observations require some important statistical considerations, making these detections controversial. For this reason, researchers at KTH have developed an independent algorithm to analyze these observations.

The goal of the project is to apply the newly developed algorithm to re-analyze images with possible plume candidates. This includes:

- Download and process HST data with photon times-series for all exposures
- Applying the plume detection algorithm, understand the statistical significance of the results including the systematic sources of error
- Compare with previously published results.

Through the project, the students will therefore get theoretical knowledge about statistical detections, as well as practical expertise in image processing and hand-on experience with HST data.

The results will be highly relevant for two large future space missions: ESA's JUpiter ICy Moon Explorer (JUICE) and NASA's Europa Clipper missions. For both missions, the presence or absence of plumes on Europa is an important constraint for the planning of the scientific measurements by the science instruments.

Context I
Suborbital Free Flyer for Near-Earth Space Research

Figure: Launch of SPIDER-2 sounding rocket from Esrange, February 2020. Photo: M. Lindh, SSC

Our society extensively relies on the use of space systems, which provide the basis for the communications, navigation and resource management. Understanding the near-earth space is important both for knowing the conditions where these systems operate, and for including the effects of space phenomena on the global atmospheric system. Over half a century of satellite research has provided a good picture of the near-earth space. The magnetic field of the Earth “carves out” a bubble in the solar wind plasma streaming from the sun, called the magnetosphere, and largely controls the processes inside it. The boundary between the neutral atmosphere and the magnetosphere is the ionized upper layer of the atmosphere, the ionosphere, between 80 km and roughly 500 km.

The lower parts of the ionosphere are not studied as extensively as the space higher up, as the satellite orbits are not stable below 300 km, and decay rapidly. The region between 50 km and 200 km is only accessible for local measurements by means of sounding rockets – suborbital probes that are launched from the ground, and return back to earth after a short ballistic trajectory. Recently, sounding rocket payloads with multiple separate measurement points, realized by multiple free-fliers which launch from the same rocket, have gained interest, since they give an opportunity to study small-scale structures in the ionosphere.

KTH has been active in this research field. A number of different student rocket projects with free-falling units (FFUs) has been conducted in the framework of the REXUS/BEXUS programme. The solutions developed in these projects have later been used in full-scale research projects, such as SPIDER and SPIDER-2 (the later launched in early 2020). The bachelor projects this year push the boundaries even further and collect the work towards the next generation of the FFUs. This work will contribute to the next project to be proposed within the REXUS programme.

Note, projects I1, I2 are especially suitable for Vehicle Engineering and Engineering Physics students.

Project I1: High altitude glider solution for returning from space

Supervisor: Nickolay Ivchenko, Space and Plasma Physics & Raffaello Mariani, Aeronautics.

Sweden has one of the few rocket launch ranges in the world that allow recovery of payloads over land (in most cases the rocket impact point is in the sea, or in places hard to access). The impact area of the Esrange Space Centre is a large area almost devoid of human activity, yet still easily accessible by helicopter. Almost all rockets launched from Esrange are recovered within 24 hours from launch.

Recovery of the FFUs allows (virtually unlimited) data storage onboard, as there is no limit on the telemetry bandwidth. Not including a radio-telemetry system also saves volume, mass and cost of the FFUs. The current solution is to have the FFUs land using a parachute, and transmit their GPS position by a simple radio-beacon, for subsequent helicopter recovery. While this works in principle, the helicopter recovery of multiple payloads is still a rather costly task.

The next natural step is to have the FFU return to base autonomously. This is the challenge in the current context. Project I1 focuses on the aeronautics part of the solution. The idea is to use a deployable structure (either of rigid wing type or of a paraglider type), initially stowed inside the FFU of the pre-defined shape, that will turn the FFU into a high altitude glider. The FFU will then glide back to the launch site, eliminating the need for the helicopter search.

In this project you will:

- Model the descent trajectory from high altitude
- Model the drag and lift of various shapes of the FFU with the deployed structure
- Investigate the possibility of controlling the direction of flight
- Build prototypes and experimentally study their predicted behaviour

Project I2: Deployable wing structure for the FFU

Supervisor: Nickolay Ivchenko, Space and Plasma Physics & Gunnar Tibert, Space Technology

The solution of the high-altitude glider to return the FFU to the launch site is an attractive concept, but it also hosts a number of challenges. One of this is the need to deploy the wing structure. At launch, the FFU needs to fit inside the rocket, and during the measurements there are also requirements on the shape, dimensions and surface properties of the unit. This means that the wing must be initially

stowed inside the unit and deployed. The deployment system then must be robust enough to survive the launch vibrations. This project will investigate possible solutions to the deployable structure.

The tasks will include:

- Identifying possible concepts of the deployment
- Developing a conceptual design of the most promising concepts
- Considering the manufacturability of the system
- Making an initial analysis of the loads on the structure
- Possibly building a prototype of the concept for initial testing

Project I3: Control system for autonomous gliding to a given location

Supervisor: Nickolay Ivchenko, Space and Plasma Physics

In this project you will focus on the autonomous flight control system for the high-altitude glider as described in the project I1. The system will use the GPS position as an input and provide the control output to the servomotors which control the flight.

The tasks include:

- Defining the requirements to the flight control system
- Understanding the basics of the control
- Implementing the software in the embedded computer system previously used in the sounding rocket experiments at KTH
- Testing the flight control system with a test object.

Project I4: Electrical power system for the autonomous glider

Supervisor: Nickolay Ivchenko, Space and Plasma Physics

The control of the high-altitude glider solution for the FFU return to the launch site will require actuation of control surfaces or other change of configuration of the system. This is usually done with miniature electrical motors.

In this task you will get familiar with operation of the DC-DC and stepper motors, and solutions for driving electronics to those.

The electrical power system to supply the motors and other parts of the control system will need to be custom designed to fit in the volume constraints of the rocket experiment, and comply with other requirements. One of the challenges may be operation at low temperatures.

The tasks in this project include:

- Defining the requirements to the power system
- Making a thermal analysis of the system, identifying the needs for battery insulation/heating, etc.
- Making a preliminary design of the system
- Implementing the design in a breadboard or real PCB
- Conducting the tests of the design

Project I5: Wire boom deployment system for electric field measurement

Supervisor: Nickolay Ivchenko, Space and Plasma Physics & Gunnar Tibert, Space Technology

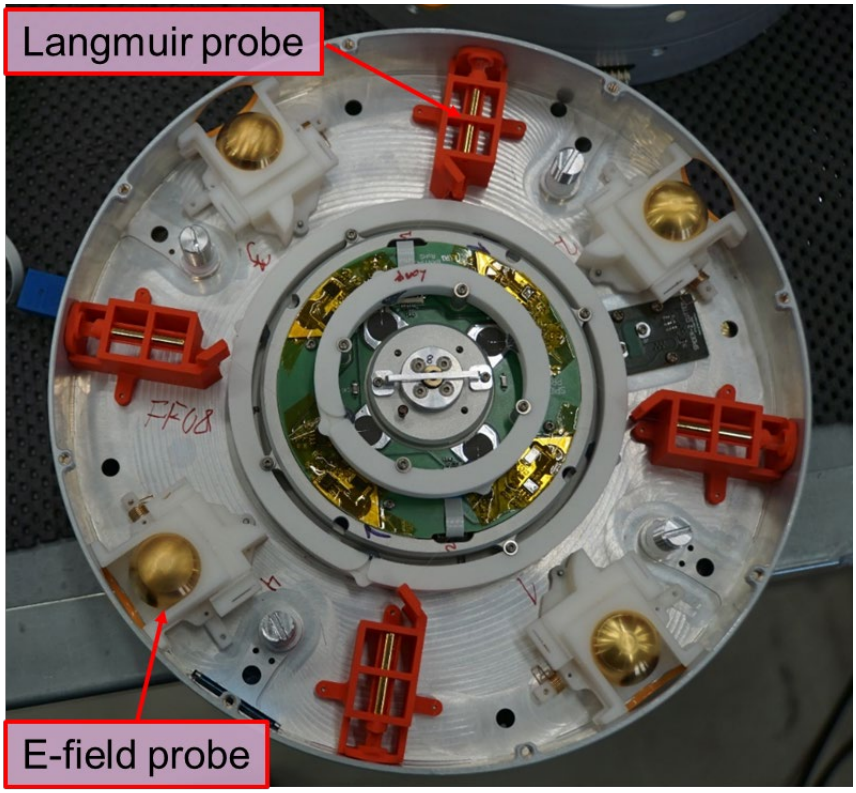


Figure: The wire boom deployment system of the SPIDER-2 in the stowed configuration.

One of the important parameters to measure in space plasma is the electric field. Measuring electric fields in space has been a special competence of the KTH Space and Plasma Physics group for decades, and we have participated in a number of large international space research missions with electric field instruments. Implementing a miniaturized electric field instrument for a sounding rocket payload is associated with some specific challenges, which will be addressed in this project.

The electric field is measured using the double-probe technique, where electrical probes (usually spherical) are deployed from the spinning body on thin wires, held out by the centrifugal force. The deployment mechanism used e.g. for the SPIDER-2 free-flier, is based on a set of spools storing thin wire. The rotation of the spool is controlled by a piezomotor, which unreels the wire in a controllable way.

The boom deployment system has been used in flight, and while generally successful, there were some concerns identified. In particular, the robustness of the system must be improved and possible failure scenarios investigated.

The tasks in this project include:

- Getting familiar with the existing boom deployment system
- Conducting deployment tests of the system and identifying possible points of failure
- Formulating the requirements to the boom deployment system and points for improvement/simplification
- Identifying possible solutions
- Conducting test of the modified system

Context J

Design and testing of novel microwave/antenna technologies

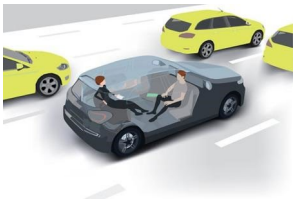
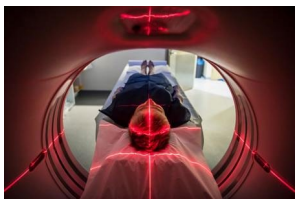
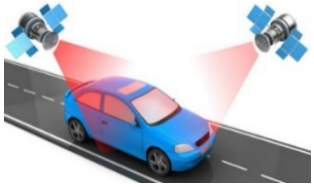
Today, microwave technology is employed in many of our technological devices and they fulfil an essential function in communication systems, intelligent cities, surveillance, medical diagnosis and space observation.

Innovative microwave designs are required daily in the products of technology-driven companies. These companies require efficient and multi-functional antennas and microwave devices that can enable:

- High data rate communications for future 5G (and beyond) networks.
- High resolution radars to detect people, vehicles and objects in smart cities.
- Non-invasive imaging of patients for early detection of health issues.
- Highly precise airport scanners that maximize the location of concealed objects.
- Precise detection of stars and planets in the outer space.
- Efficient satellite communications with the newly deployed low- Earth-orbit satellites.

Within the projects of this Context, you will be able to acquire the fundamental knowledge for designing advanced microwave devices and antennas. You will learn how to use commercial software of simulation, which is commonly employed in the industry. Finally, you will manufacture and measure a proof-of-concept. After the project, you will be able to reproduce the usual steps followed in a microwave or antenna design process.

Examples of challenges which require innovative microwave/antenna technologies:

Picture 1. Artistic rendition of 5G communications.
Picture 2. Autonomous car inter-connected with wireless systems based on 5G.
Picture 3. Patient inside a high resolution medical scanner.
Picture 4. Car communicating with LEO satellites.

Project J1: 3D printing microwave lens antennas for space communications

Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Pilar Castillo-Tapia pilarct@kth.se
Division for Electromagnetic Engineering

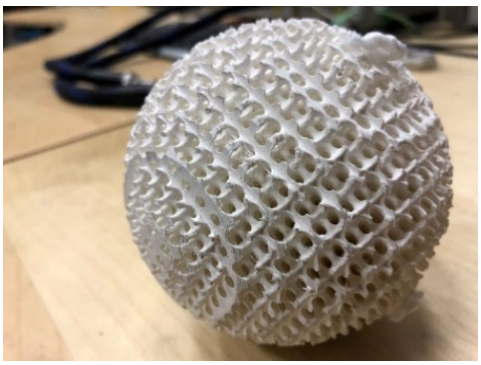
Due to the increase in the frequency bands of new communications systems, lens antennas are becoming very popular. Lens antennas can be used to increase the directivity of conventional antennas at a low-cost because they do not require complex feeding networks. Therefore, lenses are being considered as a suitable solution for terminals to communicate with the new generation of low-Earth-orbit (LEO) satellite constellations.

Additionally, 3D printers are becoming a low-cost and easy tool commonly used in industry to manufacture complex structures. Conventional 3D printers can construct structures which can be used to produce low-loss lenses.

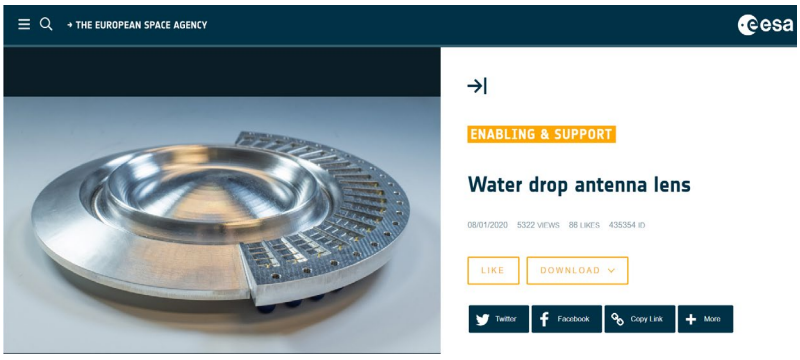
The purpose of this project is to design and measure a lens antenna for future LEO satellite communications. The lens will exploit the opportunities of 3D printers.

As a student, you will learn:

- The importance of lenses for LEO satellite communications.
- How to simulate microwave lens antennas with commercial software of simulation.
- How to design microwave lenses, and to integrate these lenses in an antenna system.
- How to use a 3D printer to produce low-loss microwave lenses.
- How to measure lens antennas in the antenna laboratory.



Luneburg lens manufactured at the Division for Electromagnetic Engineering with a 3D printer.



Water drop antenna lens antenna, designed at KTH in collaboration with the European Space Agency. This antenna is intended for satellite communications.

Project J2: 5G/6G filters based on electromagnetic periodic structures

Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Qiao Chen, qiaoc@kth.se
Division for Electromagnetic Engineering

Electromagnetic periodic structures are used in multiple practical devices. For example, these periodic structures are used to produce filters, polarizers and antennas, which find application, for example, in wireless communications.

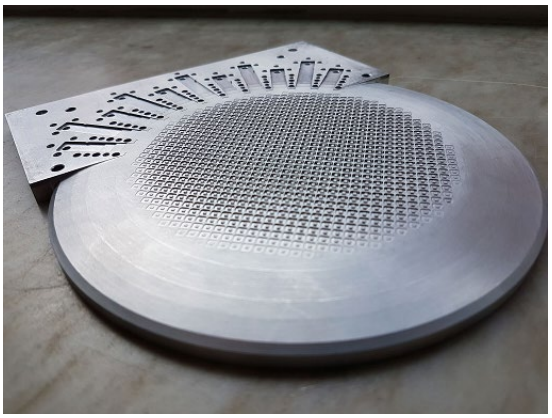
Wireless communications are rapidly evolving, and users are demanding new services in the present networks that require higher data transfer. Since the low frequency spectrum is over-crowded, the only possibility is increasing the operational frequency to the millimetre-wave regime where a broad spectra is available, which permit larger data transfer and short delays.

The existing electromagnetic technology cannot be directly extended to these new frequency bands. Therefore, new concepts for antennas, polarizers and filters are being explored.

The main goal of this project is to design, build and measure a filter, made of periodic structures, following the specifications for 5G/6G communications.

As a student, you will learn:

- The electromagnetic operation of periodic structures.
- How to simulate periodic structures with commercial software.
- How to design microwave components with periodic structures, including filters and lenses.
- How to measure a microwave filter in our microwave laboratory.



Glide-symmetric Luneburg lens antenna designed at KTH in collaboration with Ericsson AB.

Filter designed at KTH in collaboration with Ericsson AB and European Space Agency.

Project J3: Design of a leaky-wave antenna for automotive radar applications

Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Shiyi Yang
Division for Electromagnetic Engineering

One engineering challenge that we currently face is to produce sustainable and smart transport solutions. For example, we would like to enable autonomous cars that do not require drivers, or streets that adapt to traffic in order to reduce congestion and increase the mobility of commuters in our growing cities.

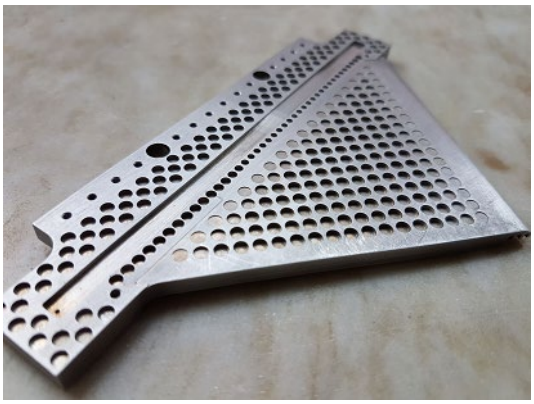
To make our vehicles autonomous, we require of radars that precisely detect objects in the streets, as well as other cars. These radars need directive antennas which are able to steer their radiating beams. One possible solution for these antennas are leaky-waves. Leaky-wave antennas are able to focus the radiation at different position depending on the frequency.

The purpose of this project is to simulate, design and test a leaky-wave antenna with intended use for an automotive radar.

In this project, the student will learn:

- The operation of leaky-wave antennas and their use for radars in vehicles.
- How to simulate leaky-wave antenna with commercial software of simulation.
- How to design a leaky-wave antenna with the desired steerable capabilities.
- How to test an antenna in the antenna laboratory.

Automotive industry makes use of radars to detect objects and other cars.



Leaky-wave antenna designed at KTH in collaboration with Ericsson AB.

Project J4: Simulation of body absorption for 5G/6G frequency bands

Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Oskar Zetterström, oskarz@kth.se
Division for Electromagnetic Engineering

The new generation of mobile communications, 5G, started to be deployed at the end of 2019. However, this first implementation of 5G will only cover part of the needs of users. Further research to increase the rates of wireless communications is currently needed to cover the expectations in the near future. Since most of the low frequency spectrum is already crowded, the only possibility is increasing the operational frequency to the millimetre-wave regime where the broad available spectra allows for larger data transfer and short delays.

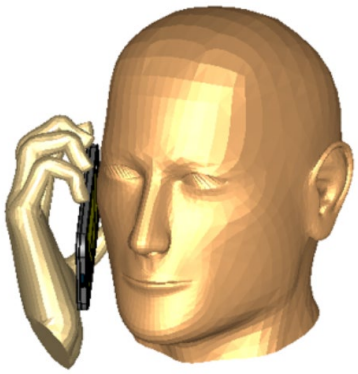
When new electromagnetic bands are employed, users and public authorities request studies that verify that the new emissions are compliant with the standards so no damage is done to humans in the locations where these new communications are taking place. The standards establish a maximum amount of transmitted energy so our bodies do not absorb more than a given amount of power. In essence, our body will transform this energy into heat, and if the amount of heat is high, it will start damaging our cells.

The purpose of this project study, with commercial software of electromagnetic simulation, the body absorption from antennas in the new frequency bands allocated for 5G and 6G.

In this project, the student will learn:

- The interaction between electromagnetic waves and the human body.
- How to model the electromagnetic properties of the tissues present in our bodies.
- How to simulate the human tissues in electromagnetic commercial software.
- How to evaluate the absorption in human bodies.

Future interconnected society thanks to the new advances in communications, 5G/6G.



Model of a head and hand in the commercial software of electromagnetic simulation.

Context K
Electrotechnical multiphysics simulation

Computer simulation is nowadays acknowledged in industry as a powerful and cost-effective tool to complement physical testing. Even though physical testing is the ultimate proof of the performance of a product or system, it brings significant time delays in development due to the need to prepare and built test samples and setups, without any flexibility when developers consider multiple possible changes. Computer simulation on the other hand enables advanced design and understanding of any system or product, and gives a broad scope for developers to be innovative by allowing the consideration of a far broader range of variants and to test “out-off-the-box” approaches. Computer simulation also allows *virtual testing* of a product or system, which in some cases is the only way to verify a design or to assess its condition when physical testing in not feasible or practical to execute. Furthermore, computer simulation also creates a virtual image of a product or system, a *digital twin,* which can be used by artificial intelligence AI platforms to follow up in real time and to take autonomous decisions the lifecycle of a product.

As a digital representation of real-world products and systems, computer simulation must consider the multiple physical phenomena simultaneously influencing a product or system including their mutual interaction. Since the interaction between multiple phenomena is generally complex, *multiphysics simulation* is necessary as a direct way to assess the effect of different interrelated physical domains. Fortunately, the simulation of the mutual interaction of complex processes is nowadays possible due to the progress in software and the powerful computing systems available today. For this reason, there is an increasing industrial need for engineers properly trained in the modeling, development and use of simulation. This context focuses on projects intended to introduce bachelor students to several examples of multiphysics simulation in electrotechnology.

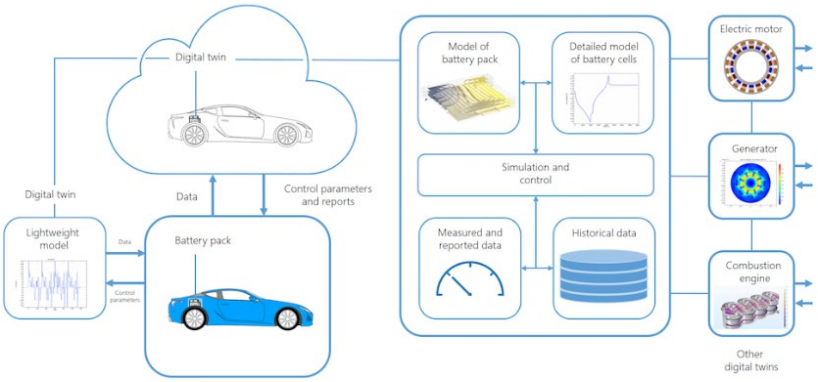


Figure 1. Sketch of the interaction of different processes in the digital twin of an electric car

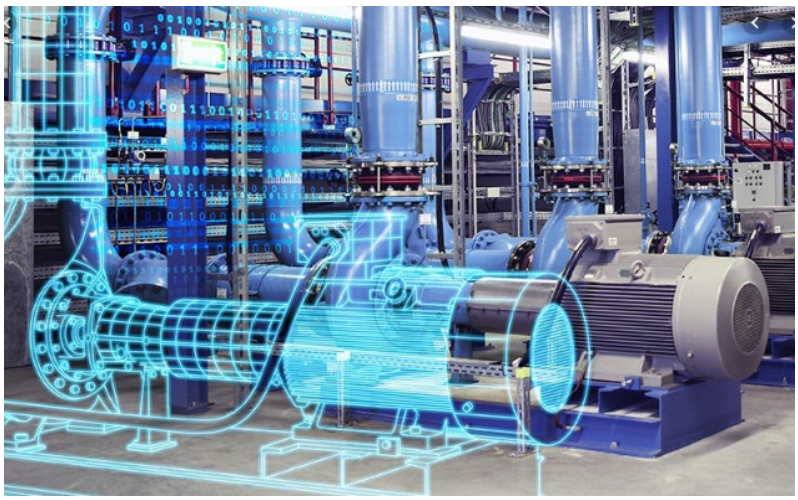


Figure 2. Illustration of a plant with electrical motors and digital twin.

Project K1: Improving Truck Efficiency with Electric Wind

Supervisor: Marley Becerra (marley@kth.se), Department of Electromagnetic Engineering KTH

The reduction of aerodynamic losses in vehicles is a direct way to reduce fuel consumption, reducing the emission of particulates and greenhouse gases as well as saving costs. Research at the KTH has shown that drag losses in heavy trucks can be efficiently reduced instead by using “electric wind” produced by a low temperature plasma. This technique, called plasma actuation, uses electric power to inject streamwise momentum into the incident flow close to separation points on bluff bodies.

This project is aimed for the students to use a *digital prototype* of a simplified laboratory plasma actuator to study different design parameters and to numerically analyse posibilities of the reactive compensation of the required high voltage power supply. The overall target of the project is to improving the electrical efficiency of both the actuator and the power supply to allow the later experimental scaling up of laboratory prototypes to real-size devices.

During this project, the students will:

- Learn about electric plasma actuation and its use for reducing aerodynamic losses
- Get familiar with COMSOL Multiphysics and to perform parametric analysis for different design variables.
- Participate in laboratory testing of different plasma actuators
- Use their knowledge in RLC electrical systems to compensate reactive power at medium frequencies (above 10 kHz).
- Propose improved design parameters for improved electric performance of a laboratory actuator.

1:6 scale model of a truck in a wind tunnel: a) the right A-pillar is equipped with plasma actuator. b) a close-up of the actuators under actuation, the violet light show the plasma, experiments by Vernet, KTH (2017)

Project K2: Estimating the failures due to lightning strikes to ultra-high voltage power transmission lines

Supervisor: Marley Becerra (marley@kth.se), Department of Electromagnetic Engineering KTH

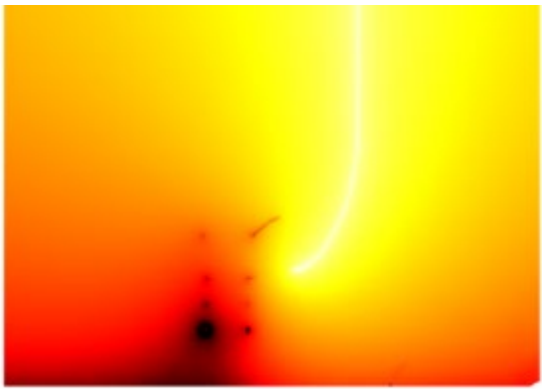
The increasing demand for electric power and the transportation of large amounts of energy over long distances requires the use of Ultra High Voltage (UHV) AC and DC power transmission lines (TLs). In addition, installation of hybrid TLs are under way, leading to larger and more complex structures. One of the challenges when designing these type of TLs is to achieve a good lightning shielding performance. However, field observations reveal higher failure rates than those estimated by methods in the international standards. These failures have been until now the main cause of line outages in EHV-TLs and UHV TLs, as reported in the literature.

In this project, the students will extend a new methodology developed at KTH to estimate the incidence of lightning strikes to UHV power transmission lines. The project will focus on the analysis of the topography on the lightning performance along a single section of a real UHV power line in Uchinada, Japan to validate the estimations with field observations.

During this project, the students will:

- Get familiar with SLIM (Self-consistent Leader Inception and Propagation model) to simulate the conditions for downward and upward lightning from the considered structures
- Learn to deal with topography maps obtained in Google maps and to process them to produce a finite element method geometry.
- Construct the geometry of the transmission line section and the transmission line for Finite Element Method calculations with COMSOL Multiphysics.
- Investigate the lightning exposure of a real power line along an actual topographic terrain profile.

Left: Photograph of an UHV transmission line struck by lightning. Right: Example of a real power transmission line in a complex topography

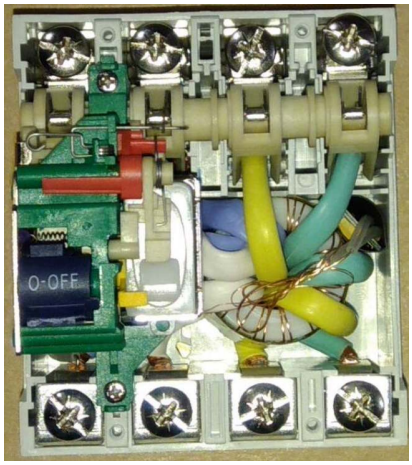


Simulation of a lightning strike to a UHV power line on flat ground

Project K3: Electromagnetic and mechanical model for type-A residual-current device

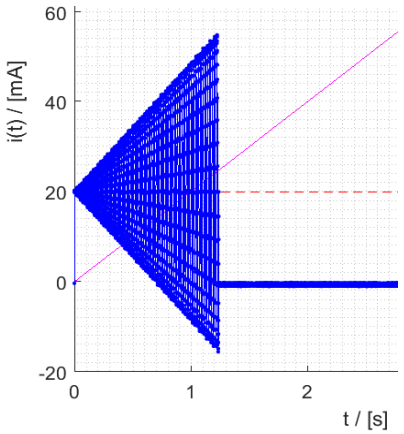
Supervisor: Nathaniel Taylor (taylor@kth.se),
Division of Electromagnetic Engineering KTH

Residual-current circuit breakers (sv: *jordfelsbrytare*) are now a requirement for many types of circuit in new electrical installations, and are found in many older installations too. They detect a current-imbalance ('residual') of tens of milliamps, in circuits with normal loads of tens of amps. A common type in Sweden has sensitivity of 30 mA and is sensitive to 'type A' currents, meaning currents that are alternating at power frequency and that possibly are rectified or chopped. This type of RCD is often a purely passive electromechanical device, meaning that it operates from the imbalance current without needing any voltage between the poles.



Increasingly, other current waveforms such as higher frequencies or smooth dc may be found in modern devices with electronic switching. More complicated and (currently) expensive types of RCD exist that have well defined operation with such currents: e.g. types F and B. However, it is of interest to know how sensitive type-A RCDs are to these currents and how much these currents may interfere with detection of power-frequency currents happening at the same time.

We already have some measurements of sensitivity and speed of several type-A RCDs with a range of currents. For example, the plot on the right shows a 20 mA dc component with a growing 50 Hz ac component, leading to tripping at about 20 mA of ac, which is still well within specification.



In this project, the group will model a type-A RCD, considering the current-balance transformer's magnetic properties, the construction of the tripping coil with its permanent magnet and release-coil (picture below), and the electric circuit including capacitors and diodes that comes between these. The purpose of the model is to predict tripping sensitivity and speed for a range of situations such as dc steps, different frequencies of ac, and superpositions of these. The choice of modelling environment will be by agreement between group and supervisor, after the group has studied the options. Examples are a programmed model or a finite-element application.

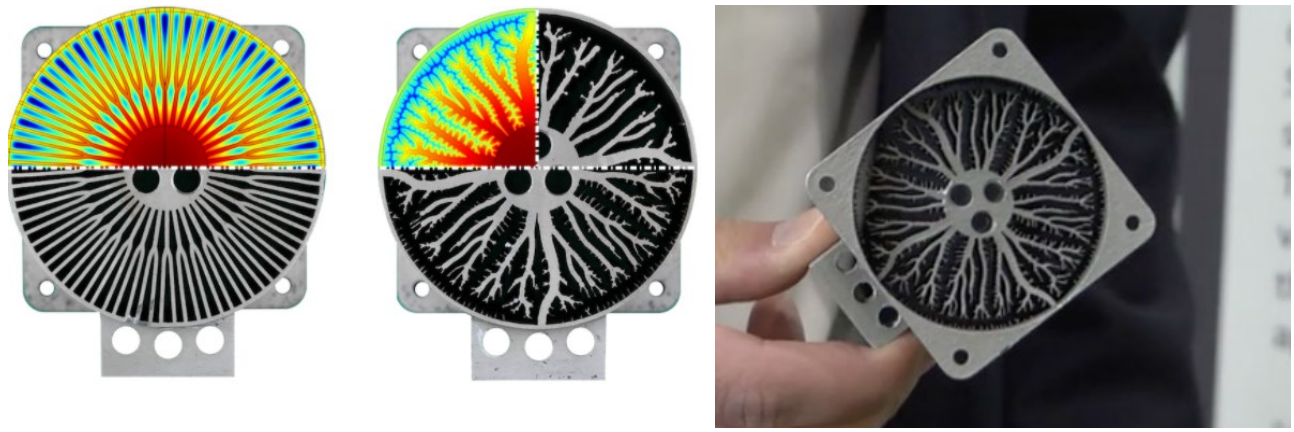
Project K4: Topology optimisation for 3D printing in electrotechnology

Supervisor: Marley Becerra (marley@kth.se), Department of Electromagnetic Engineering KTH

3D printing is a technique of additive manufacturing that provides broad opportunities for electrotechnical products to reach minimum weight and maximum performance through structural shapes that cannot be easily produced with standard methods. Topology optimization is a modeling computer method to optimize the material layout within a given design space with the goal of maximizing performance. Electrothermal products are a good example of multiphysics systems that can benefit of 3D printing to reach optimum thermal performance with low weight.
This project aims to analyse the different modeling strategies for topological optimization and to implement a simple 2D multiphysics model to optimize the topology of a high current busbar. The topology should be optimized to maximize convective convective cooling to reduce the temperature of the busbar.

During this project, the students will:

- Get familiar with topology optimization and with optimization in general
- Implement a simple COMSOL Multiphysics model including electric and thermal physics coupled with optimization
- Evaluate suitable optimization functions to perform the topology optimization
- Evaluate the thermal performance of different designs
-



Left: Examples of different topology evaluations using computer simulation of a heat sink. Right: 3D printed heat sink after topology optimization

Context L
AIoT: Artificial Intelligence and the Internet of Things

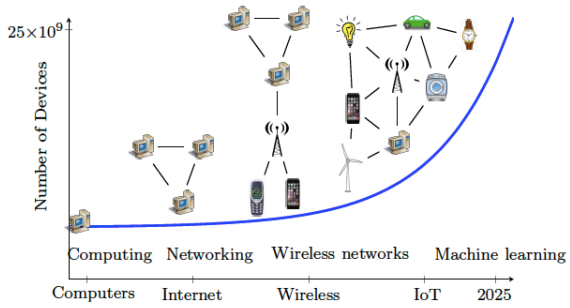


Figure 1: *Four technological revolutions: Computers, Internet, Wireless Phones, and Internet of Things (IoT) or "the all-connected and digitalized world". With future wireless networks and IoT, any system or object that can be connected via communication networks will become "intelligent". An essential part of the "intelligence" is machine learning.*

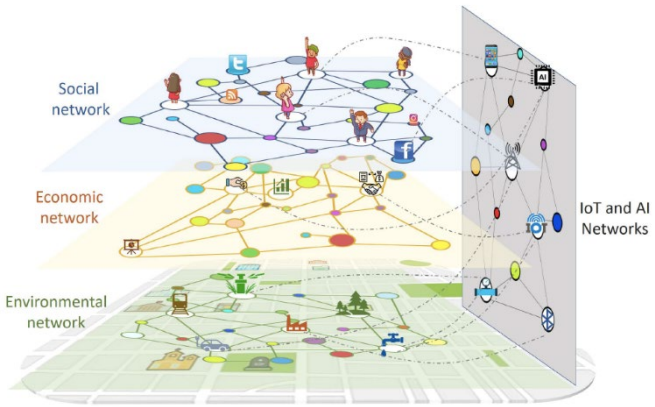


Figure 2: *Machine learning in communication networks with distributed nodes and data sets will face formidable challenges, due to the size of local data sets, limited computation and energy and narrow bandwidth of the nodes, heterogeneity of communication protocols, privacy, and security. Distributed machine learning is conceived for high performing networks of processors (often in data centres), and not for "the connected world".*

In the past decades, we have seen a series of computing–information-communication revolutions that started with computers, followed by computer networking, and up to wireless networks (see Figure 1). We are now at the onset of the fourth revolution: "the all-connected and digitalized world", where networks will bring automatic data analysis and decision making in any object, transforming it into an "intelligent" system (see Figure 2). Current predictions specify that, around 2030, the number of networked objects will be around 100 billions and that the fourth revolution has the potentiality to create a new multi-trillion economy. One of the main characteristics of the fourth revolution is the huge data generation. It appears that the last three years have produced 90% of the world's data available up to now, especially due to devices such as sensors in Internet of Things (IoT) or smart phones.

Such wealth of data is forcefully motivating the development of intelligent data analysis methods, namely machine learning and Artificial Intelligence. Thanks to AI, speech recognition and automatic text entry can be performed, or good photos are automatically selected by smart phones, or cars see and avoid obstacles. To achieve such impressive results, machine learning needs big datasets and very huge computational and communication resources. For example, the Google AlphaGo has been trained with around 30 million possible moves to beat a Go grand champion. However, in the fourth technological revolution, data sets of any size will be distributed among several nodes (people, devices, objects, or machines) that might not be able to perform the computations and to share data. Existing AI methods are mostly intended for proprietary or high performing networks (e.g., in data centres), and would greatly stress communication networks such as IoT and 5-6G wireless networks.

One major issue to apply AI over communication networks is the fundamental bandwidth limitations. The huge number of nodes and their data sets transmissions may congest the practically available

bandwidth. The emerging technology of extremely low latency communications, will rely on short packets that carry few bits. Techno-economical forecasts indicate that, in the coming years, IoT systems such as smart grids or smart cities will be mostly served by narrow band IoT. For example, to monitor and control water distribution lines, an IoT network will be underground and underwater, where the nature of the communication channels gives low data rates with unreliable links and delays. Communications within the human body can rely only on few bits per second. The nodes generating data may not have enough communication bandwidth to transmit data where it has to be analyzed, or simply not enough computational power to perform local analysis. A further problem is that in the incipient fourth technological revolution, key societal concerns are privacy and security. A malicious observer could reconstruct node's (such as a person's) private information, or misuse the analysis of data belonging to others.

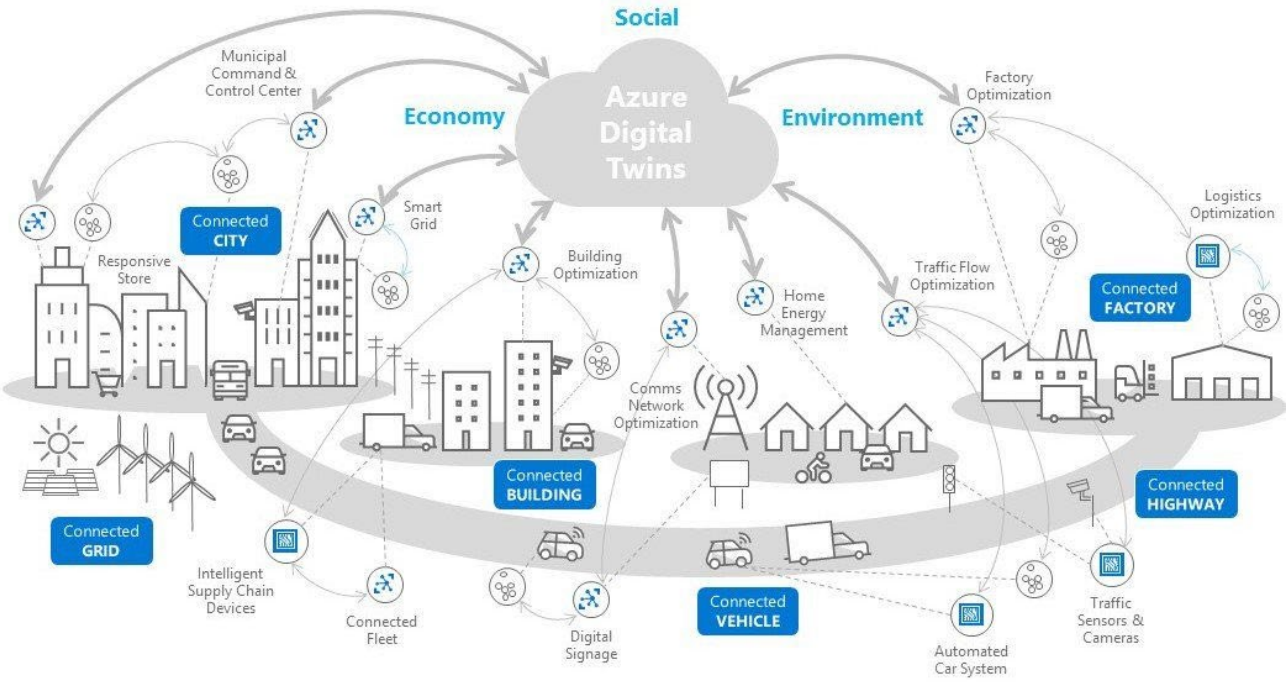
In this Bachelor Thesis context, you will study a subset of exciting topics within Artificial Intelligence and IoT (AIoT):

- Distributed optimization in AI and IoT
- Activity Recognition Using IoT and Machine Learning
- Water Monitoring with Machine Learning
- Asynchronous Over-The-Air Computation for Federated Learning
- Data-driven System Engineering
- Internet of Thing Hacking
- Cyber Threat Modeling and Attack Simulations
- Distributed Machine Learning for Cyber-attack Detection in Smart Grids
- Distributed Machine Learning for Generation and Detection of Attacks Against Continuous Authentication

We describe in the projects in the detail in the following pages.

Project L1: Distributed optimization in AI and IoT: the effect of communication delays on convergence rate

Supervisor: Thomas Ohlson (ttohlson@kth.se), Carlo Fischione (carlofi@kth.se)



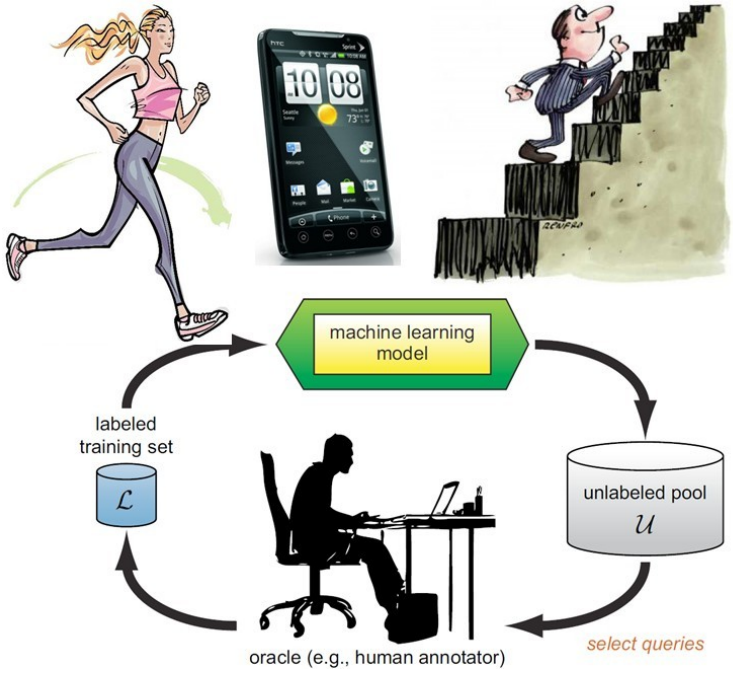
With IoT just around the corner, there is an urgent need to develop and understand distributed methods for machine learning. In the end, this becomes a problem of distributed optimization, and there are already many methods for dealing with these. However, while the performance of many centralized algorithms is well-understood, this is not true for their distributed/decentralized counterparts. This is especially true when communication delay is taken into consideration, which is essential when optimizing over a communication network, such as an IoT network.

The challenge of this project is to understand the how the convergence rate of a distributed optimization algorithm of choice depends on the communication delay between the nodes. This would include a study of the latest literate, combined with simulations of different optimization scenarios and possibly theoretical studies.

This project aims at understanding the effects of communication delays on the performance of certain distributed optimization algorithms. The results can help to understand the potential and the difficulties for optimization in real-life communication networks.

Project L2: Activity Recognition Using IoT and Machine Learning

Supervisor: Hossein Shorkri-Ghadikolaei (hshokri@kth.se), Carlo Fischione (carlofi@kth.se)



Revolutions in cheap sensor designs and internet-of-things (IoT), along with recent progress in artificial intelligence and machine learning, provides exciting new opportunities to collect and analyze continuous sensor data. Recognizing daily activities is fundamental in many applications, including city development and health-related recommendations. The activities include walking, running, cycling, driving, and using public transportation.

The challenges of this project consist of reading the sensor data from IoT devices (in particular a smartphone) and use machine learning models (in particular time-series) to recognize the activity. In some activities, you may need to work with third-party API to get map and time-table of public transportation in Sweden and use them in the learning process. The sensory data may include some missing values and some errors, which should be considered in the training of the machine learning models.

The project aims at developing a service that reads sensory inputs from smartphone/smartwatch and uses machine learning models to recognize user activity. The activities include standing, walking, running, cycling, driving, subway/metro, bus, ferry, and in-flight. For each activity, we need to know the start-time and stop-time to make a time-line of user activity. The project may require creating a simple dataset for some of these activity-recognition tasks and training some models. The resulting system will find many applications in city planning and health-related recommendation.

Project L3: Water Monitoring with Machine Learning

Supervisor: José Mairton Barros Da Silva Júnior (jmbdsj@kth.se), Carlo Fischione (carlofi@kth.se)

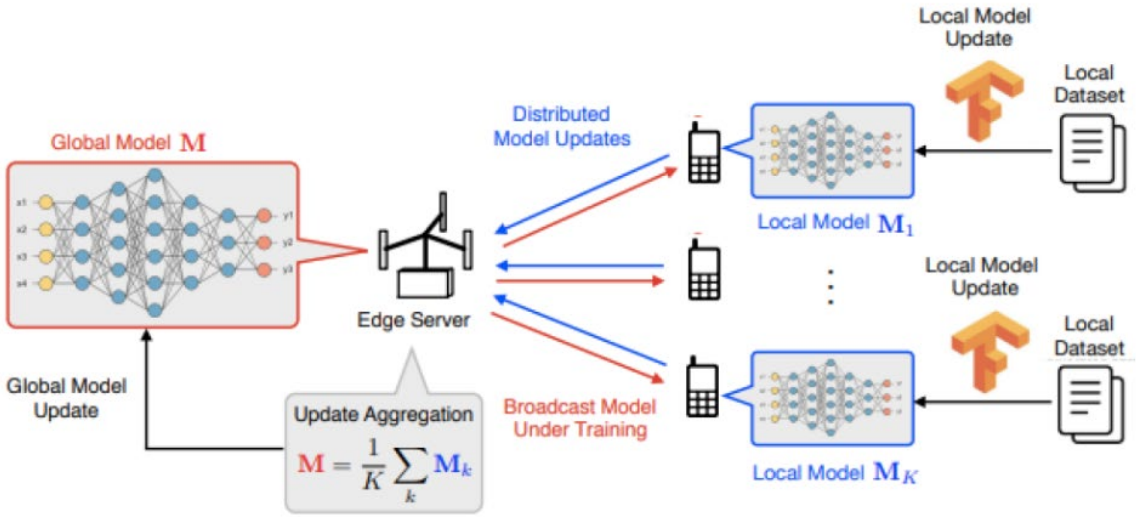
Monitoring the quality of drinking water in water distribution network is essential to ensure public health. Wireless sensors, as a complement of manual sampling, can automatically collect data related to the water quality in the distribution network. The collected data need further analysis to suggest if there are anomalies happen in the distribution network.

In real-world distribution network, the water conditions, in terms of temperature, water flow speed, pressure, have large variations, which may greatly affect the false alarm rate of the anomaly detection. The challenge of the thesis is to reduce the influence of the large variations in the anomaly detection, such that the false alarm rate is minimized. Another challenge is that the data to be analyzed in the thesis project comes from real-world measurements, which means that there might be some unforeseen characteristics in the data.

The project aims at developing an approach based on machine learning to reduce the false alarm rate of an IoT wireless sensor prototype that monitors water quality.

Project L4: Asynchronous Over-The-Air Computation for Federated Learning

Supervisor: Henrik Hellström (hhells@kth.se), Carlo Fischione (carlofi@kth.se)



With the growing prevalence of Internet of Things devices, constantly collecting information about physical phenomena, we have an unprecedented amount of data at our disposal. The availability of enormous mobile data and recent breakthroughs in the field of machine learning foster a great environment for distributed machine learning applications. However, current wireless communication techniques are not optimized for machine learning and may be unsustainable with the exponential growth of traffic.

To facilitate upcoming distributed machine learning applications, a new paradigm of wireless communications research called Learning-Driven Communication (LDC) emerged in 2018. The fundamental idea behind LDC is to design novel wireless technologies with design objectives targeted towards distributed machine learning.

This project in particular would deal with an LDC technique called Over-the-Air Computation for Federated Learning. With this technique, each device will calculate a small update to the global learning model using their measured data. These updates are then transmitted simultaneously over the same radio resource. By pre-processing the data appropriately, the constructive interference in the wireless channel can be utilized to calculate an average of the model-updates “in-the-air”. However, a major limitation of this technique is that it requires strict synchronization among sensor devices, which is notoriously difficult to achieve in practice.

The project aims at evaluating the effect of asynchronous communication in Over-the-Air Computation for Federated Learning. The evaluation could either happen through the usage of simulations, mathematical analysis or both. Using the results of the evaluation, a feasibility study on different synchronization methods would be critical for practical implementation of these systems.

Project L5: Data-driven System Engineering

Supervisor: Rolf Stadler, stadler@kth.se

Background: IoT and other services will share a common communication and processing infrastructure, in order to achieve cost-efficient and robust operation. A critical issue will be to ensure service quality, whereby different services have very different requirements. This project focuses on achieving service quality with help of statistical learning on operational data.
Recent advances in computing and networking technologies enable the collection and processing of measurements from networking and computing devices, in order to predict, for instance, service quality of applications, such as video streaming or data stores. These techniques are based on statistical learning methods.

The Project: The students will analyze traces from testbed measurements and build predictive models. They will evaluate these models regarding prediction accuracy and computational overhead.

- The first task is to build and evaluate models that predict service metrics, such as response times or video frame rates, of services running on the testbed.
- Second, the students investigate the relationship between computational overhead and prediction accuracy for models produced by different learning methods including linear regression, random forest, and neural networks.
- Third, the students build and evaluate predictive models that forecast service metrics for different time horizons.

For the project, the students will use the Anaconda environment (anaconda.com), including Jupyter notebook, and the scikit-learn machine learning packages (scikit-learn.org). For evaluation, they will have access to compute servers.

Prerequisites: statistics, programming skills in Python; basic concepts of machine learning.
Literature: Goodfellow, Ian, Yoshua Bengio, Aaron Courville, and Yoshua Bengio. “Deep learning.” Cambridge: MIT press, 2016.

Project L6: Internet of Thing Hacking

Supervisor: Pontus Johnson (pontusj@kth.se)

The Internet of Things entails that a plethora of things become connected to the Internet and fitted with sensors and actuators. Many of these things will be low-cost. However, historically, low production cost has not been conducive to high information security. Sayings such as “The S in IoT stands for Security” reflect the feelings of many observers of the field. The pervasiveness of insecure IoT in smart cities presents a serious risk to society, as more and more critical functions of the city are controlled by automated IoT solutions.

In recent decades, the information security community has come to the realization that white hat hacking is an important activity in the security process. White hat hackers find and responsibly disclose vulnerabilities before malicious actors exploit them.

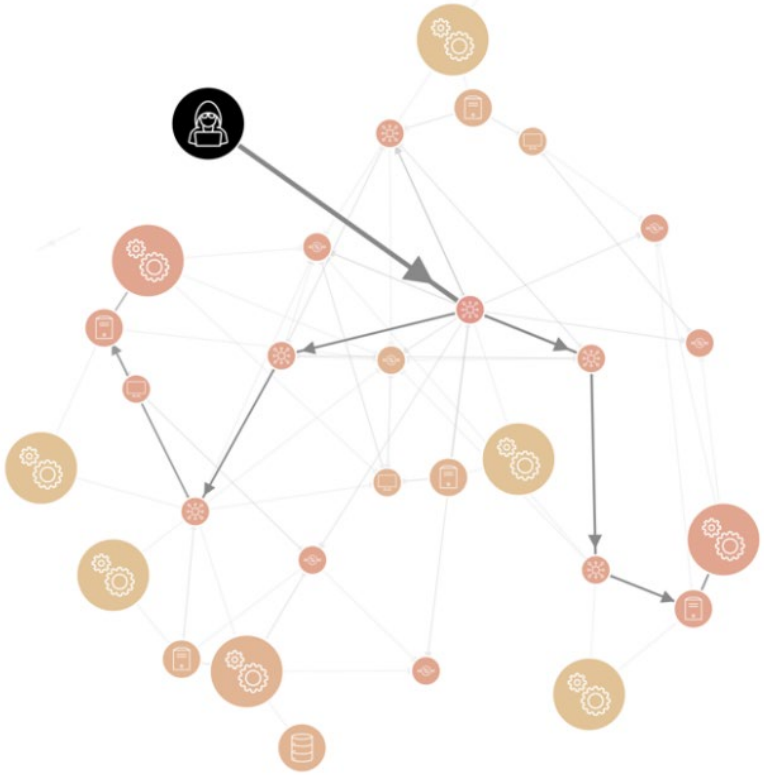
The main objective of this project is to select and explore the information security of a specific IoT device, and to attempt to hack it.

- What are typical weaknesses in common Smart City IoT devices?
- Which devices appear to feature the most easily exploitable vulnerabilities, with the potentially gravest consequences?
- What methods of penetration appear to explore the most promising attack surfaces? Are access controls flawed? Are there weaknesses in the cryptographic implementations?

Is it possible to create a proof-of-concept exploit of a device?

Project L7: Cyber Threat Modeling and Attack Simulations

Supervisor: Robert Lagerström (robertl@kth.se)



With the general digitalization of our society by IoT and AI, immensely complex IT-infrastructures are being formed. Obviously, ensuring that these infrastructures are resilient to cyber attacks is vital for the well being of our society. However, only to overlook this environment is challenging not to mention the understanding and assessing the cyber security posture of it.

Attack simulations may be used to assess the cyber security of complex systems. In such simulations, the steps taken by an attacker in order to compromise sensitive system assets are traced and documented. Attack graphs constitute a suitable formalism for the modeling of attack steps and their dependencies, allowing the subsequent simulation. The Meta Attack Language (MAL) has been proposed for the design of domain-specific attack languages. The MAL provides a formalism that allows the semi-automated generation as well as the efficient computation of very large attack graphs.

MITRE ATT&CK™ is a globally accessible knowledge base of adversary tactics and techniques based on real-world observations. ATT&CK thus constitutes a common language for many in the cyber security guild.

This project aims at creating a MAL-based language using (a subset of) the attacks listed and described by ATT&CK so that it can be used for attack simulations. The attacks in the new language will be individually tested and the language as a whole validated by simulating known attacks. A possible end activity could be to use the language to model an enterprise IT infrastructure at a Swedish company.

Project L8: Distributed machine learning for cyber-attack detection in smart grids

Supervisor: Ezzeldin Shereen (eshereen@kth.se), György Dán (gyuri@kth.se)

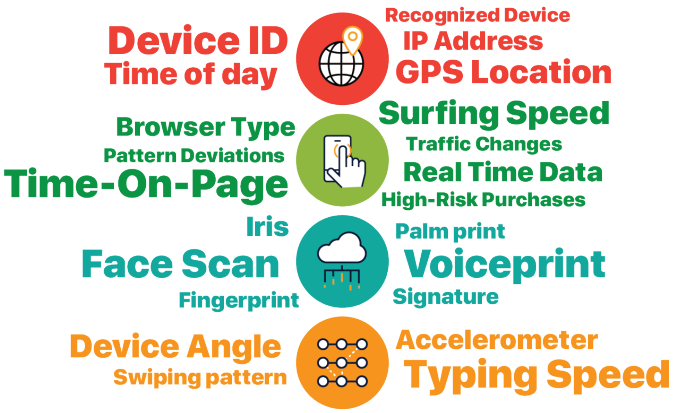
The security of power transmission and distribution grids has been the focus of an ever-growing attention. Recent advances in networking have enabled a plethora of applications for present and future power grids such as smart metering, voltage stability monitoring, and power system state estimation. However, these recent advances have also increased the grid's vulnerability to cyber-attacks, which could have devastating economical, and ecological consequences, such as the infamous attack on the Ukrainian power grid in December 2015. One such growing cyberthreat is attacks targeting the time synchronization of phasor measurement units, e.g., by spoofing GPS signals.

A promising approach for the detection and mitigation of cyber-attacks is using machine learning. As the number and the capabilities of the network components in the power grid increase, the components can generate and record huge amounts of data, which could be of great value not only for operations but also for detecting attacks. By employing state-of-the-art machine learning algorithms to harness the potential of this data, many attacks could potentially be detected before inflicting significant damage to the grid. Nonetheless, an important aspect of a machine learning-based attack detectors is that they should be trustworthy. For example, they should be robust to adversarial attacks. Furthermore, a distributed solution is usually preferred, since it might be infeasible to collect all data in one location.

In this project you will investigate the vulnerability of modern power grids to data manipulation attacks, will develop attack scenarios, and will investigate the potential of distributed machine learning algorithms to detect the attacks in a timely manner. For the evaluation you will be able to work with publicly available power grid data sets.

Project L9: Distributed machine learning for generation and detection of attacks against continuous authentication

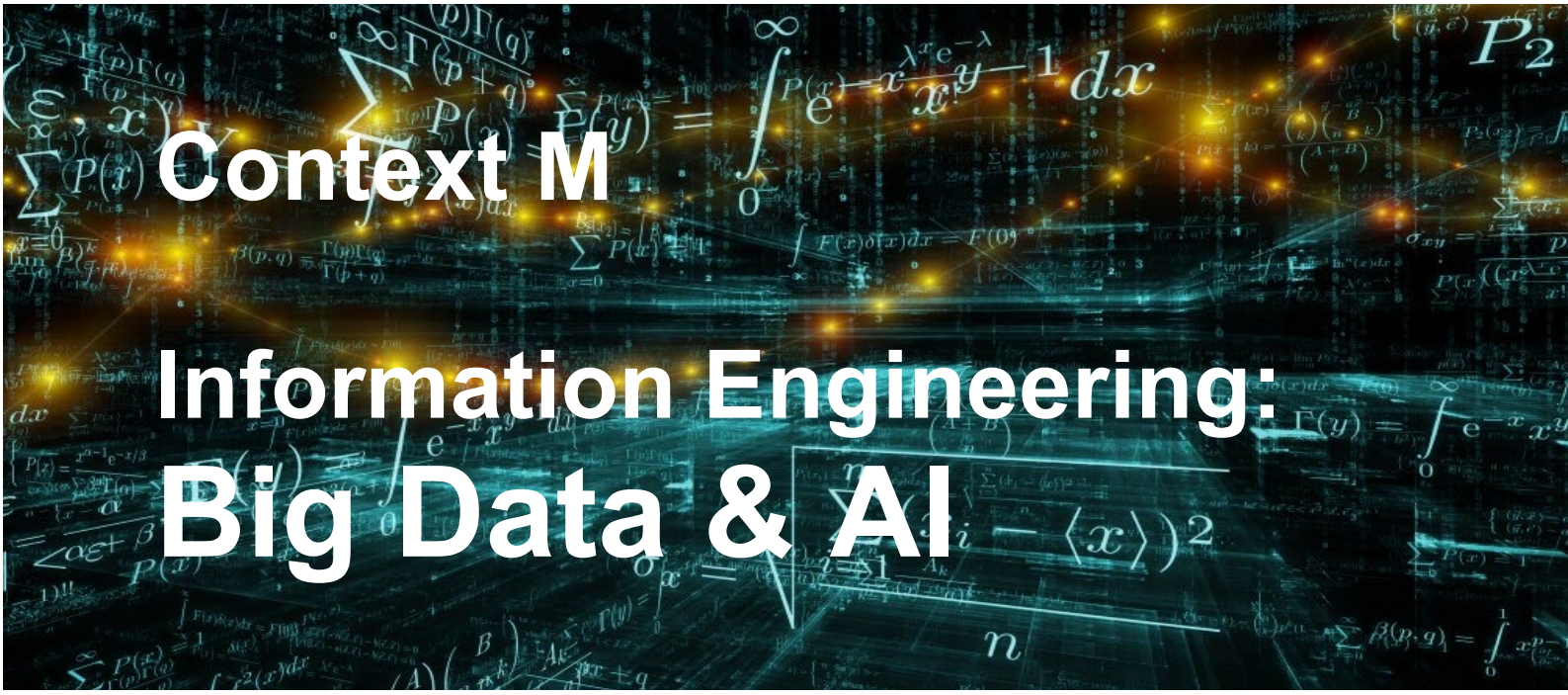
Supervisor: Ezzeldin Shereen (eshereen@kth.se), György Dán (gyuri@kth.se)



Continuous authentication (CA) is emerging as a promising security solution for authentication management for websites, private networks, and even mobile apps. When using CA, user access is not granted based on one-time authentication (e.g., a password), but instead logged-in users are continuously verified in the background without affecting the user experience. The verification can be based on the observed user behavior, such as a user-specific typing pattern or mouse movements or on intrinsic user features such as continuous face recognition. The common expectation is that CA would allow to mitigate common threats, such as identity theft and session hijacking.

Recent advancements in CA have shown that state-of-the-art CA systems based on machine learning classifiers can accurately distinguish a user´s behavior from that of other users. However, whether the CA system would be able to distinguish a user from an attacker whose objective is to impersonate the legitimate user, is a more complex question. With huge progress in the field of generative modeling, and especially Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs), the security of CA systems should be put under scrutiny. In principle, generative modeling could enable an attacker to generate data that mimic the user behavior with high accuracy.

In this project the objective is to investigate the feasibility of learning adversarial examples that evade state of the art CA solutions. As a first step, you will make yourself familiar with statistical models and machine learning methods used for CA, and generative models that can be used for creating adversarial input. You will then design a generative model for creating an evasion attack and will assess the ability of the generative model for bypassing CA. The evaluation will be based on publicly available continuous authentication datasets from multiple sources ranging from keyboard patterns to smartphone touch and swipe patterns.



Context M

Information Engineering: Big Data & AI

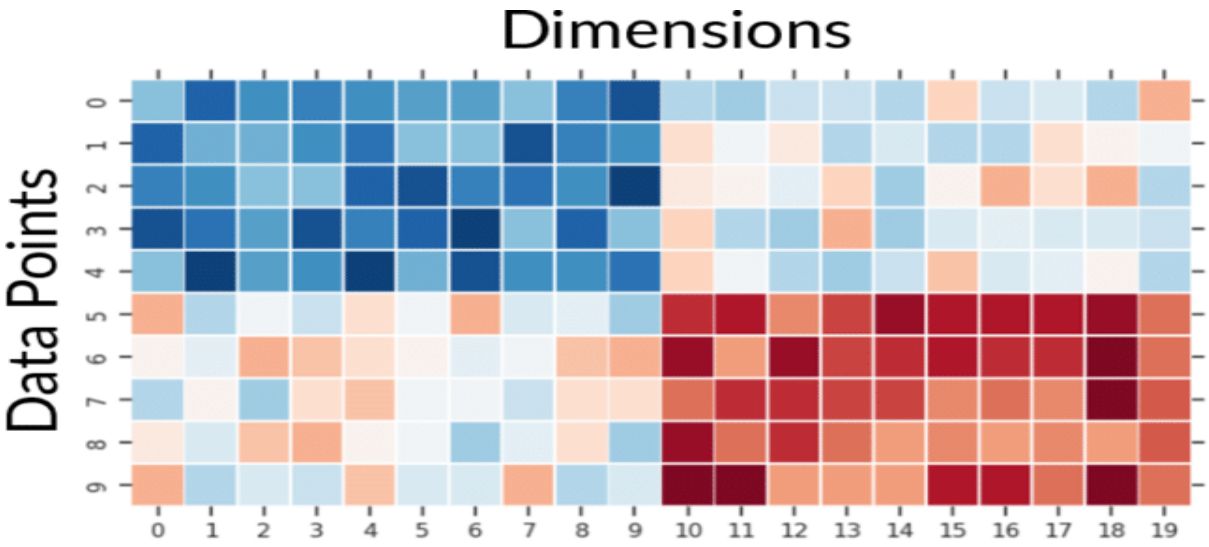
Big Data and artificial intelligence are broad topics with huge technological and economical potentials and therefore is of interest in many areas. From an engineering point of view, it is mostly related on how to process data. Currently, information and communication technology (ICT) is penetrating all systems to make them *smart,* e.g. we envision smart cities, smart homes, smart grids, etc. or Internet of things in general. The smartness of the systems is built on the principle to sense the system environment and then draw smart decisions on it. However without algorithms that extract information from the data, the information is buried in the data and cannot be exploited. Thus, the process of extracting information will be the key ingredient of many future technologies and is the main objective of technologies nowadays known as artificial intelligence (AI), machine learning, data mining, pattern recognition, data analytics, adaptive signal processing etc. which are all instances of information engineering.

In general, we can say that the more data we have, the smarter the system will be. Thus, advanced smart systems sooner or later face the big data problem, which commonly means that the amount of the data is *too big* to be processed e.g. with standard tools. Therefore, there are huge research efforts developing novel information processing and data analytic methods, which enable future systems to deal with larger and larger data sets.

Innovative information processing and data analytic methods are traditional topics of the Information Science and Engineering Division. Thus, the subprojects offered in this course will address fundamental topics and problems in the area with a strong engagement of the department's teachers. Accordingly, all offered Bachelor projects are closely related to some of the on-going research projects in the division. In particular, we offer project that deal with sparse high-dimensional linear regression models, decentralized decision making and prediction for IoT, contribute to the next generation genome sequencing technologies, checking limitations of current deep neural network implementations, testing intelligence of AI systems, improved document scanning mechanisms, and deep-learning based multi-stage biometric identification system. Since information processing is quite abstract, all projects require a good mathematical background and solid programming skills.

Project M1: Robust Variable Selection in High-Dimensional Data

Supervisor: Magnus Jansson, janssonm@kth.se, Information Science and Engineering Division



Problem statement: High-dimensional datasets with large number of potential covariates (dimensions) and very few measurements (data points) to explain the response variable is common in many research fields. In such large datasets, assuming that the data points obey a linear relationship with the covariates, selection of the true variables, which best describe the data is an important requirement in data analysis in the field of finance, biology, marketing etc. The job is challenging especially in the presence of multi-collinearity and non-normality of data.
Till date a wide variety of covariate selection techniques for linear models have been proposed such as orthogonal matching pursuit (OMP), least absolute shrinkage and selection operator (LASSO), elastic net, etc., each having different mathematical properties. As such, it is possible that they may lead to different solutions, i.e., the subset of covariates selected for the same dataset may vary for different methods. A current problem for the researcher is to know the extent to which the choice of method of selection will impact upon study results and therefore, the extent to which results will be reproducible with different methods.

Aim of the thesis project: The aim of this bachelor thesis project is to gain insights into the field of variable selection in sparse high-dimensional linear regression models, evaluate a relatively high-dimensional dataset to compare results obtained from well-documented, automated methods of variable selection.
The dataset for this project will be either from the field of biology (example: Gene expression data) or finance (example. Boston housing prices) and will be provided to the students.
The purpose is to identify the extent to which variable selection would change depending on the method used and whether combining results across methods could provide additional insights into the selection process.

References

1. Marques, Elaine Crespo, et al. "A review of sparse recovery algorithms." *IEEE Access* 7 (2018): 1300-1322.
2. Ding, Jie, Vahid Tarokh, and Yuhong Yang. "Model selection techniques: An overview." *IEEE Signal Processing Magazine* 35.6 (2018): 16-34.

Project M2: Distributed Machine Learning for IoT

Supervisor: Ragnar Thobaben (ragnart@kth.se), Div. of Information Science and Engineering (ISE)

IoT application like smart homes and smart buildings generate a large amount of data today (e.g., sensor readings) that are typically collected through a network infrastructure and stored and processed centrally (e.g., in a cloud infrastructure) in order to enable new data driven services for the users. This approach leads to several concerns; for example, centralized processing of user data comes at a high communication cost, it may lead to privacy breach, and in some cases, may be infeasible due to real-time latency constraints. The goal of this project is therefore to investigate and implement distributed machine learning tools that enable decentralized decision making and prediction. Specifically, this project will investigate how machine learning techniques like teacher/student learning and knowledge distillation (e.g. [1]) can be used to distil smaller local models from a given larger global model in order to distribute decision-making and prediction functionalities in the network. An example of such an approach where knowledge distillation is considered for model compression in an IoT context is given by [2].

The steps in the project are now as follows:

- In self-studies, the students are expected to acquire the required machine learning skills to execute this project. Following publicly available online lectures has been a successful approach to this in previous years.
- For a given IoT dataset (e.g., smart home data), the students are expected to identify interesting prediction and classification problems (e.g., presence or absence of a person, status of heating system), and to train and implement a global machine-learning model (e.g., an artificial neural network) for these tasks.
- Based on the global model, the goal is to train smaller low-complexity models that capture some properties of the global model. The work in [2] can be used as a guide.

The project is fairly open and leaves students with a lot of space to develop and pursue own ideas. Since this freedom also can be a burden, this project is only recommended for creative students with strong mathematical and programming background. Students working in this project will be supported by Ragnar Thobaben.

References

[1] G. Hinton et al., "Distilling the knowledge in a neural network," arXiv preprint arXiv:1503.02531, 2015.

[2] K. Bhardwaj et al., Marculescu. "Memory-and communication-aware model compression for distributed deep learning inference on IoT," ACM Transactions on Embedded Computing Systems, 18:5, 2019.

Project M3: Dynamic modelling of DNA Helicase for genome sequencing

Supervisor: Joakim Jaldén, jalden@kth.se, Information Science and Engineering Division

The latest generation of DNA sequencing methods are able to electrically read the bases of a single DNA molecule as it passes through a nanopore of a measurement device. This can happen by either recoding ionic currents that flow along with the molecule and parallel to the DNA sugar-phosphate backbone, or quantum tunneling currents that bridges individual nucleotide bases in perpendicular to the backbone. Either way, unconstrained translocation through the poor is too fast to be recorded, so typically a DNA helicase molecule is used to both separate the two strands of the DNA double helix and ratchet the DNA through the pore one nucleotide base at the time.

A complicating factor is that the DNA helicase consumed ATP molecules, an energy carrying molecule of the cell, and the speed at which the DNA molecule translocate through the pore thus depends on the ATP concentration, which may vary across the experiment. This causes problems in the interpretation of the electrical signals obtained from the sequencing device. The purpose of this project is therefore to create a mathematical dynamical model for the DNA helicase molecule that links the translocation speed to the ATP concentration, and to estimate the translocation speed from the raw electrical measurements.

This bachelor thesis project will provide a piece to the puzzle of developing next generation sequencing technologies with the context of a large-scale project that involves diverse expertise. A brief overview of the project can be found at https://bit.ly/2FjwEZH. It is recommended for this project that you are comfortable with the Python programming language and have some experience with the Linux command line environment.

Project M4: Beyond Deep Learning in the Era of Big Data

Supervisor: Saikat Chatterjee, sach@kth.se, Information Science and Engineering Division

For years, ‘Object Recognition’ has been one of the most classical, yet challenging, areas of research in the signal processing and machine learning society. In the last decade, the ever-growing interest in big data has influenced many of the research societies, including machine learning; where nowadays, with availability of big object recognition datasets such as, ImageNet or MNIST, a classification performance of ‘almost’ 100 percent is in demand. To achieve such a high performance, Deep Neural Network has emerged as a potential candidate in recent years. The prime limitations of today’s deep learning are their prohibitive training cost and lack of interpretability. In this project, we use alternative neural network-based structures to improve the state-of-the-art performance for various classification and regression datasets. This is mainly to go beyond currently available

methods. To this end, we will employ some new research methods developed in our research and compare with currently popular neural network architectures, such as Extreme Learning Machine (ELM) and Deep Neural Networks (DNN), and try to design new neural networks based on the requirements of the problem. In doing so, we may utilize different methods, like Gaussian Mixture Model, Kernel Regression, Sparse dictionary learning, etc. The steps of the project are as follows:

- Reading and understanding the related materials and mathematical tools
- Preparing the experimental platform for datasets
- Implementing some of the current neural networks architectures to compare their performance with your own architectures
- Designing and implementing alternative new neural network architectures
- Writing a report and comparing your methods with others (Possibly a research article)

*Students must have a preliminary background in matrix linear algebra and probability.

**For interested students, we have an extension part as in the following.

In every machine learning algorithm, the number of the training samples is a critical parameter. It is expected that by using more number of training samples, we can get a better performance. Consider an image classification dataset, e.g. Caltech 101, in which the number of training samples in Class 1 is 'much' smaller than the number of the samples in other classes. In this particular dataset, if we look at the classification accuracy of Class 1, it is well-less than the average classification accuracy, regardless of the learning method we are employing. Now, the natural question that arises here is that how we can improve the classification accuracy of that particular Class 1, in which we don't have enough samples to achieve an acceptable performance? In this project, we tend to find a solution for the above question. One easy answer, though, can be to generate new artificial samples from Class 1. Another solution might be the possibility of inferring information from other classes such that it can be used to compensate the lack of training samples in Class 1. Ways to this goal will be sought in this project.

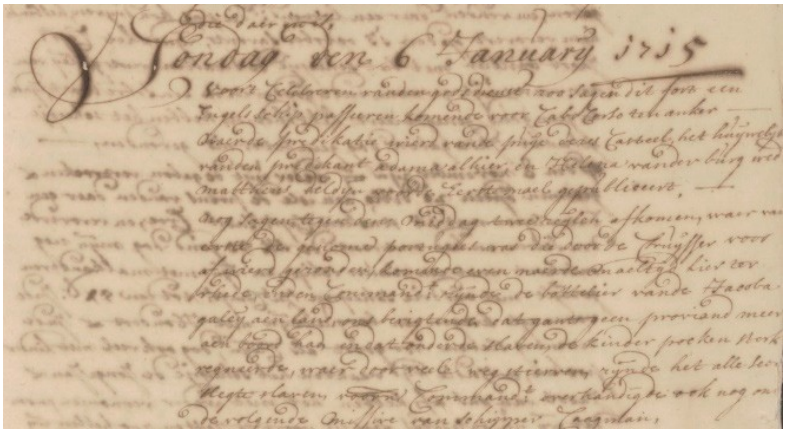
Project M5: Intelligence test of AI system using a fun experiment.

Supervisor: Saikat Chatterjee, sach@kth.se, Information Science and Engineering Division

Abstract: Differentiating between human and doll is a difficult problem. More from pictures of them. Suppose we show picture of a doll to AI system and ask to classify as a doll or human? Little kids can have this problem and can wrongly identify between them. While we are not aware of such a study in child development to test their cognition, we can formulate a platform to test the AI power. The project requires photography, creating light conditions and development of neural networks.

Project M6: Improving Scanned Documents where the Reverse Side Shows Through

Supervisor: Mats Bengtsson, mats.bengtsson@ee.kth.se, Information and Science Engineering Division



Even though the internet is flooded by more or less interesting data, generated from all sorts of sources, ranging from artists and bloggers to various sensors and other machines, a lot of valuable information is still buried in libraries and archives around the world. This cultural heritage, in the form of printed books and handwritten manuscripts is successively made available in digital form, but this digitalization involves many challenges.

One of the challenges when scanning a document appears if the paper is so thin that the text or images from the reverse side of the page shows through. Especially, in hand-written manuscripts and some old prints, the ink may have bleeded through the paper, making it more or less impossible to interpret the scanned information. However, show-through effects can also appear when scanning modern printed papers, since some light passes through the paper during the scanning process.

Luckily, you often have access to scans of both sides of the paper, meaning that you have access to two images, which both contain information about the original information that was written or printed on the two pages. This makes it possible to apply different signal processing methods to try to separate the information from the two pages. The bleed-through or show-through phenomenon is typically non-linear, thus requiring non-linear restoration methods. Related techniques for separating multiple sources that have undergone a mixing process are also used in audio processing, for separation of several simultaneous sound sources, based on microphone signals. This is called blind source separation.

The goal of this project is to identify a couple of algorithms from the literature and implement and evaluate these both on data that has been generated synthetically, so that the “true” solution is known, but also on authentic scans. Even though neural networks are known to be good candidates for non-linear processing algorithms, there are surprisingly few publications proposing such solutions for this particular problem. Therefore, there might be possibilities to propose and try out new solutions. The evaluation of the different algorithms can be based both on some mathematically defined “objective” performance criterion, but also on a more “subjective” visual impression.

References

[1] Oda, Mikio, and Hiromi Miyajima. "Show-through cancellation in scanned documents using two-layer bidirectional neural networks." *2014 Joint 7th International Conference on Soft Computing and*

Intelligent Systems (SCIS) and 15th International Symposium on Advanced Intelligent Systems (ISIS). IEEE, 2014.
[2] Huangy, Yi, Michael S. Brown, and Dong Xu. "A framework for reducing ink-bleed in old documents." *2008 IEEE Conference on Computer Vision and Pattern Recognition*. IEEE, 2008.
[3] Sharma, Gaurav. "Show-through cancellation in scans of duplex printed documents." *IEEE Transactions on Image Processing* 10.5 (2001): 736-754.
[4] Ehsandoust, Bahram, et al. "Blind source separation in nonlinear mixtures: separability and a basic algorithm." *IEEE Transactions on Signal Processing* 65.16 (2017): 4339-4352.

Project M7: Deep Learning-based Multi-stage Biometric Identification

Supervisor: Tobias Oechtering, oech@kth.se, Information Science and Engineering Department

Machine learning models based on neural networks and deep learning are adopted in many areas since they provide a very powerful framework for supervised learning. In this work, we are interested in implementing a deep learning-based multi-stage biometric identification algorithm. The problem of biometric identification system is studied in [1, 2, 3]. The objective of biometric identification is to predict the user identity, which corresponds to the label in the classification problem of machine learning. Therefore, the problems of biometric identification and classification are similar. Thus, it is intuitive to implement machine learning to realize biometric identification. However, there is also a major difference between these two problems. The number of labels in the classification problem is usually limited, e.g., 10 labels in the CIFAR-10 dataset, 3 labels in the IRIS dataset, etc. While in biometric identification problem, the number of users can be much larger than that. Therefore, implementing a machine learning algorithm in biometric identification could lead to possible degradation of performance.

To overcome this problem, we propose to design a multi-stage algorithm based on deep learning. The users are divided into several groups. We first train a deep neural network (DNN) with all the users, with labels corresponds to the group index. Then another DNN is trained by the users in the same group, with labels corresponds to the true user index. Suppose that we divide the users into N groups, then this two-stage algorithm results in N + 1 DNNs. This method can also be generalized to M-stages with M > 2.

In this project, a fingerprint dataset or face scans dataset should be used.

1. Implement a basic DNN to identify (classify) all the users.
2. Implement the proposed two-stage approach to identify the users. Try with the different numbers of groups and analyze the impact on the performance, e.g. complexity and training/validation error.
3. Compare the performance of the two-stage method with the basic method and analyze the result.
4. Implement the proposed N-stage approach to identify the users, where N > 2. Similar to the second goal, try with different numbers of groups and analyze the impact on the performance, e.g. complexity and train- ing/validation error.
5. Compare the basic method, the two-stage method, and N-stage method, and analyze the result.

In the listed five goals, the first three aspects are necessary to accomplish the project, since they are the basic steps for designing a neural network. The fourth and fifth goals are optional.

Required Skills: This project requires some basic knowledge of deep learning and solid programming skills, such as Phyton. Some basic knowledge in information theory would be useful but it is not mandatory.

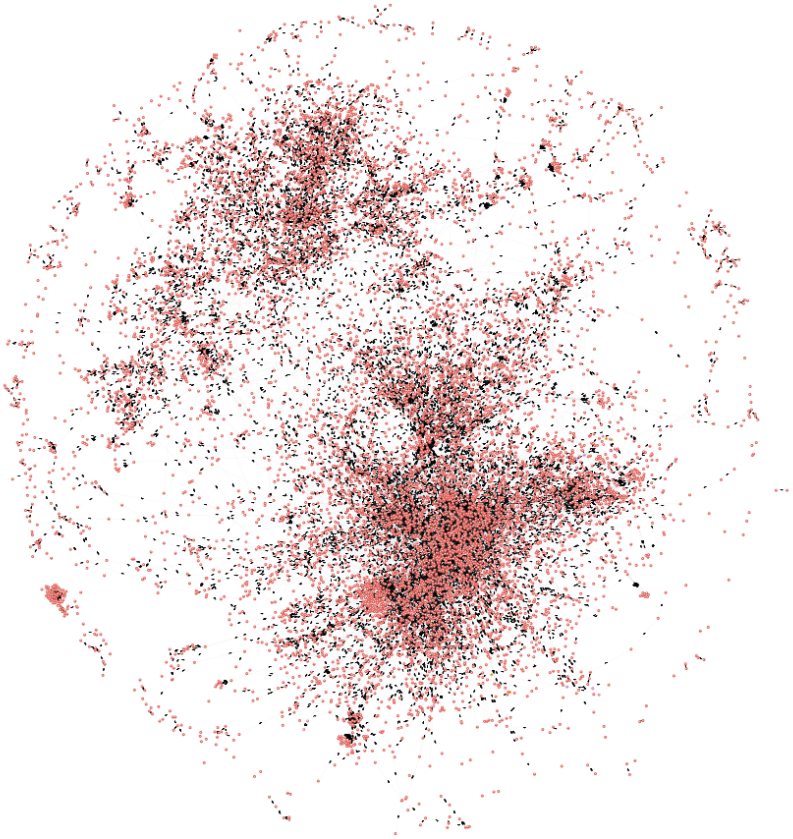
References

[1] F. Willems, T. Kalker, J. Goseling, and J. P. Linnartz, “On the capacity of a biometrical identification system,” in Proc. IEEE Int. Symp. Inf. Theory, Jun. 2003, pp. 82–87.

[2] F. Farhadzadeh and F. M. J. Willems, “Identification rate, search and mem- ory complexity tradeoff: Fundamental limits,” IEEE Trans. Inf. Theory, vol. 62, no. 11, pp. 6173–6188, Nov. 2016.

[3] L. Zhou, M. T. Vu, T. J. Oechtering, and M. Skoglund, “Fundamental limits for biometric identification systems without privacy leakage,” in 2019 57th Annual Allerton Conference on Communication, Control, and Computing (Allerton), Sep. 2019, pp. 1105–1112.

Context N
Automatic bug fixing



General description

In this research project, we invent systems to automatically fix software bugs. Our systems repair Java code, are strongly validated on real bugs and large scale programs. Our software prototypes are all made open-source for sake of reproducible research and open-science.

Read more:

- Curated introductory pointers about program repair
- Curated introductory pointers about self-healing software
- Survey on automatic bug fixing
- Our best-of-breed automatic repair systems for Java: Nopol, Astor, NpeFix

Project N1: Automatic Categorization on AI Patches with AST Analysis

Supervisor: Martin Monperrus, KTH Royal Institute of Technology

KTH has invented a new system called Sequencer for producing patches with machine learning [1]. Sequencer learns from past diffs using sequence-to-sequence learning. The student will perform a large scale analysis of the Sequencer patches. The experiment will involve the Gumtree AST diff library and will be done on a scientific computing grid.

1. SequenceR: Sequence-to-Sequence Learning for End-to-End Program Repair
2. Benchmark of single-line bugs

Project N2: Automatic Program Repair of Bears with Repair Templates

Supervisor: Martin Monperrus (KTH Royal Institute of Technology)

Description: In automatic program repair, template-based repair is an effective way to reduce programs with little overfitting [1]. The student will implement template-based repair in Astor [3], based on the consolidated list by Liu et al [1]. The student will design design and perform a large scale experiment of template-based repair on the BEARS benchmark [2], with quantitative and qualitative analysis.

1. TBar: Revisiting Template-based Automated Program Repair
2. Bears: An Extensible Java Bug Benchmark for Automatic Program Repair Studies

https://github.com/SpoonLabs/astor

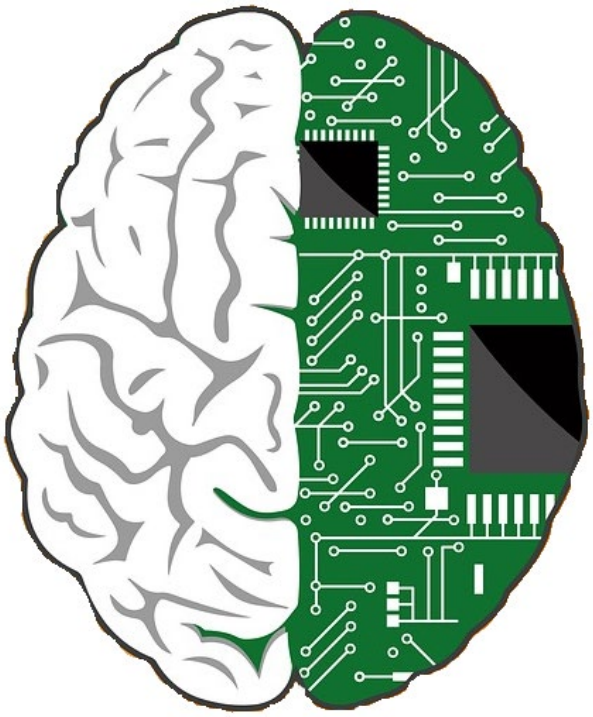
Project N3: Neural Repair of Static Analysis Warnings

Supervisor: Martin Monperrus, KTH Royal Institute of Technology

Description: Static analysis tools are much used in industry to statically detect bugs and code smells. You will research in the area of machine learning for repairing static analysis warnings. You will devise, implement and evaluate an approach based on sequence-to-sequence learning. The considered static analysis tools are SonarQube-java and Facebook infer.

1. Automatically Generating Fix Suggestions in Response to Static Code Analysis Warnings (2019)
2. Adversarial Robustness for Code (2020)

Context O
Computational brain modelling and brain-like computing



The general focus is here on developing, studying and/or applying connectionist (network based) brain models. The proposed topics range from simulating detailed spiking neural networks to investigating and validating more abstract brain-like computing architectures. Projects can be formulated to either address theoretical questions or test the networks' functionality in applications.

Please bear in mind that project details and specific research questions within the proposed themes are discussed individually with students depending on their interests. There is also a lot of flexibility in defining the scope and size of these projects. Some project ideas at the cross-sections of the following themes can be proposed/found. Students will have an opportunity to learn to use dedicated simulation software (with a possibility to rely on Python interface) or exploit their programming competence to build their own computational tools for theoretical or applied research. The focus however is on the scientific essence of the project, not on the methodology used.

The suggested projects are organized in three main themes, each of which describes a set of proposed topics. The lists of topics and some project ideas are not meant to be limiting in any sense and can therefore be easily expanded by students' own ideas.

Project O1: Simulations and analysis of neural network models with emphasis on attractor memory networks

Supervisor: Pawel Herman (paherman@kth.se), Department of Computational Science and Technology (CST)

***General theme*:**
There have been a range of theoretical concepts of brain computations proposed in computational neuroscience. Among the connectionist (network-based) approaches to modelling brain function, an attractor theory of neural computations has recently received particular attention. The functionality of attractor networks has been found helpful in explaining various perceptual and memory phenomena. Consequently, these models can be considered as fundamental components of systems level approach to modelling brain function within the framework of network-of-networks architecture. An implementation of attractor memory models can range from a more biologically plausible networks of spiking neurons to more abstract networks of units with continuous rate-based input/output.
More biophysically detailed models with spiking neurons and synapses provide an opportunity to study rich neural dynamics in close relation to biological data, and specifically, recordings from the brain tissue. This way both dynamical and functional aspects of fascinating cortical phenomena can be studied. Such spiking neural network models are usually developed using dedicated simulation software, e.g. Nest, Neuron, Genesis etc.
More abstract networks relying on rate-based units (i.e. with non-spiking real-valued input/output) on the other hand allow for constructing larger systems with the aim of exploring functional aspects of the simulated attractor memory system. In this context, both generic theoretical investigations into computational capabilities of memory (learning, memory capacity etc.) as well as specific applications in pattern recognition, whether in a biological or non-biological data mining context, can be pursued.
Within this theme other computational theories of the brain, e.g. liquid state machines, can also be studied. In this regard, computational or dynamical aspects as well as application-oriented questions may be explored. Students can make use of existing software simulators or developed their own implementations of network models.

Project ideas

a) Studying the effect of different connectivity patterns, network architectures and their dimensionality on the dynamics and function of the attractor model.

b) Investigating the sensitivity of the model to the level of biological detail being accounted for (discussion on the required level of complexity and the relevance of biological constraints).

Exploring population-level (e.g. simple mean-field approximation) approaches to describing the neural dynamics exhibited by a modular attractor network.

Project O2: Brain-inspired or brain-like computing algorithms – theoretical developments and applications

Supervisor: Pawel Herman (paherman@kth.se), Department of Computational Science and Technology (CST)

General theme:

Development of brain models to study neural phenomena, as broadly discussed in topic 1.1 above, often leads to better understanding of the nature and purpose of neural computations. From a broader perspective, these computations can be seen as an inspiring model for novel approaches to generic information processing. Good reputation of neural network architectures in this regard is largely due to the impressive capabilities of information processing in the brain, which robustly handles large volumes of noisy multi-modal data received in continuous streams. Consequently, brain-like computing has long been considered as a particularly appealing concept in a broad field of information science. With the increasing availability of powerful computing platforms and intensive development of brain models as well as a growing body of knowledge about computational mechanisms underlying brain function, there is a surge of interest in adapting these functional aspects to devise algorithms for more generic applications in the field of data mining, pattern recognition etc. These efforts are urgently needed and particularly relevant to real-world problems involving so-called big data, for example in exploratory analysis of large volumes of high-dimensional neuroimaging data for research or clinical purposes.

Project ideas

a) Adapting selected brain-like computing paradigms for large-scale data mining, e.g. to perform exploratory search for patterns in brain imaging data (medical diagnostics, see also Theme 3).

b) Devising new brain network inspired approaches to generically process temporal or sequential data and/or comparing to the existing state-of-the art attempts.

c) General evaluation and validation of brain-like computing algorithms on speech recognition, computer vision or other challenging real-world problems.

d) Testing robustness (sensitivity analysis, noise handling capabilities, computational speed) and benchmarking brain-like computing methods against more conventional machine (/statistical) learning techniques on a selected set of benchmark problems.

Devising network hierarchical architectures to model behavioural phenomena like prediction, expectation and filtering (at a reasonable level of abstraction).

Project O3: Bayesian learning in spiking neural network models

Supervisor: Pawel Herman (paherman@kth.se), Department of Computational Science and Technology (CST)

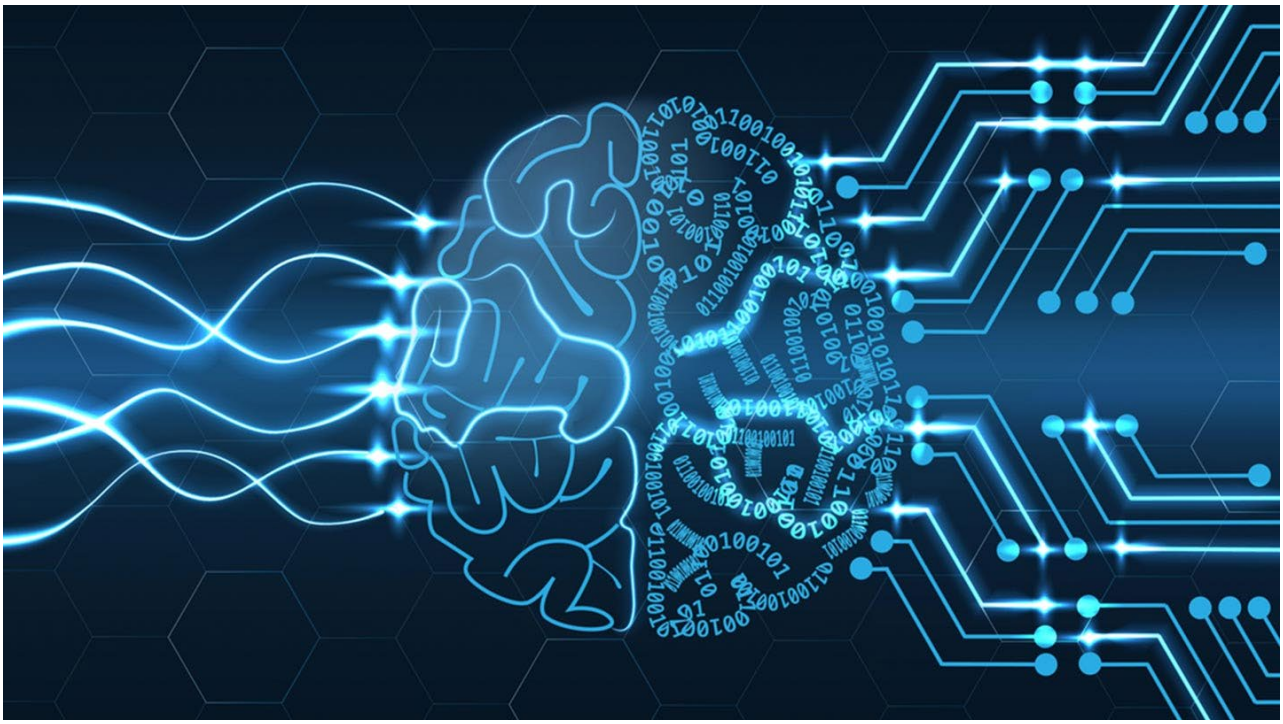
***General theme*:**
The theoretical framework of Bayesian statistics is commonly considered as an intuitively attractive model for representing and processing uncertain information in the brain. It has received a lot of attention in computational studies of learning and inference mechanisms underlying brain function. Since the Bayesian machinery for capturing probabilistic information in distributed neural networks corresponds to a commonly accepted and biologically inspired Hebbian idea of synaptic processes taking place in the connections between cells, there have been numerous attempts to adapt Bayesian inference as an unsupervised learning principle. In this context it is particularly challenging to translate Bayesian algorithms from abstract theoretical formulations to biologically plausible computations in spiking neural network models. In the project a student will support the ongoing work in the lab, where our own learning scheme (Bayesian Confidence Propagating Neural Network, referred to as BCPNN) has been developed.

Project ideas

a) Benchmarking synaptic Bayesian-Hebbian learning rules in a spiking sparse activity cortical associative memory and/or in popular pattern recognition/machine learning tasks.

b) Simulation and analysis of spiking neural network models pre-trained with a Bayesian learning algorithm; studying implications of Bayesian learning on the network dynamics and function.

CONTEXT P
ARTIFICIAL INTELLIGENCE



In this context we have collected projects that are about AI: the development of intelligent agents, that can take in information, reason about it, take decisions and act upon those, in a more or less autonomous manner. With this definition, AI encompasses both reasoning and logic as well as systems that learn from data.

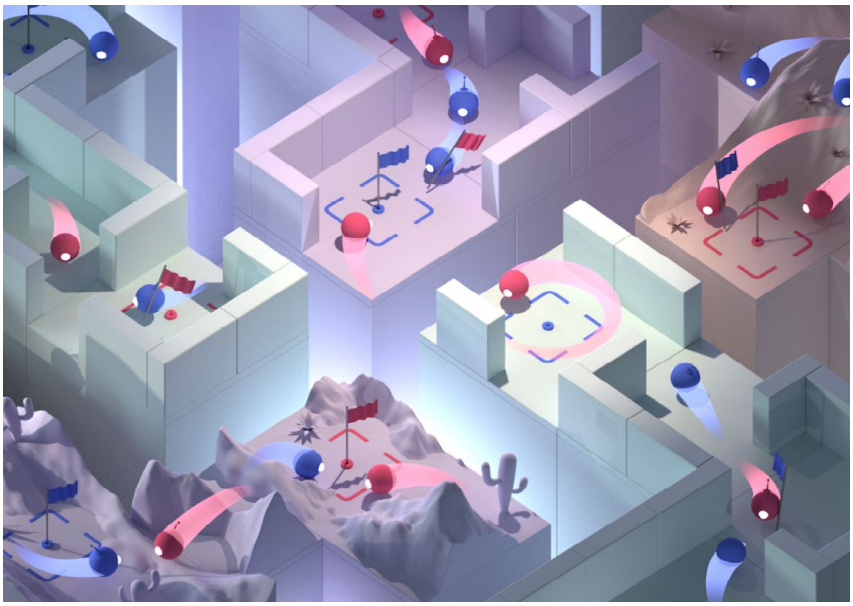
Project P1: Knowledge-Based Strategies for Multi-Agent Systems

Supervisor: Dilian Gurov (dilian@kth.se), Division of Theoretical Computer Science

Key Words: Multi-Agent Systems, Game Theory, Epistemic Reasoning

In a multi-player game, a coalition of players is attempting to achieve an objective within a (potentially hostile) environment, considered to be the opponent. Solving such a game means to find a strategy that achieves the objective regardless of the moves of the environment. Rescue missions involving robots and humans or pursuit-evasion games are examples of such games, often called multi-agent systems.

An interesting, but complicating circumstance is when the players have limited knowledge about the current state of affairs, say due to limited observation capabilities. Such games are called games of imperfect information. A related aspect is posed by the communication capabilities between players. The problem of strategy synthesis under imperfect information and limited communication is known to be hard, and is an active research area.
The present project investigates the modelling of such games, as well as algorithmic techniques for strategy synthesis. In particular, the project focuses on strategies based on the notion of knowledge. In the context of this project, knowledge refers to information, structured suitably, stored and updated during the course of a play, for deciding on a course of action.



Inspirational Reading:

[1] Doyen, L., Raskin, J.F.: Games with imperfect information: Theory and algorithms. Lectures in Game Theory for Computer Scientists pp. 185–212 (2011)

[2] Berwanger, D., Kaiser, L., Puchala, B.: A perfect-information construction for coordination in games. In: Foundations of Software Technology and Theoretical Computer Science (FSTTCS'11). LIPIcs, vol. 13, pp. 387–398 (2011)

[3] Huang, X., van der Meyden, R.: Synthesizing strategies for epistemic goals by epistemic model checking: An application to pursuit evasion games. In: Proceedings of AAAI 2012 (2012)

Project P2: Taktisk AI

Handledare: Mika Cohen (mikac@kth.se, mika.cohen@foi.se)

Nyckelord: Two-Player Zero-Sum Games, Monte-Carlo Tree Search, AlphaZero

Bakgrund

De senaste årens utveckling av självlärande AI har i grunden förändrat hur abstrakta strategispel bedrivs och kan bedrivas. Ett abstrakt strategispel kan med en måttlig arbetsinsats ges en AI som på egen hand lär upp sig själv i spelet genom att spela mot sig själv om och om igen. Det här innebär att det nu är praktiskt möjligt att utveckla AI även för nischade abstrakta strategispel så som exempelvis de specialiserade datorkrigsspel som används inom försvarsmakter runt om i världen för att utveckla och träna militär taktik och strategi.

Syfte

Projektet syftar till att utveckla en AI för ett abstrakt strategispel från FHS/FOI.

Metod

AI:n spelar det abstrakta strategispelet med hjälp av Monte-Carlo Trädsökning (MCTS), en form av förstärkt inlärning som bl.a. utgör kärnan i AlphaZero från Google DeepMind.

Projektet implementerar sin egen ”spelmotor” för det abstrakta strategispelet. I och med att spelet definieras av ett litet antal, enkla spelregler förväntas det underlätta att arbeta med en egen (avskalad) implementation (utan grafik, etc.).

Nytta

Projektet förväntas ge input till forskning om taktisk AI som bedrivs på FOI.

Litteratur

Bakgrund

- *DeepMind's superhuman AI is rewriting how we play chess*, Matthew Sadler och Natasha Regan, Wired, 2019
- *Krigsspel på officersprogrammet*, https://www.fhs.se/arkiv/berattelser/2018-03-15-krigsspel-pa-officersprogrammet.html

Teori

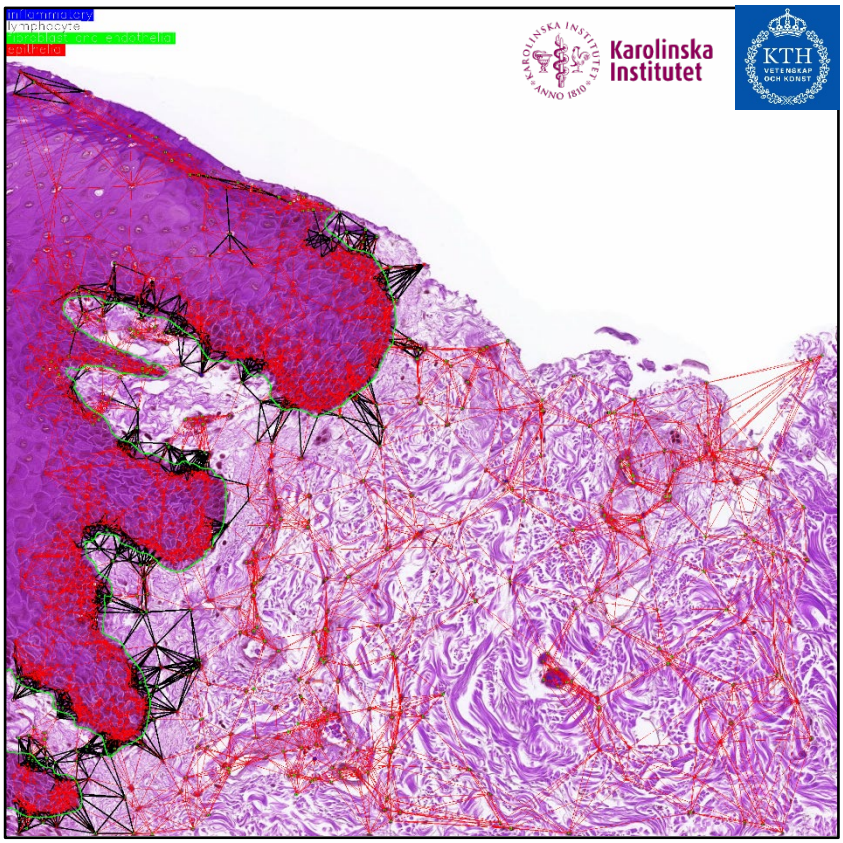
- *Monte Carlo Tree Search and Related Algorithms for Games*, N. R. Sturtevant, Game AI Pro 2, 2017
- *Monte-Carlo Tree Search in Board Games*, M. H. M. Winands, Handbook of Digital Games and Entertainment Technologies, 2016

Tidigare kexarbete i CELTE-3 under samma tema (Taktisk AI)

Wargaming with Monte-Carlo Tree Search, Erik Kalmer och Christoffer Limer, 14:th NATO operations research and analysis conference, https://events.sto.nato.int/index.php/upcoming-events/event-list/download.file/1650, to appear.

Project P3: Boosting Machine Learning by Stain Normalization in Digital Pathology

Supervisor: Karl Meinke (karlm@kth.se) Division of Theoretical Computer Science

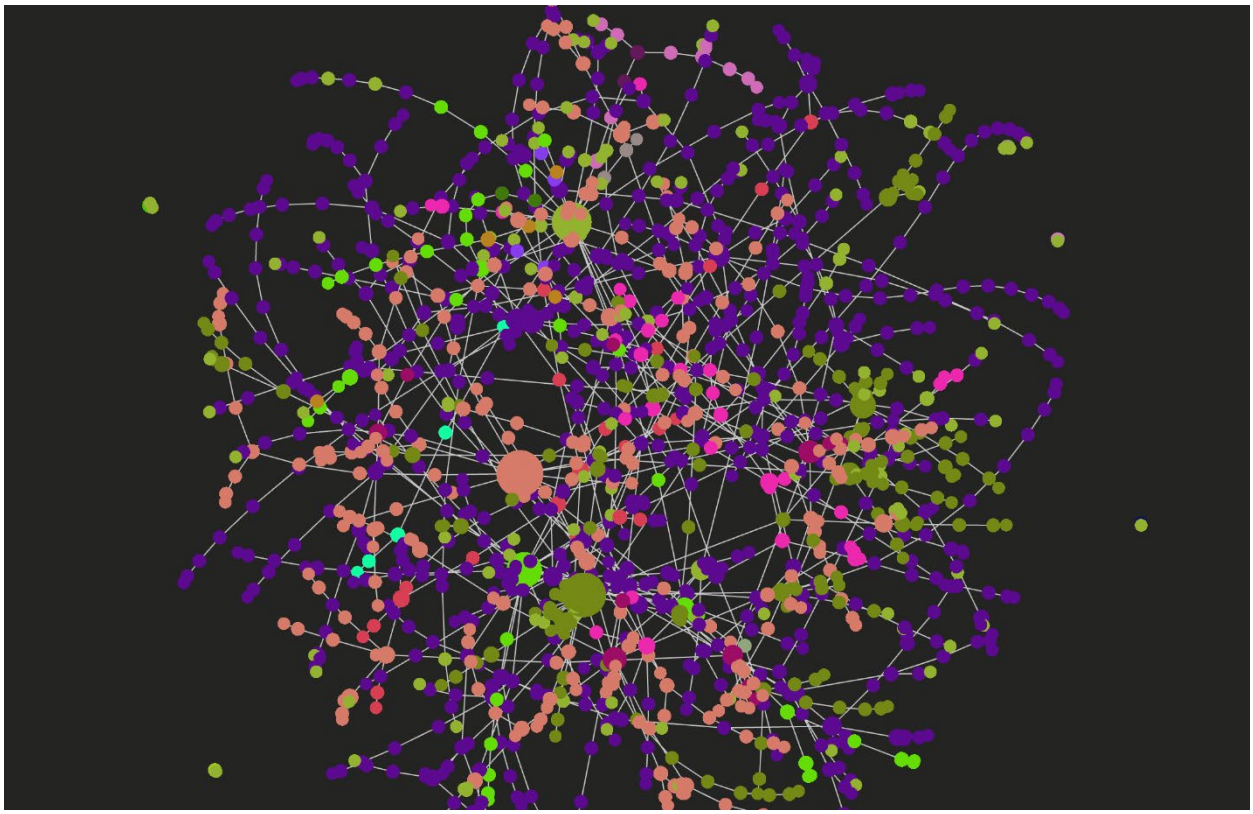


For this project, we are seeking two students with an interest in machine learning (ML) to join a collaborative research project between the Oral Biology and Medicine Group at the Department of Dental Medicine, KI, and Theoretical Computer Science Division, KTH-EECS school. Our long-term KI-KTH collaboration aims to develop ML methods for digital pathology that give faster, more precise diagnostics for patients.

This bachelor thesis project will investigate the use of color normalization algorithms and ensemble learning to boost the performance of CNNs for cell nucleus detection and classification in H&E stained and digitalized oral tissue samples. There is also a need for CNN models that are robust towards data sets coming from different laboratories and hospitals, which is currently a significant challenge. The hypothesis to be investigated in this project is that combining a variety of color normalization (CN) algorithms through ensemble learning is more effective than using any specific CN.

The students will work with an existing KI data set for oral mucosa, Python programming, PyTorch, the EfficientNet CNN, and the publicly available Stain Normalization Toolbox from Warwick University. Access to GPU processors through SNIC is available.
Digital image analysis for diagnostic purposes is a rapidly emerging application of machine learning, and this project is a good stepping-stone towards further ML studies and possibly a future career!

CONTEXT Q
Big Graphs of Software Packages



The software infrastructure for scientific research depends on third-party packages developed and maintained by vibrant open source software communities. Large package repositories include CRAN for R, Pypi for Python, Maven for Java. These package repositories share one property: they form very large graphs of interdependent software packages that provide a reliable and safe backbone for scientific computing and the web of science. The three projects explore different dimensions of these big graphs.

The Maven Dependency Graph: a Temporal Graph-based Representation of Maven Central. https://zenodo.org/record/1489120

Project Q1: Evolutionary patterns in big software graphs

Supervisor: Benoit Baudry, Software and Computer Systems, baudry@kth.se

Software graphs are composed of software packages and dependency relations between packages. Both evolve regularly over time. New packages are added in the graph and existing packages evolve to offer new features or fix issues. Dependencies evolve according to the popularity of packages and changes in needs. This project investigates the existence of patterns in graph evolution to identify trends, such as migration from one package to another or the systematic co-occurence of some evolutions.

[1] "From time series to complex networks: The visibility graph." Lacasa, Lucas, et al. *Proceedings of the National Academy of Sciences* 105.13 (2008): 4972-4975.
[2] “On the evolution of technical lag in the npm package dependency network”. Decan, Mens, Constantinou, . In *International Conference on Software Maintenance and Evolution (ICSME)* (2018,).

Project Q2: Labeling the chain of dependencies

Supervisor: Benoit Baudry, Software and Computer Systems, baudry@kth.se

Software represent the dependency relationships among software packages. Given one package, the developers of this package need to be informed about the provenance of all the packages on which they depend. These packages are labeled, but the current labeling is meant for storage and retrieval (technical, unique ids). It does not adequately capture the provenance of packages. This project investigates the automatic generation of semantic labels for the provenance of packages.

[1] Cox, Russ. "Surviving software dependencies." *Communications of the ACM* 62.9 (2019): 36-43.
[2] Levy, Elias. "Poisoning the software supply chain." *IEEE Security & Privacy* 1.3 (2003): 70-73.

Project Q3: Topology of software graphs

Supervisor: Benoit Baudry, Software and Computer Systems, baudry@kth.se

This project characterizes the topology of software graphs in order to determine the existence of critical nodes or fragile areas in software ecosystems. The scientific and IT communities heavily rely on software packages to reuse functionalities. Hence, it is essential to determine early the potential risks in reusing specific packages. Graph analysis can support this risk assessment task for the scientific community

[1] “Analyzing 2.3 Million Client-Library Maven Dependencies to Reveal an Essential Core in APIs”. Harrand, Benelallam, Soto-Valero, Barais, Baudry. https://arxiv.org/pdf/1908.09757
[2] "Error and attack tolerance of complex networks."Réka, Jeong, Barabási. Nature 406.6794 (2000): 378-382.

CONTEXT R
EMBEDDED SYSTEMS

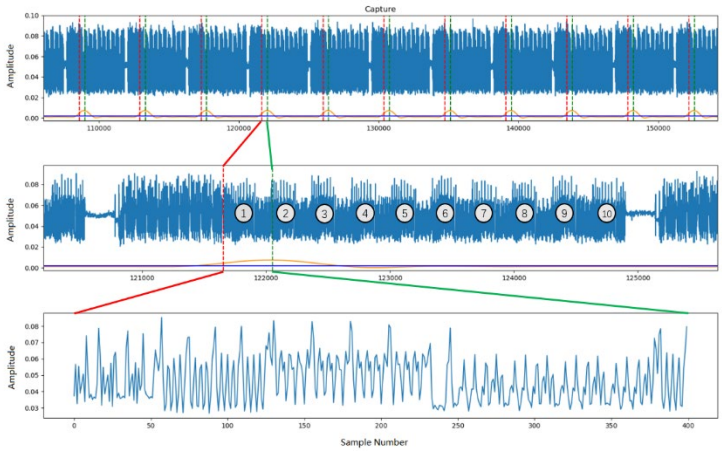
Advanced embedded systems perform an increasing amount of vital functions in areas like transport, communication or health care. Embedded computer systems are integrated into a physical or electrical environment and react continuously with this environment and have to satisfy different requirements, such as real-time, power, size or costs.

The design process is inherently complex, because these systems consist not only of analog and digital hardware, but also of an increasing amount of software controlling the functionality of the system.

In this context, we have collected four projects that are about such advanced embedded systems.

Project R1: Breaking encryption using EM far field side-channels

Supervisor: Elena Dubrova (dubrova@kth.se), Department of Electronics at EECS in Kista



The Internet of Things (IoT) brings with it a need for secure wireless communications. Since deployed IoT devices need to handle encryption and decryption locally, there is concern about side channel leakage of information. The side-channel information can be used to perform Side Channel Attacks (SCA) wherein an attacker can infer the key used in the encryption process.

At present, the Advanced Encryption Standard (AES) is widely accepted and used for encryption. For example, AES is used for Wi-Fi and Bluetooth Low Energy. Successful key recovery of AES has been presented in the past. Recently a new type of side channels was discovered and a successful attack on a device running AES was presented [1].

This new side channel, called screaming channels by the team discovered it, is a far field EM radiation from mixed-signal circuits. The normal information leakage seen in power measurements couples with another signal being broadcast on an antenna. This results in a modulation of the transmitted signal. The modulation corresponds to information leakage.

What makes this different from traditional EM side channel attacks is that we no longer need to measure in the near field which tends to be very close for radio frequency devices. Successful far field EM attacks employing deep learning have been performed up to 15 meters away from the victim device [2], which corresponds to the operating range of a class 2 Bluetooth device.

The project will include:

- Replicating the attack presented in [2] on a WiFi device
- Evaluating its efficacy and determining its limitations
- Exploring state-of-the-art techniques in EM side channel attacks

The candidates are expected to have good background in the following fields: Side channel analysis, radio technology, cryptography, and embedded systems.

Further Reading:

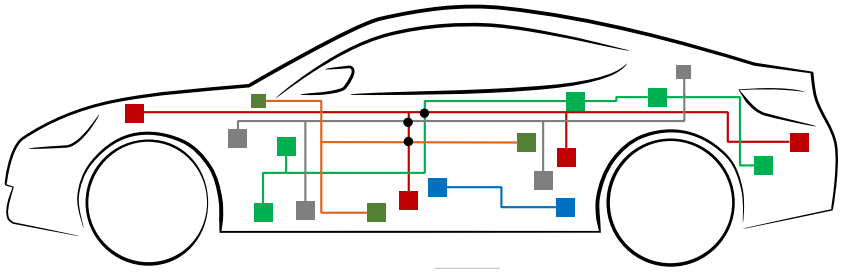
[1] Screaming Channels: When Electromagnetic Side Channels Meet Radio Transceivers, G. Camurati, et al., ACM CCS'2018, see https://www.youtube.com/watch?v=0IafNH2WHxk.

[2] Far Field EM Side-Channel Attack on AES Using Deep Learning, R. Wang, H. Wang, E. Dubrova, ACM Workshop on Attacks and Solutions in Hardware Security (ASHES'2020), https://eprint.iacr.org/2020/1096.

Project R2: Design and Development of a Communication Middleware for Distributed Embedded Systems using Code Generation

Supervisor: Matthias Becker (mabecker@kth.se), Electronics and Embedded Systems

Background:
The complexity of embedded systems is steadily increasing. Both in the number of functions implemented by the embedded platform, but also in the number of electronic control units that are integrated in these systems. One of the prime examples is the automotive industry, where over hundred electronic control units realize the different functions of the car. Many of these functions are subject to timing constraints. This means, correct behavior of the system does not only depend on the result of the computation but also on the time the result is produced.
Such distributed embedded systems contain heterogeneous compute nodes that communicate via shared buses. Powerful compute nodes utilize multi-core CPUs with Linux based real-time operating systems and smaller compute nodes that are based on single-core microcontroller and dedicated real-time operating systems.
To overcome this complexity, Model Based Engineering with code generation is used to automatically generate code from application models but also to configure middleware and drivers for the concrete applications [1].



Project Proposal:
The goal of this thesis project is to develop a communication middleware to be used on heterogeneous compute nodes, that translates high-level signals which are exchanged on application level to messages of the underlaying communication buses.
While the middleware shall be designed to support multiple bus types, the focus of this project is the CAN bus. With this, the middleware needs to map signal IDs to CAN message IDs, as well as segment and reassemble messages that are larger than the maximum payload of a CAN message.
The configuration of the middleware shall be automatically generated from a high-level model using a code-generation framework. During this process, each signal ID is mapped to a CAN messages, with the possibility of multiple high-level signals being transmitted by the same CAN message. As the priority of a CAN message is determined by its message ID, the assignment of message IDs shall be done using an optimal priority assignment algorithm [2]. This is a very important step as the quality of the priority assignment directly relates to the usable bandwidth of the bus. During the code generation process it is also important to verify that each CAN message can meet its timing constraints by computing the response time of each message [2].
Evaluations shall demonstrate different properties of the middleware such as the execution times on the different compute node types.

Further Reading:

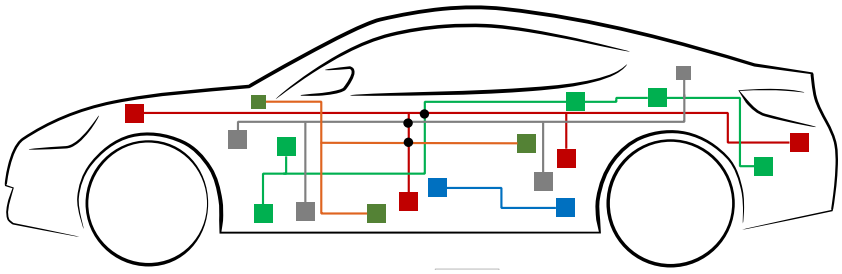
[1] Goseva-Popstojanova, K, Kahsai, T., Knudson, M. et al. Survey on Model-Based Software Engineering and Auto-Generated Code. NASA/TM–2016–219443.

[2] Davis, R.I., Burns, A., Bril, R.J. et al. Controller Area Network (CAN) schedulability analysis: Refuted, revisited and revised. Real-Time Systems 35, 239–272 (2007).

Project R3: From Application Model to Implementation – Generating Application Skeletons for Real-Time Operating Systems

Supervisor: Matthias Becker (mabecker@kth.se), Electronics and Embedded Systems

Background (same as for Project R2):
The complexity of embedded systems is steadily increasing. Both in the number of functions implemented by the embedded platform, but also in the number of electronic control units that are integrated in these systems. One of the prime examples is the automotive industry, where over hundred electronic control units realize the different functions of the car. Many of these functions are subject to timing constraints. This means, correct behavior of the system does not only depend on the result of the computation but also on the time the result is produced.
Such distributed embedded systems contain heterogeneous compute nodes that communicate via shared buses. Powerful compute nodes utilize multi-core CPUs with Linux based real-time operating systems and smaller compute nodes that are based on single-core microcontroller and dedicated real-time operating systems.
To overcome this complexity, Model Based Engineering with code generation is used to automatically generate code from application models but also to configure middleware and drivers for the concrete applications [1].



Project Proposal:
The goal of this project is to automatically generate code skeletons for real-time task sets from an application model that serves as input to the code generation process. Generating the system architecture code as well as the system calls to the operating system simplifies the development process and reduces coding errors. With this, the project also ties into an overall Model-Based Engineering design flow.
The input model will be provided in the AMALTHEA file format (https://www.eclipse.org/app4mc/) and describes the application model and details such as access to shared resources and synchronization mechanisms.
The work shall be extensible, and it shall be possible to generate code for different target operating systems. Focus of the thesis project will be two target operating systems, based on single (https://www.freertos.org/) and multi-core processors (https://www.litmus-rt.org/) respectively.
Evaluations shall be performed to assess the correctness of the generated code as well as the limitations of the approach.

Further Reading (same as for project R2):

[1] Goseva-Popstojanova, K, Kahsai, T., Knudson, M. et al. Survey on Model-Based Software Engineering and Auto-Generated Code. NASA/TM–2016–219443.

[2] Davis, R.I., Burns, A., Bril, R.J. et al. Controller Area Network (CAN) schedulability analysis: Refuted, revisited and revised. Real-Time Systems 35, 239–272 (2007).

Project R4: Telemetry system for a Formula Student electric vehicle

Supervisors: Carl-Mikael Zetterling (bellman@kth.se), Mark Smith (msmith@kth.se), Electronics and Embedded Systems together with the Electronics team of the KTH Formula Student organisation

Background:
With the rapid increase of complexity in modern vehicles in the form of sensors and electronic systems, collecting and analysing sensory data in real time has become vital both for vehicle safety, optimization, and testing. This trend of heavy digitalization of vehicles is equally apparent within the Formula Student competitions, with race cars growing in complexity each year to further optimize vehicle performance and to facilitate driver less technologies.
Since bidirectional telemetry is not allowed while competing this system would purely be used for testing purposes. Nevertheless, such a system would allow team members to monitor vehicle data in real-time which would greatly improve the efficiency at which we can implement and troubleshoot new systems during testing. Bidirectionality in the system could also allow the modification and tweaking on the fly, further simplifying the testing process.
Such a system could also be made flexible enough to be a general data-collection platform usable within other sectors where medium-long range real-time data collection independent of existing networks is necessary.

Project Proposal:
The objective of the thesis is to implement a wireless telemetry solution for the KTH formula student race car that allows for the real time monitoring of all sensory data that is being collected by the car. The first problem to consider will the evaluation of different communication protocols, ICs and antennas to fulfil the requirements set by the team while keeping within the constraints set by regulations on radio-communication.
The aim should be to design a system flexible enough to last through several car models to merit the investment of time and money. Ease-of-use is also vital since the formula student team has a high throughput of members that quickly need to understand how to analyse data using the telemetry system. Thus, an intuitive user interface needs be designed that is accessible via a laptop on the test-site. Another key goal of the implementation is a minimum weight and form factor of all physical parts in the race car.