Projektvalskatalog för kandidatexjobbs-projekt inom elektroteknik VT2020

I denna valkatalog kan du hitta information om alla kandidatexjobbsprojekt inom programmet elektroteknik på EECS, KTH som erbjuds våren 2020. Kandidatexjobbskursen för programmet elektroteknik (EF112X) pågår hela vårterminen. Projekten utförs i grupper om två. Omfattningen på arbetet är 10 arbetsveckor på heltid. Varje kandidatexjobbsprojekt är en del av en större kontext. I år erbjuder vi 76 projekt inom ramen av 18 större kontext:

Kontext inom: Systemteknik och robotik

- Kontext A: Automated vehicles in complex and uncertain situations (J.Mårtensson,7 projekt)
- Kontext B: Autonomous robotic systems (D. Dimarogonas, 3 projekt)
- Kontext C: Learning in Dynamical Systems (C. Rojas, 5 projekts)

Kontext inom: Elkraftteknik

- Kontext D: The CO2-free power system (M. Amelin, 3 projekt)
- Kontext E: HVDC grids (I. Jahn, 3 projekt)
- Kontext F: Kraftsystemstyrning (L. Nordström, 3 projekt)

Kontext inom: Elektromagnetism, fusion och rymdteknik

- Kontext G: Fusion - solens energikälla på jorden (T. Johnsson, 3 projekt)
- Kontext H: Jupiter’s Galilean moons and asteroid Ceres (L. Roth, 4 projekt)
- Kontext I: Space Systems (N. Ivchenko, 5 projects).
- Kontext J: Design and testing of novel microwave/antenna technologies (O. Quevedo Teruel, 5 projekts)
- Kontext K: Electrotechnical multiphysics simulation (M. Becerra, 4 projects)

Kontext inom: Information och nätverksteknik

- Kontext L: AIoT: Artificial Intelligence and the Internet of Things (C. Fischione, 9 proj.)
- Kontext M: Big data and AI (T. Oechtering, 7 projekt)

Kontext inom: Datavetenskap och maskininlärning

- Kontext N: Automatic bug fixing and self-healing software. (M. Monperrus, 3 projekt)
- Kontext O: Neural network based brain models (P. Herman, 3 projekt)
- Kontext P: Artificial Intelligence (M. Cohen, 3 projekt)
- Kontext Q: Algorithms: from theory to experiments (D. Na Nongkai, 3 projekt)
- Kontext R: Multimodal speech signal processing for conversational robots (J. Beskow, 3 project)

Viktiga datum

Informationsmöte: Måndag, 7 okt 2019, kl 15-18, sal D2

Projektval: 28-29 nov 2019 (fysik- och farkoststudenter väljer 1-15 nov 2019)

Kursstart: vecka 3, 2020 (1 timme kick-off info och första möte med handledaren)

Kursslut: vecka 21, 2020 (1 dag kl 8-17 presentationsdag)

Kurs-PM

All information om kursens uppbyggnad finns i kurs-PM. En preliminär version kommer att läggas ut den 1. november 2019 i KTH social under kurskoden EF112X.

Tillgängliga projekt 2020

Alla projekt som erbjuds vårterminen 2020 finns beskrivna i denna pdf-fil. Läs igenom projektbeskrivningarna noggrant. I valet markerar ni vilka projekt ni helst vill göra. Obs, inom ramen av kandidatexjobbskursen som ges på skolan för elektro- och systemteknik, kan man inte "skräddarsy" sitt eget projekt tillsammans med en handledare. Du måste välja ett av de tillgängliga projekten som finns beskrivna.

Val av projekt

När sker valet?

Valet av kandidatexjobbet görs under perioden 28 - 29 november 2019. Undantaget är fysik- och farkoststudenter som väljer 1 - 15 november, 2019. 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 KTH social under kurskoden EF112X (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 som en en-personsgrupp (du kommer sedan tilldelas en projektpartnern.

Tilldelning av projekt

Valresultatet kommer att anslås på kursens hemsida i Canvas innan jul.

Lycka till!

Anita Kullen (kullen@kth.se), kursledare för EF112X kandidatexjobbskurs inom elektroteknik

Context A: Automated vehicles in complex and uncertain situations

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

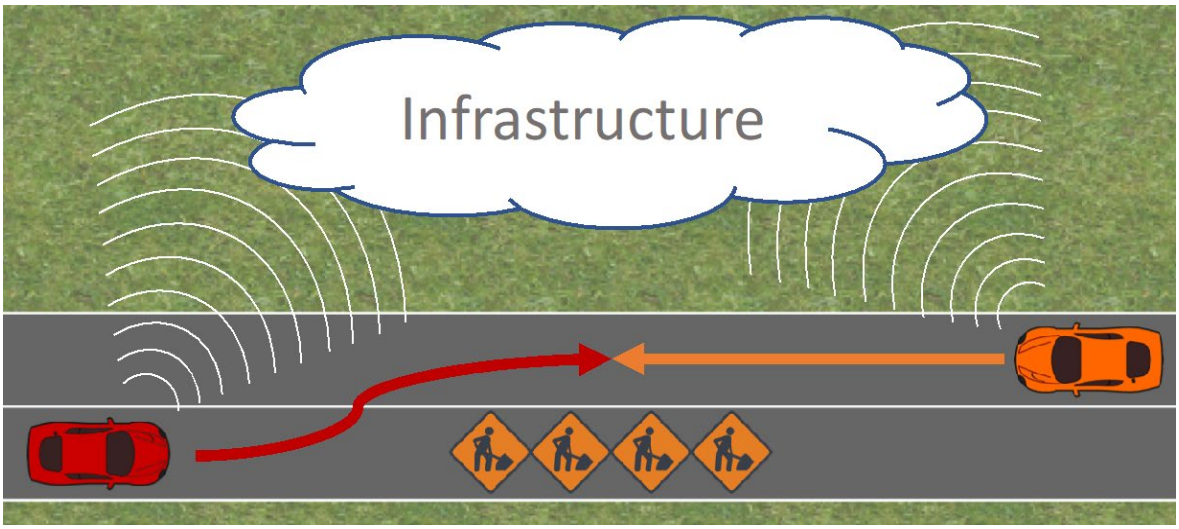
The vision of our future transportation system is that we are able to radically improve the accessibility, efficiency and safety by developing new vehicles, functions and services that take advantage of the rapid advances in sensor, information, and communication technologies. In particular we foresee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

The introduction of connected, autonomous vehicles offers new challenges, as we can expect an increased traffic demand, but also new opportunities for sensing and controlling the traffic. The data that most of the vehicles nowadays provide are already widely used to measure the traffic conditions. It is natural to consider how vehicles could also be used as actuators, driving them in a specific way so that they affect the traffic positively.

However, the traffic environment is extremely complex and uncertain, not the least due to presence of humans, both as pedestrians and drivers of manually driven cars, as passengers of automated vehicles, or as (remote) operators of the fleets. In this context we aim at a deeper understanding of decision-making and control for automated and semi-automated vehicles in uncertain and complex situations.

Project A1. Optimal and scalable conflict avoidance algorithms for autonomous vehicles

Supervisor: Elis Stefansson, Division of Decision and Control Systems, elisst@kth.se



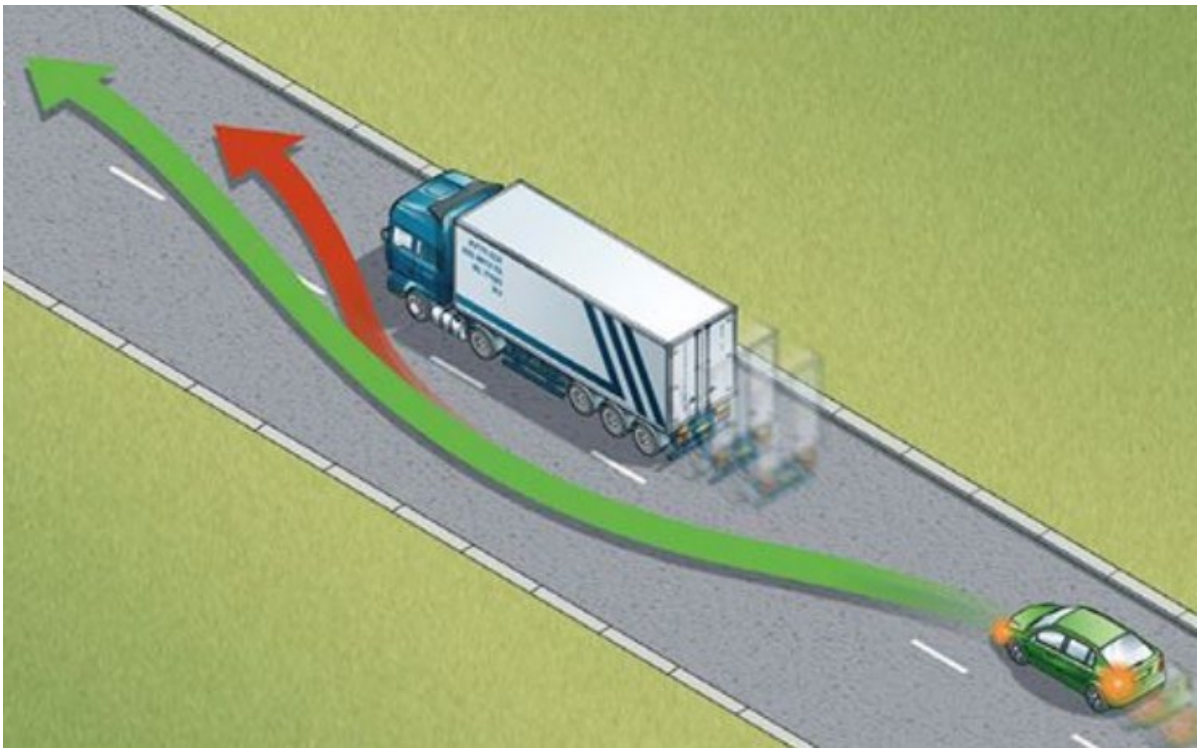
The deployment of autonomous vehicles (AV) has recently received substantial attention. Yet, AV:s still encounter situations where they act sub-optimally. In particular, sharing the road with other vehicles may generate complex interactions, hard to optimize individually for the AV:s. An example is given in the figure, where both AV:s wants to drive in the same lane due to road work. Here, the AV:s can't merely optimize for themselves, but also need to take into account the other AV's plan.

One solution is to let the infrastructure centrally resolve such delicate conflicts by finding the globally optimal solution for all AV:s involved in the conflict and then execute this solution by transmitting it to the corresponding vehicles. Arguments favoring this approach are the following: The infrastructure typically have more computational power, hence solves the problem more efficiently; The infrastructure ideally knows potential conflicts beforehand and can thus precompute solutions before the AV:s encounter them. However, globally optimal solutions are still typically cumbersome to obtain due to the large problem size. To deal with this, different approximations methods can be considered: This is the aim of this project. More concretely, the following should be addressed:

- Formulate the conflict in the example as an optimal control problem.
- Understand how the optimal solution can be obtained by solving a PDE equation known as the Hamilton-Jacobi-Bellman (HJB) equation.
- Solve the HJB equation numerically using approximation schemes.
- Evaluate how well the approximation schemes scales (e.g., with the number of AV:s in the simulation).

Project A2. Safe and efficient overtaking by learning human driving behavior

Supervisor: Yulong Gao, Division of Decision and Control Systems, yulongg@kth.se

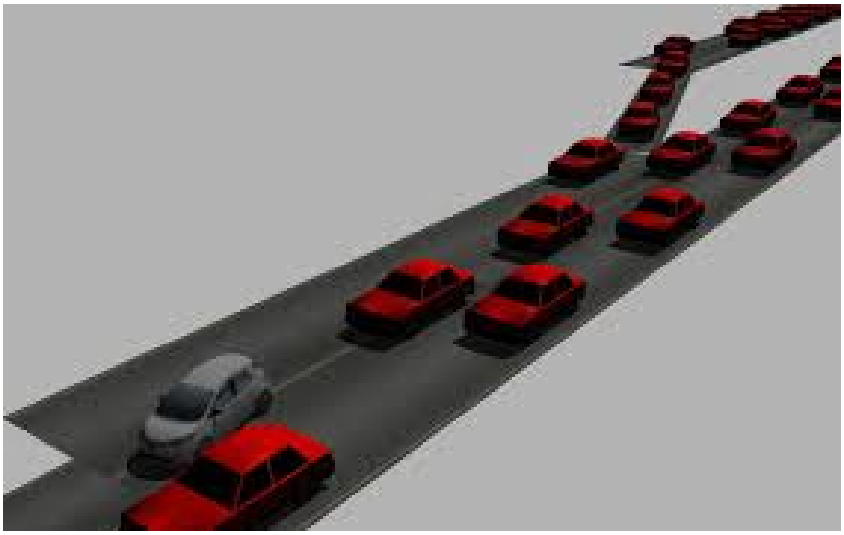


There are many interesting and important problems arising when we introduce automated vehicles into mixed traffic settings where they must interact with human drivers. How to overtake a human-driven vehicle with an automated vehicle is one example of these mixed traffic problems. During the overtaking process, learning the human's behavior (aggressive or non-aggressive) from the measured data is important for designing a safe and efficient overtaking controller.

- Propose a mathematical model for the human's behavior.
- Design a learning algorithm to distinguish the human's behavior.
- Design a safe and efficient overtaking controller for the automated vehicle.
- Implement and evaluate your solutions in simulation, and possibly with real data and humans in the loop.

Project A3. Controlling traffic with moving bottlenecks

Supervisor: Mladen Cicic, Decision and Control Systems, cicic@kth.se



One of the ways connected autonomous vehicles could be used for traffic control is using them as controlled moving bottlenecks to help dissipate stop-and-go traffic waves. In this project, this traffic control measure is to be designed and simulated. The SUMO microscopic traffic simulator will be used to build a simple model of a highway section, with some level of traffic flow. Next, interfacing SUMO with MATLAB, we simulate the formation of a stop-and-go traffic wave by disturbing some of the vehicles. We control another, special vehicle, representing a connected autonomous vehicle, in such way that the traffic flow at its position is restricted. Since the controlled vehicle will be upstream of the stop-and-go wave, this will reduce the inflow to it, accelerating the stop-and-go wave dissipation. With the stop-and-go wave dissipated, the traffic can return to the undisturbed state, and the throughput of the highway section would be increased.

The project can approximately be split into five parts:

- Build the simulation environment using SUMO microscopic traffic simulator connected with MATLAB.
- Identify the relation between the speed of the moving bottleneck, the volume of incoming traffic, and the overtaking traffic flow.
- Model and identify the dynamics of an externally created stop-and-go traffic wave.
- Design a control algorithm using the identified model of interaction between the controlled moving bottleneck and the stop-and-go wave, in order to help speed up the stop-and-go wave dissipation.
- Simulate the designed control algorithm to demonstrate its effectiveness.

Project A4. Coordinated platoon departures

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

Platooning is when a string of vehicles drive with small intermediate distances, and a high degree of automation and communication are used to assist the drivers to ensure safety and energy efficiency. The main benefits of platooning are: (1) the reduced work load of the drivers due to the high degree of automation and (2) the reduced energy consumption due to the reduced air drag. Platoons can be formed on roads if vehicles adjust their speeds in order to merge, or, as will be considered in this project, they can be formed at places where vehicles normally meet and rest, e.g., gas stations, freight terminals, parking places, etc. The decision whether to wait for someone or leave alone can be helped by statistical models of arrivals and departures from the meeting place and this will be studied in this project.

The student in this project will:

- Collect data of incoming vehicles at a place where platoons may be formed (real data from physical location)
- Approximate a statistical distribution of the collected data.
- Use the data and/or the approximated distribution to coordinate vehicles to platoon.

Project A5. Natural and Assistive Driving Simulator UIs

Supervisor: Frank Jiang, Division of Decision and Control Systems, frankji@kth.se

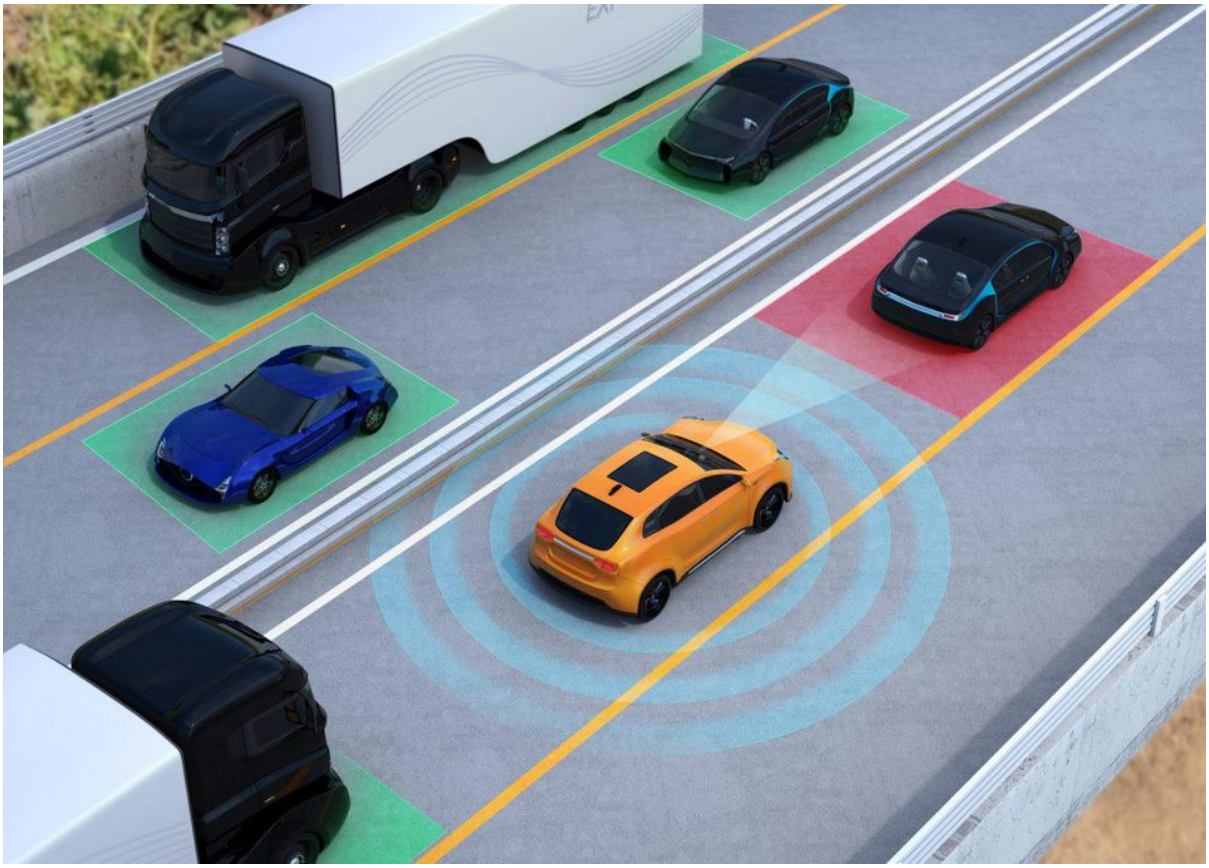
As automated vehicles that rely on machine learning or data-driven approaches become more prominent, the value of data and validation in driving simulators grows. Due to the lack of data and our inability to accurately model human driving behavior, researchers are relying on high-fidelity driving simulations to collect driving data and learn more about human behaviors safely. However, even when the graphics and physics of these driving simulators improve, often the user interface is underdeveloped and leaves a human user unable to drive efficiently. For example, often the methodology of mapping steering wheel and pedal inputs to the acceleration and steering of a vehicle or the design of the haptic feedback on the steering wheel are overlooked.

Tasks:

- Develop three driving modes for highway, city, and parking lot driving with mappings from steering wheel and pedals to control inputs for a virtual car
- Design controllers for haptic feedback on the steering wheel for each driving mode
- Implement the UI approaches on an existing driving simulator platform at the Smart Mobility Lab
- Run an experimental campaign on human volunteers to evaluate and iterate the UI design

Project A6. Interaction and communication between automated vehicles and human actors in traffic

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



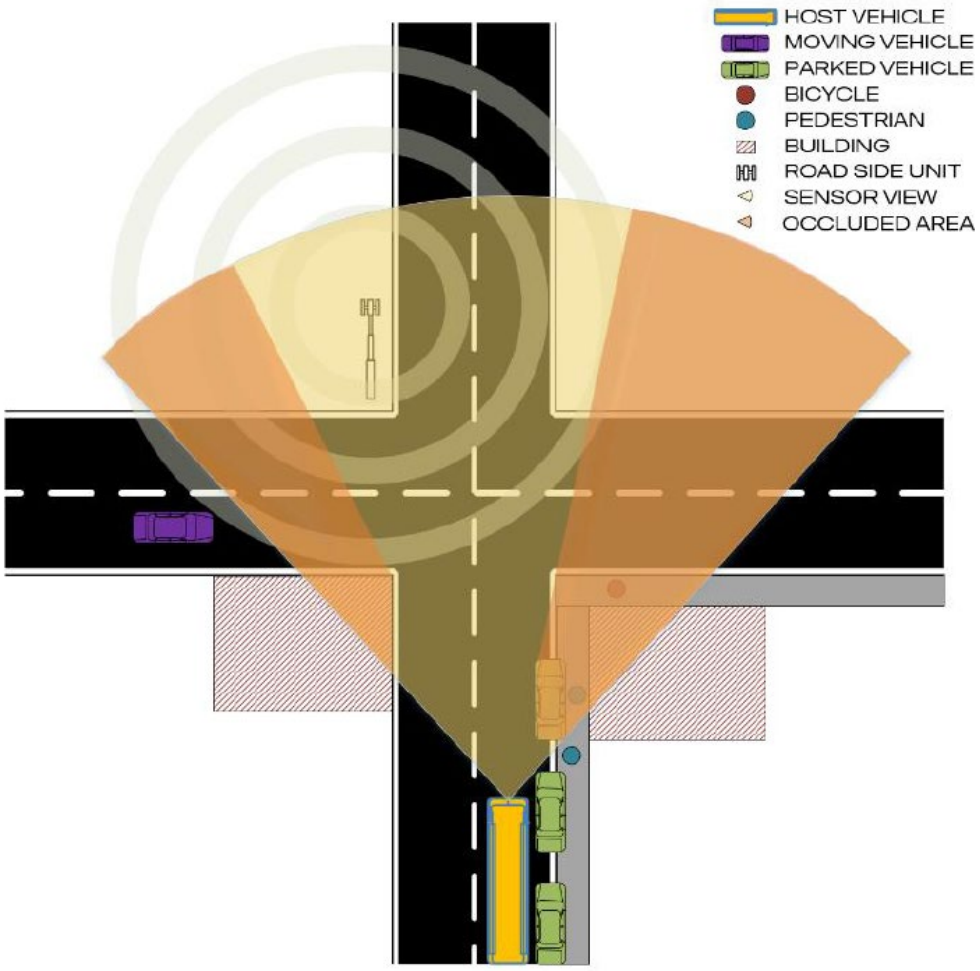
One critical prerequisite for the success of the deployment of automated vehicles (AVs) on public roads is the ability for them to handle the challenges when interacting with other human actors. This can be done by actively predicting the intention and behavior of human actors through complex modeling for the planning and decision making of AVs. Perhaps another more straightforward and efficient approach is to set up a communication and interaction protocol between AVs and human actors, in which case the human intensions and decision making of AVs can be actively exchanged and interpreted mutually for improved traffic and safety.

Tasks:

- Identify scenarios where AV and human actor interaction and communication are critical.
- Suggest and identify the level of communication and the technology required for such communication (audio, light signals, cloud..)
- Implementation in a simulation environment and evaluation of the resulting system structure.

Project A7. Shared traffic information and sensor data for intelligent intersections

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



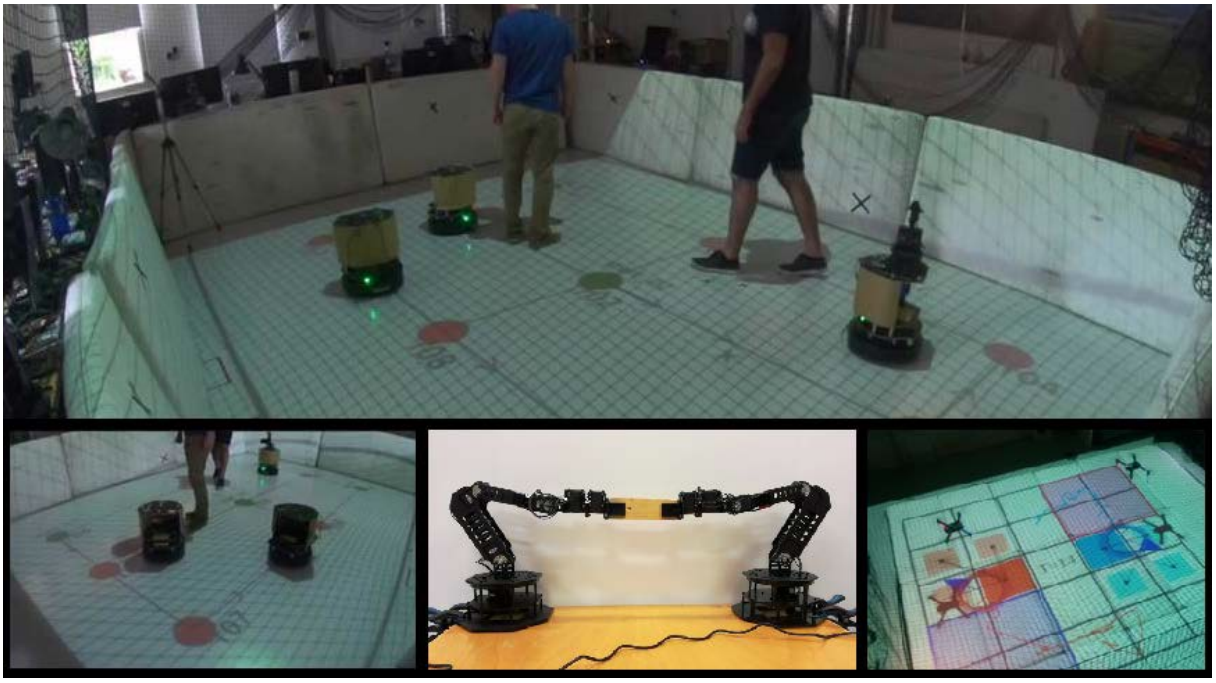
The traffic intersection is a highly complex and challenging scenario for Autonomous Vehicles (AVs). Challenges such as heterogeneous traffic flow, obstacle inside the blindspots of AVs sensor range can cause errors in trajectory planning and safety issues. With the help of cloud communication and data sharing, additional traffic information can be obtained from neighboring AVs or even from a centralized intersection controller gathering information from traffic actors and infrastructures and redistribute the information among actors for the benefit of improved safety and traffic flow in the intersection.

Tasks:

- identify scenarios in which data sharing will benefit intersection
- design the system and algorithms that handle the data sharing, with data coming from different actors and infrastructures, and how the resulting information should be distributed.
- evaluate of effectiveness of the resulting system, in terms of traffic performance and safety.

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

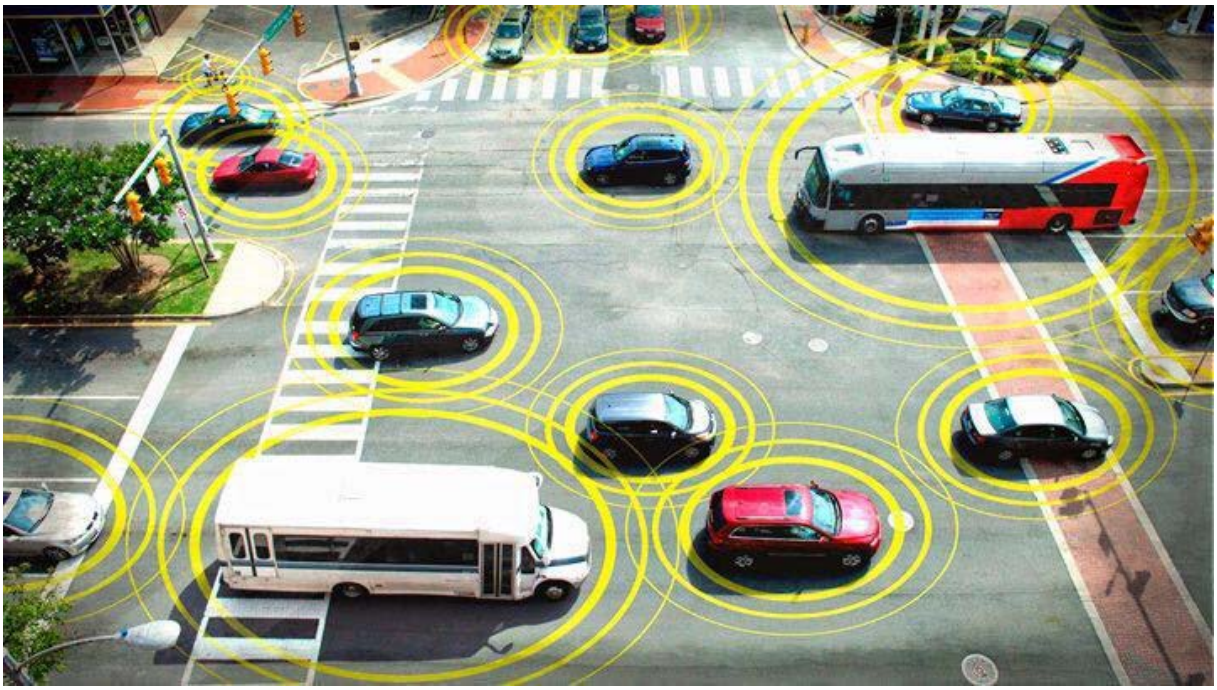
Supervisor: Xiao Tan <xiaotan@kth.se>

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:
• Model the geometric shape of a quadrotor UAV mathematically.
• Study how to control a quadrotor UAV and how to perform trajectory planning of a quadrotor UAV.
• Develop a motion planning algorithm to navigate UAV in an obstacle-cluttered environment.

Project B2. 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 communication imperfections and constraints that may degrade the system performance significantly. Hence, there is a need to understand the fundamental relationship between how the control parts and the communication parts of the distributed system interact. In this project, the aim is to study how to coordinate a team of AGVs to perform group tasks under communication network. Certain communication constraints have to be addressed, such as limited channel capacity and quantization.

Project B3. High level motion planning for a multi-agent system

Supervisor: Sofie Ahlberg <sofa@kth.se>

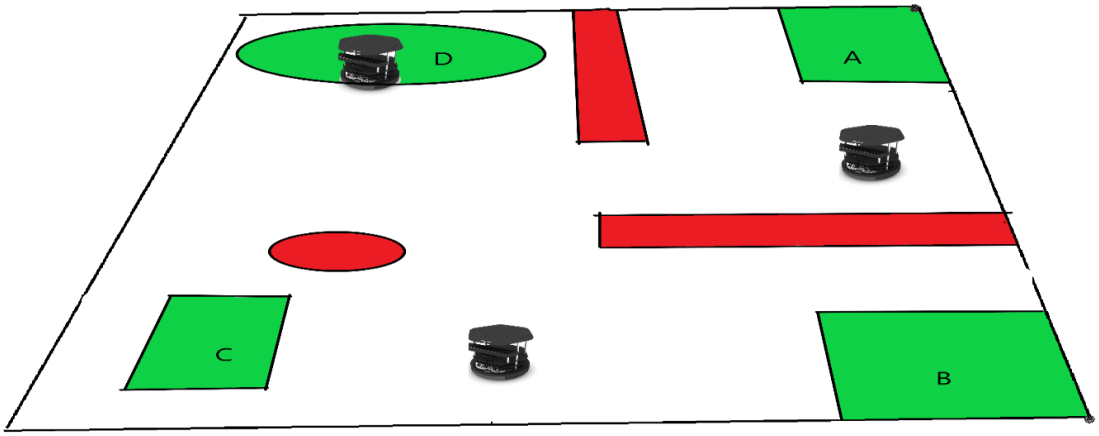


Figure 1: The robots needs to avoid the red areas, and meet up at the green areas. The order in which they visit the green areas is determined by the system to optimize the completion time.

Controlling the motion of a robot can be done in multiple ways. One option, which would work well for implementations where non-technically trained people are involved, is control synthesis for high level tasks. High level tasks refers to more abstract tasks (e.g. visiting every room in the building) compared to low level tasks which are more specific (e.g. going to point x with speed v). Control synthesis refers to automatically finding a plan based on information of environment and a given task. When multiple robots are considered (i.e. a multi-agent system) the planning becomes more complicated since we have to consider how they affect each other.

In this project we want you to suggest a framework for multi-agent control synthesis (i.e. finding controllers for each robot). Your framework should be able to plan for high level tasks considering obstacles and target regions where the robots should meet up. One possible approach is to use Linear Temporal Logic (LTL) to express these tasks but you are free to use other solutions.

The project should address the following tasks:

- Make a mathematical model of the environment the robots are moving in and the dynamics of the robots.
- Suggest a framework which returns a plan that satisfies given tasks of the form ‘avoid area X’ and ‘meet up at area Y’. The framework should be optimal in some sense with respect to time, meaning you have to take the transition times and potential waiting times into consideration when planning. This may affect which trajectories the robots follow as well as in which order the target regions are visited.
- Illustrate that the suggested framework works with simulations and theoretical descriptions.
- Discuss the advantages and disadvantages of this approach. What limitations does the solution have? What assumptions do you need to make?
- Reflect on the future of mobile robots in society and in settings where the operator has no technical background.

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.

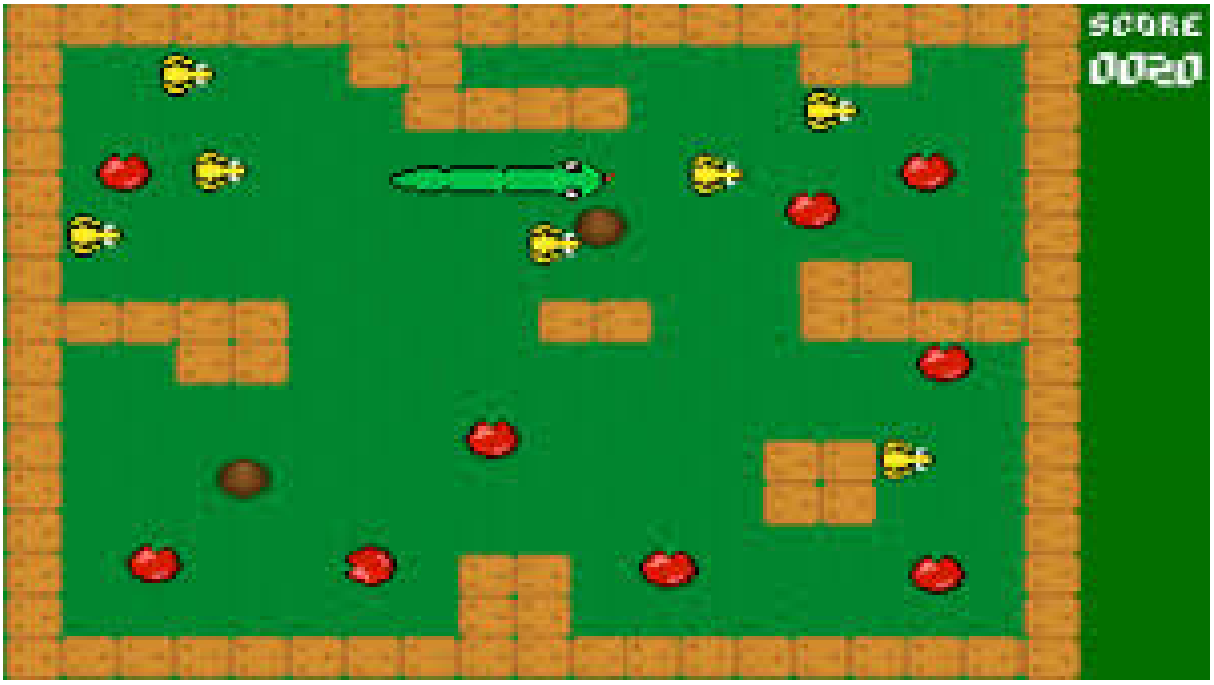
3. Propose algorithms for learning and predicting the patterns of financial data based on the stated assumptions.

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:

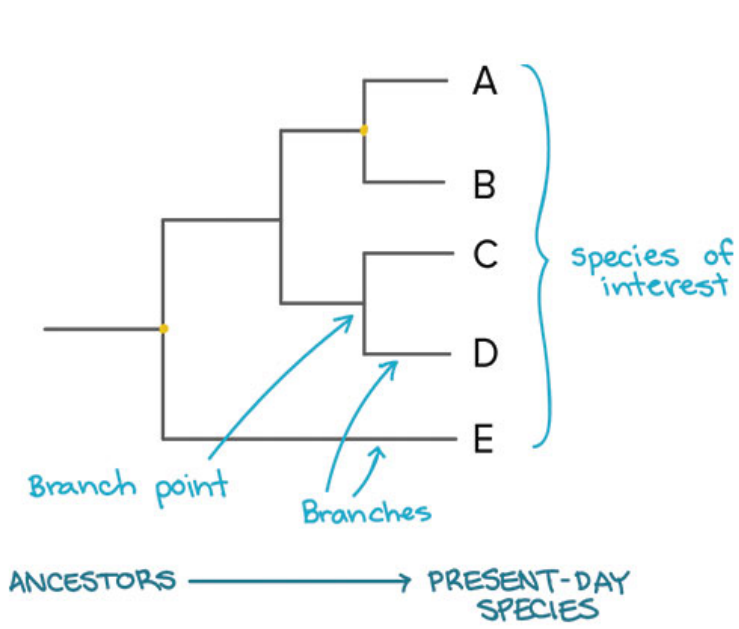
1. Model the warehouse and encode the tasks robots have to accomplish.

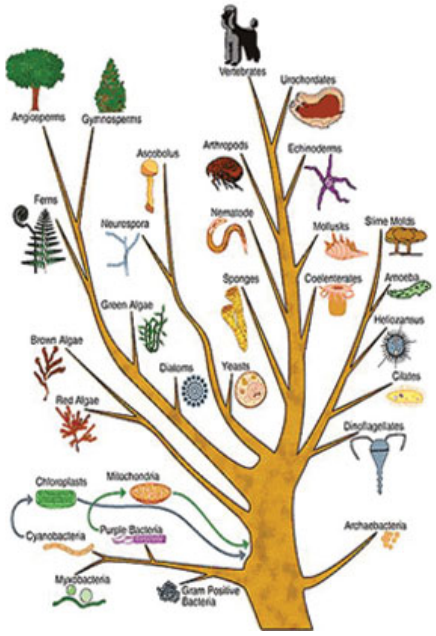
2. Develop and implement in each robot a deep RL algorithm.

3. Simulate the resulting complex dynamical system.

Project C4. Learning the Tree of Life

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





A central problem in evolutionary biology is piecing together the tree of life, which describes how species evolved from each other. Most modern systems of classification are based on evolutionary relationships among organisms – that is, on the organisms' phylogeny. Classification systems based on phylogeny organize species or other groups in ways that reflect our understanding of how they evolved from their common ancestors. More precisely, a phylogenetic tree is a binary tree whose leaves represent extant species (*i.e.*, species that are currently living) and whose internal nodes represent extinct species. When an internal node has two children, it represents a speciation event, where two populations split off into separate species. In this project we will try to build a phylogenetic tree starting from a stochastic model defined on it where each edge introduces its own randomness that represents mutation.

More specifically, the main tasks of the project include:

1. Develop an evolution model for the phylogenetic tree.

2. Propose different algorithms for learning the structure of the phylogenetic tree and estimating the splitting frequencies.

3. Evaluate the computational and statistical performance of the fitting algorithms.

4. Reflect on the limitations of both the proposed model and the used algorithms.

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

Supervisor: 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.

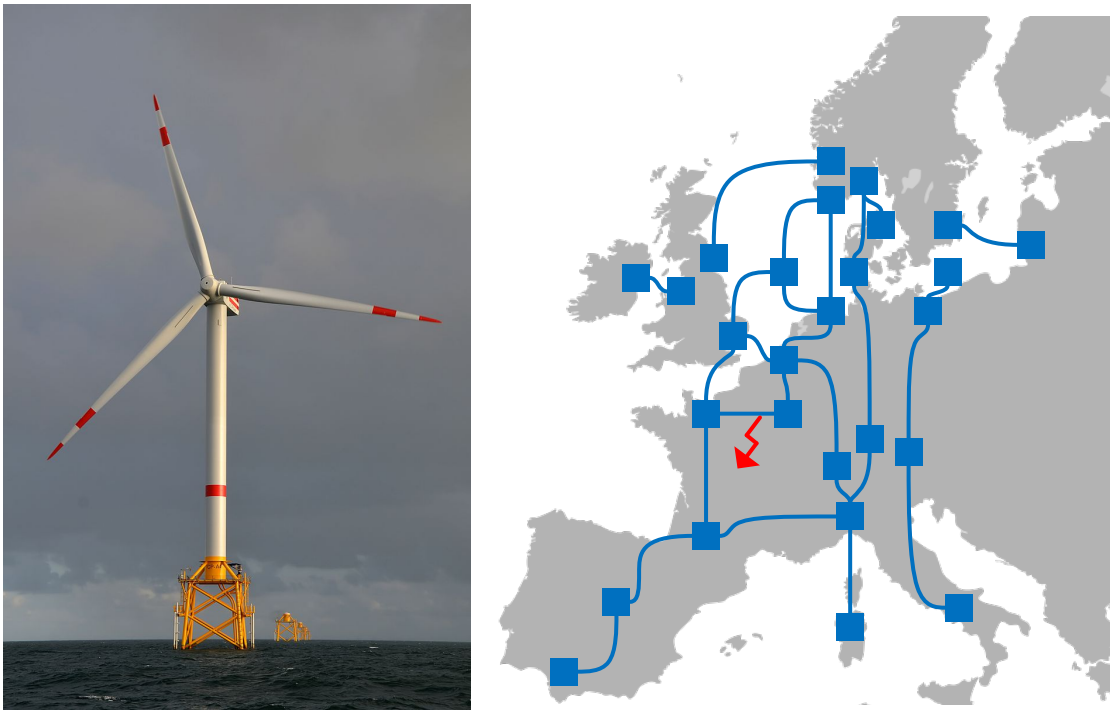
Context E: HVDC grids

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.



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

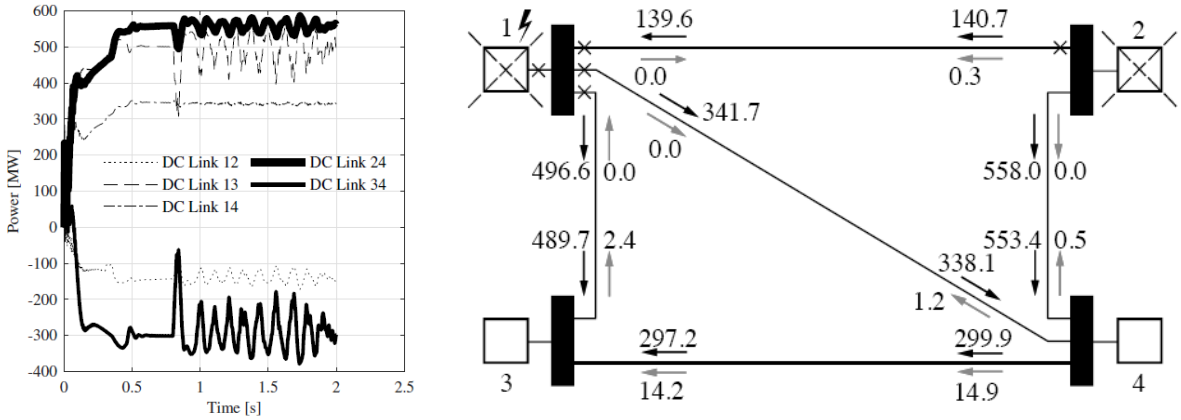
Projekt E1: Operation and control of HVDC grids

Handledare: Stefanie Heinig, sheinig@kth.se, Avdelningen för elkraftteknik

This project aims at studying the basic operation and control of a four-terminal HVDC grid. The student will learn about different converter control strategies and compare their influence on the grid. In general, a basic understanding of how a future HVDC grid can be operated should be developed. Comparative studies are to be conducted in an existing PSCAD simulation model of the four-terminal HVDC grid.

The work contains

1. Literature study on HVDC grids and converters
2. Basic control principles of converters (voltage droop control, constant current/power control, constant voltage control)
3. Implementation of different power flow scenarios and controllers
4. Simulation of a four-terminal HVDC grid
5. Comparison of controller implementations and grid control strategies (centralized and distributed voltage control)
6. Deployment of one of the control functions in an industrial-grade hardware (MACH)[1] used as a controller for real/physical HVDC systems.
7. Report



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

[1] https://new.abb.com/systems/hvdc/mach-control-and-protection-system

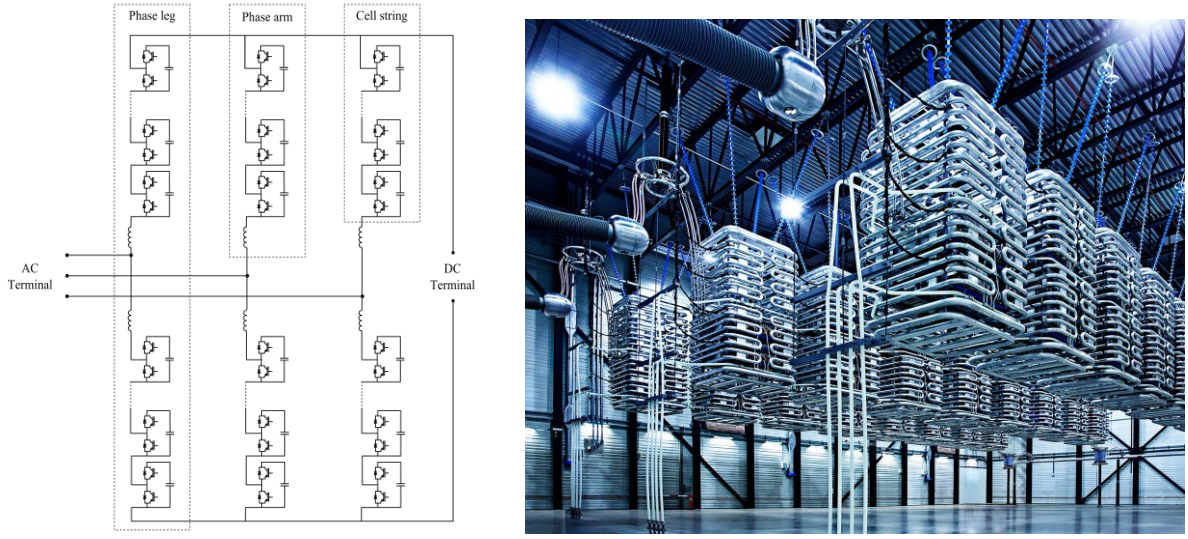
Projekt E2: Implementation of nodes in HVDC grids

Handledare: 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.



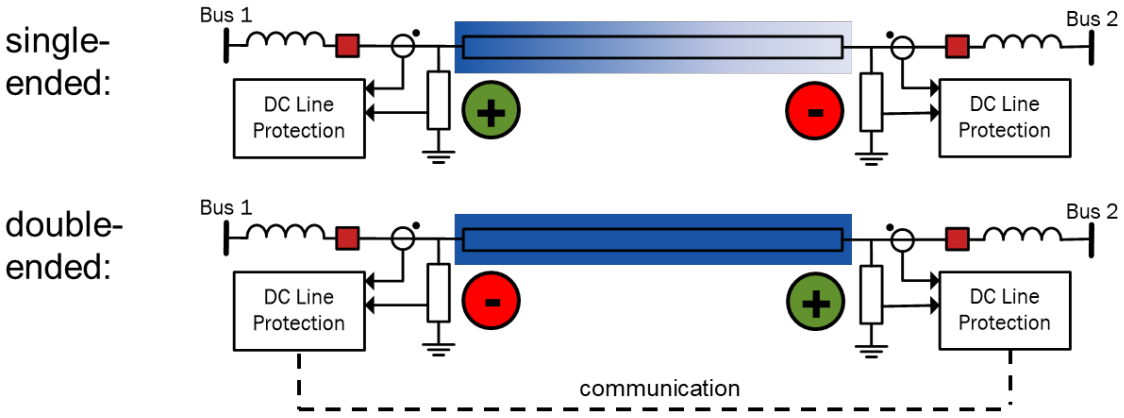
MMC-based HVDC converter. Left: circuit schematic. Right: photo of actual converter

Projekt E3: Digital protection of an HVDC grid using optic fibre communication

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

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

This project will focus on modern digital protection functions in a HVDC (high-voltage direct-current) grid. In particular, double-ended protection using high-speed optic fibre communication between two cable ends shall be investigated. Instead of using information from one cable end (single-ended), information from two cable ends is used for short circuit detection (double-ended). This means that double the amount of information is available which is advantageous, but at the same time a communication delay of the optic fibre needs to be considered which can be of disadvantage. Methods for double-ended fault detection shall be implemented in PSCAD simulation. PSCAD is the most common simulation platform for studies in HVDC (but also AC grids) and is used in both research and industry.



Figur 3: Schematic diagram of single- vs. double-ended fault detection for a HVDC cable.

Project tasks:

1. Literature study of HVDC grids, protection and optic fibre communication
2. Implementation of double-ended protection building upon an existing model. The existing model has single-ended protection already implemented.
3. Simulation of some fault cases (both single-ended and double-ended protection)
4. Comparison and evaluation of results
5. Report

KEX-jobbet utförs på Engelska eller Svenska.

Kontext F: Kraftsystemstyrning

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 and Implementation of Wide Area Measurement System

Supervisors: Lars Nordström, larsno@kth.se, Electric Power and Energy Systems
Oscar Utterbäck, oscaru@kth.se Electric Power and Energy Systems
Robert Eriksson Robert.eriksson@svk.se Svenska Kraftnät

Power system monitoring and control is largely done using SCADA and EMS systems that work in the time-span of several seconds providing pseudo-real-time monitoring of the power system. Hence, power system dynamic phenomena are not at all captured by these systems. To complement the SCADA/EMS systems high sampling rate measurements using Phasor measurement units (PMUs) in so called Wide Area Measurement Systems (WAMS) have been proposed and are also installed and operational in many TSO grids. These systems provide control room operators with a much more detailed view of power flows and to some extent dynamic phenomena in the grid, it is still debatable to which extent this information can successfully be used in control of the grid with a human in the loop.

The Swedish TSO Svenska Kraftnät uses a simulator suite, ARISTO, in their training procedures of new control room engineers. This simulator is based around the SCADA paradigm, and generally produces RMS values of the state of the grid at a rate corresponding to the SCADA systems. In order to prepare for the use of PMUs, it is of interest to the TSO to enable the simulator to produce corresponding data streams. This data is produced at a rate in the order of 10-100 Hz, and packaged according to the IEEE C37.118 protocol, which is implemented and in use by industry standard monitoring, protection, and control equipment. Further, this data is synchronized via GPS, enabling a concurrent view of the grid at specific points in time.

Objective
The main objective is to design and implement a proof of concept that enables ARISTO to produce data in the C37.118 format. The project will involve using and interfacing with the ARISTO simulator, understanding and working with the C++ API, and generating data packaged in the PMU protocol.

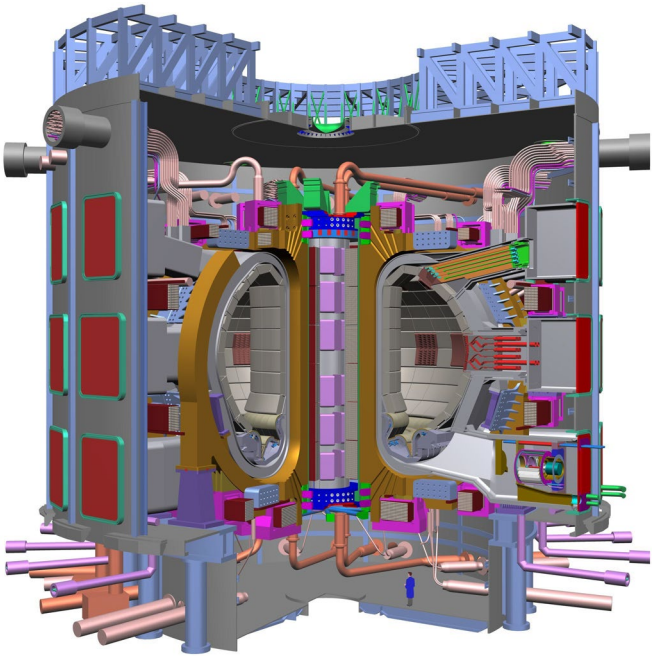
Additional objectives include transmitting the data over TCP/IP, investigating the possibility of producing the data at the PMU rate, and visualizing the data in a graphical user interface.

This project is suitable for 1 to 2 students. The students should be comfortable with programming, preferably in C++, as the simulator software has a C++ API. Java knowledge and a willingness to learn is also acceptable.

Kontext G: Fusion - solens energikälla på jorden

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.

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.



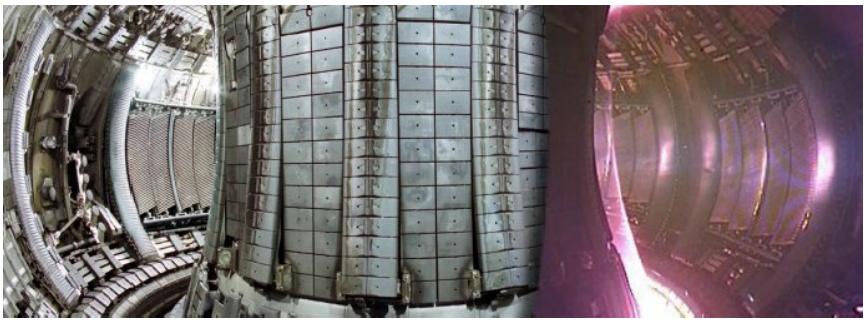
Den 73m höga fusionsreaktorn ITER som nu byggs i södra Frankrike och som ska stå klar 2020. ITER väntas kunna producera 10 gånger mer energi än den förbrukar.

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.

Project G1: Accelerator-based studies of plasma-modified wall materials from controlled fusion devices

Handledare: Per Petersson, per.petersson@ee.kth.se, FPP
Marek Rubel, rubel@kth.se, FPP
Sunwoo Moon, sunwoo@kth.se, FPP

Under the 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. These forces can be applied using magnetic fields, as is being studied with the device Extrap-T2R at KTH. The heat necessary for fusion reactions poses very severe requirements on the selection of most 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 simulate the effect of the plasma by the irradiation of materials by a hydrogen beam and later investigations by many techniques. The results can finally be compared with previously measured data by similar and other methods.

Several parts of the system already exist but needs to be put together. The work will have two main parts. First, the design and implementation of a sample manipulator including mechanical parts, electronical drivers and the control software. Secondly the designed system should be tested by making an implantation and analyzing the results.

The project is part of larger program of investigation of material and can be adjusted in cooperation with the student.

Introductory Part

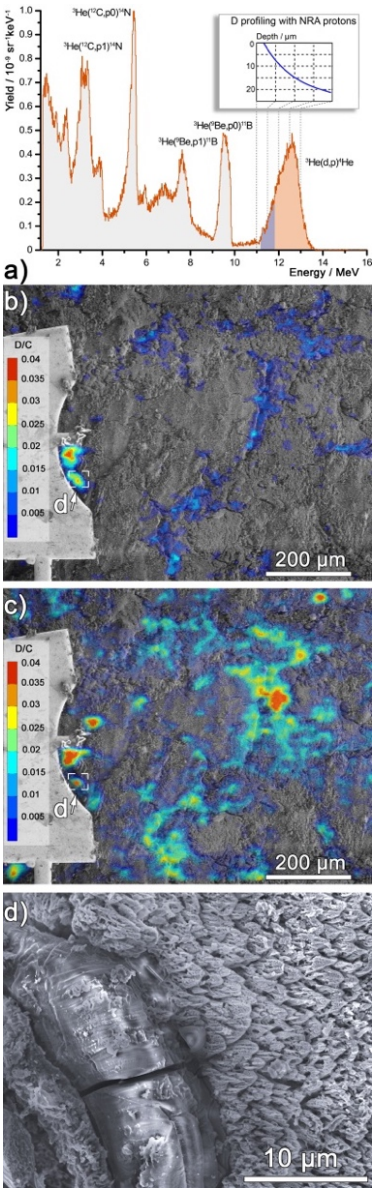
Visit to the Tandem Accelerator Laboratory of Uppsala University and introduction to accelerator-based material analysis techniques.

Main Tasks

- Construction of motor system for controlling a sample manipulator.
- Design of control software and user interfaces
- Exposure of samples.
- Computer analysis of experimental data.
- Writing report

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

Handledare: 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 $^{3}He^{++}$ ions is scanned over the surface and the energy spectrum of the protons emitted from the $^{3}He(d,p)^{4}He$ 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 ^{3}He 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.

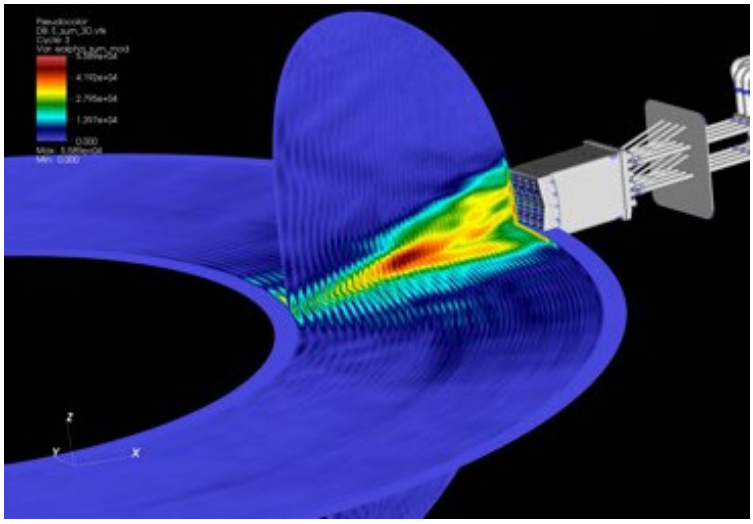
a) *Proton spectrum from a scanned area on carbonfibre surface from JET, with deuterium and beryllium present, both at the surface and in depth.*
b) *Lateral distribution of deuterium near the surface (based on the low energy part of the energy distribution of protons originating from deuterium).The 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) *d, Detail from image c, showing a half buried particle, which has a high deuterium content*

Project G3: Modellering av radiovågsuppvärmning i tokamaken JET

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

Bränslet i en fusionsreaktor är en blandning av väteisotoperna deuterium och tritium. Deuterium finns i stora mängder i havsvatten. Tritium är mycket ovanligt på jorden, men kan skapas i en fullskalig fusionsreaktor. Dock finns det idag ingen fusionsreaktor som är tillräckligt stor att producera tritium, så dagens fusionsexperiment använder i de flesta fall rent deuterium för att studera den fysik som kan hjälpa oss att bygga ett kraftverk i framtiden. Men nu under hösten 2020 kommer det europeiska experimentet JET i England att köra experiment med en blandning av deuterium och tritium, dvs riktigt bränsle. Detta är tredje gången någonsin som man använder deuterium and tritium, senast detta hände var 1997.

I detta projekt kommer vi att studera hur man värmer ett deuterium-tritium plasma till 100-200 miljoner grader med radiovågor i JET. Vi kommer att använda koden FEMIC för att simulera hur radiovågorna kan exciteras av en antenn och propagera in till plasmats centrum där de kan absorberas av joner och elektroner. Vi ska undersöka hur vågorna kan beskrivas av teoretiska modeller och hur de påverkas av olika typer av joner inne i plasmat. Men framför allt ska vi undersöka de viktigaste uppvärmnings-scenarierna som man planerar att använda. Vi ska titta på olika mått som beskriver kvalitén på uppvärmningen, för att avgöra vad de olika scenarierna har för för- och nackdelar, samt hur de kan användas på JET och i en reaktor.

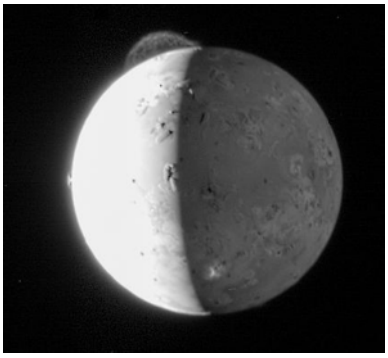


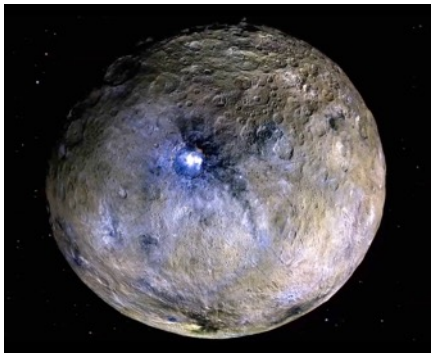
Elektrisk fältstyrka från en numerisk simulering av radiovågsuppvärmning i ett fusionsplasma.

Målen med detta projekt är:

- Läsa relevant litteratur om radiovågsuppvärmning och plasmafysik.
- Lära sig att använda FEMIC-koden och COMSOL Multiphysics.
- Bygga mindre analysverktyg för att analysera data från FEMIC-koden.
- Designa och utföra simuleringar av uppvärmning i JET.
- Att beskriva kvalitativt de tilltänkta uppvärmningsscenarierna. Framför allt, hur kan ett tredje jonslag användas för att optimera uppvärmningen?
- En kvalitativ och kvantitativ analys av simuleringsresultaten av de olika scenarierna som besvarar frågorna;
    - Vad är för- och nackdelarna med olika scenarier, samt hur kan de användas i ett fusionsexperiment, eller en reaktor?
    - Vilka är bäst för att ge hög fusion i JET?
    - Vilka är bäst lämpade att användas i en reaktor?
- Skriva en rapport och en presentation av resultaten.

Kontext H: Jupiter's Galilean moons and asteroid Ceres





Jupiter is the largest planet of our Solar System. After the discovery of 10 more moons in 2017, Jupiter has now a total 79 moons. The four largest are known as Galilean moons after their discoverer Galileo Galilei. The innermost Galilean moon, Io, is the volcanically most active known object with hundreds of hot spots and huge eruptions. Io might even have a global ocean of magma under its crust. The three other Galilean moons, Europa, Ganymede and Callisto, are covered with ice and harbor giant water oceans under the ice. All four moons have thin atmospheres, which produce auroral emissions when interacting with the Jupiter surroundings, in a similar process to that produces the polar lights at Earth.

Inside the orbit of Jupiter lies the asteroid belt. With a diameter of about 950 km, Ceres is both the largest of the asteroids and the only unambiguous dwarf planet in this region. In January 2014, emissions of water vapor surprisingly were detected from several locations. This was unexpected because large bodies in the asteroid belt typically do not emit vapor and the source for this water vapor is still unknown.

The projects in this context study the interiors or dilute gas environments of two of the large Jupiter moons and of dwarf-planet Ceres. **You will work with original data from spacecraft missions or the Hubble Space Telescope to find out more about these amazing water and fire worlds!**

Project H1: Io magma ocean through Alfvén wing characteristics

Supervisor: Aljona Blöcker, aljonab@kth.se, Space and Plasma Physics

Under the solid crust of the extremely volcanic moon Io might exist a gigantic global 'magma ocean' (Fig. 1, left). The existence of such ocean of molten magma inside Io was postulated based on magnetic field perturbations measured very close to the moon by the Galileo spacecraft (Fig 1, right). Interestingly, the magnetic field perturbations from the magma ocean can also be seen far away in Io's 'Alfvén wings'!

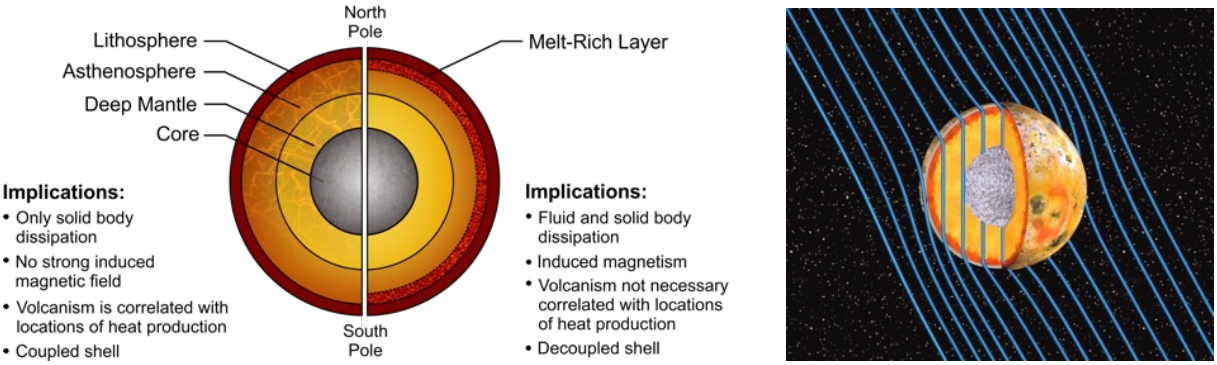


Figure 1. Left: Two scenarios for Io's interior. Right: How magnetic induction in a magma ocean would change the magnetic field near the moon.

Io is surrounded by a fast-moving flow of plasma and represents an obstacle to this flow generating complex interactions. An important characteristic of this interaction is the propagation of Alfvén waves (particular waves in a plasma) and the associated development of 'Alfvén wings' which modifies the electromagnetic field far away from the moon. The presence of an induced magnetic field shifts and shrinks these 'Alfvén wings'. Both the shrinkage and the shifting depend on the strength of the magnetic field induced in the magma ocean.
In this project, the influence of induction in a magma ocean on Io's Alfvén wings will be analytically and geometrically investigated. The results of the model will be compared to original measurements by the NASA Galileo spacecraft.

The tasks in this project will be:

- Become familiar with electromagnetic induction for spherical geometry and the moon-plasma interaction at Io.
- Derive general results of how magnetic induction in an ocean would affect the shape of Io's Alfvén wings.
- Apply your analysis to real or generic spacecraft encounters to Io

Project H2: Variability of Io's aurora and the moon's footprint on Jupiter

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

Because Jupiter's aurora is generated by processes within the magnetosphere like perturbations around the large Galilean moons. The moons themselves also have aurora (not only the planet). These moon auroras provide insight into the processes far out the magnetosphere and are thus a perfect complement to the investigations of the planet's bright aurora.

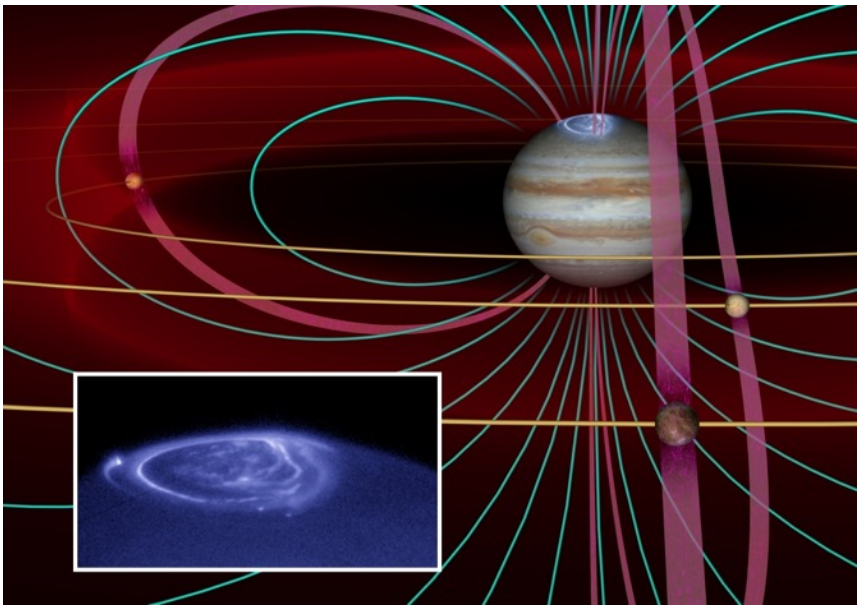


Figure 2. The Galilean moons connect to the huge planets through "flux tubes". The inlet shows an HST image of Jupiter's aurora with the localized moon footprint features.

The arrival of the Juno spacecraft in 2016 provided a unique opportunity to observe the moon aurora simultaneously with observations of the moon footprints in Jupiter's aurora. On several occasions, Juno's UV spectrograph obtained high-resolution images of the moons' footprints, which are the auroral signatures of the strong electromagnetic interactions taking place between these moons and the magnetosphere. Simultaneous observations by the Hubble Space Telescope of the local moon aurora were carried out to connect the source processes at the moons (moon aurora) to the effects far away in Jupiter's atmosphere (moon footprints).

In this project, the students learn how to analyze time-series of data and to extract systematic (real) variability from random (stochastic) changes. The results will be compared to the latest results from NASA's unique *Juno* mission that is still in orbit around Jupiter. The tasks involved in this project:

- Retrieve and become familiar with time-resolved HST data from Io.
- Generate time-series for the brightness of particular auroral emissions
- Fit periodic functions to the extracted time-series and determine the average maxima and minima as well as deviations from the average.
- Compare the variability to the variability of the footprint emissions.

Projekt H3: Detecting water plumes on Europa using HST

Supervisor: Gabriel Giono, ggiono@kth.se, Space and Plasma Physics

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.

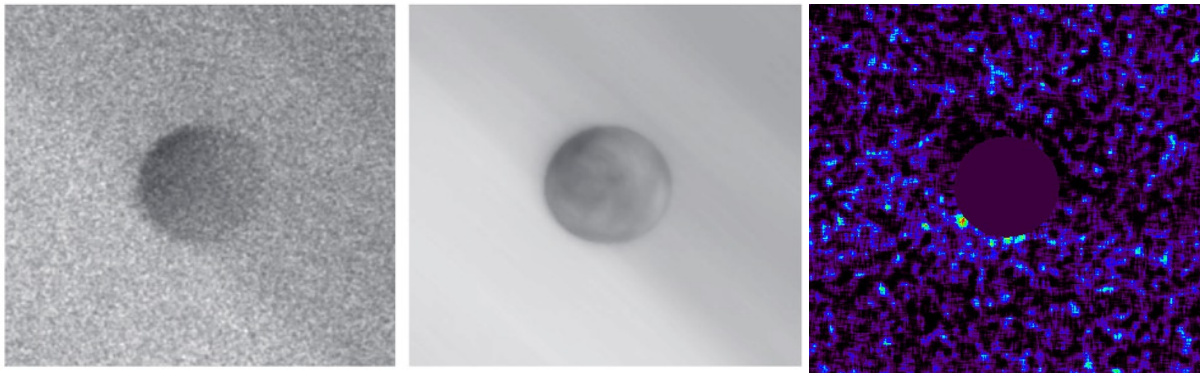


Figure 3. Left: Europa in transit in front of Jupiter as observed by HST. Middle: Modelled observation of the transit. Right: Map of the outliers' statistical significance.

Project H4: What is the course of the water vapor at dwarf-planet Ceres?

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

In early 2014, the Herschel Space Observatory discovered that there are several localized (not more than 60 km in diameter) mid-latitude sources of water vapor on Ceres, indicating that approximately 3 kg of water per second is released from Ceres' surface (Fig. 5). Vaporization of the ice in the surface through sublimation like seen at comets is too low at Ceres to explain the seen water vapor release, because Ceres is too far from the sun.

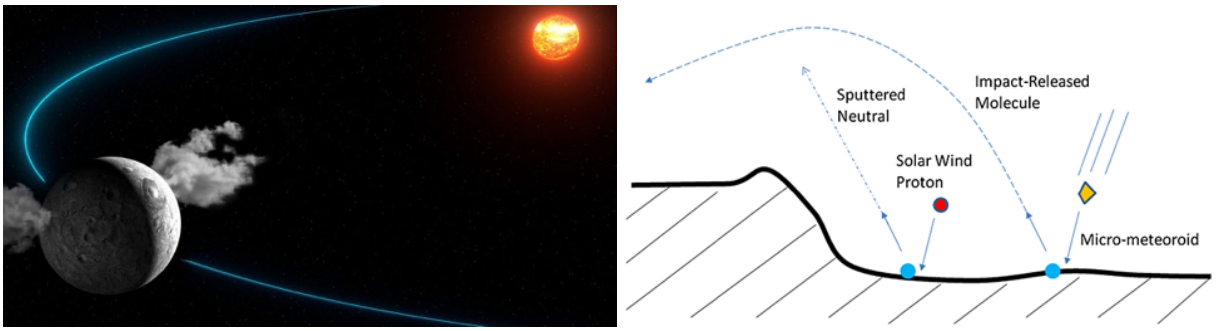


Figure 4. (Left) Artists concept of water vapor release from Ceres, with the Sun to the right. (Right) Impact of energetic protons from the Sun might be a source of the water.

In 2017, a study revealed that the water vapor detection occurred just at times when the Sun released an energetic blob of particles. This suggested that the water vapor release at Ceres might be triggered when charged particles (protons) from the Sun hit the surface, a process is called surface sputtering. However, it has never been shown quantitatively whether sputtering is efficient enough to produce 3 kg/s of water. In this project, the student will for the first time make a quantitative estimation on whether proton sputtering can cause the water vapor releases at Ceres.

Steps include:

- Retrieve and analyze formulae for the efficiency (yield) ice surface sputtering depending on the surface and charged particle conditions
- Estimate the flux and energy for charged particles from the Sun during extreme events.
- Numerically integrate the sputtering yield formulae for the case of a solar particle event hitting Ceres ice surface.

The results potentially shed light on the mystery of Ceres' elusive water atmosphere.

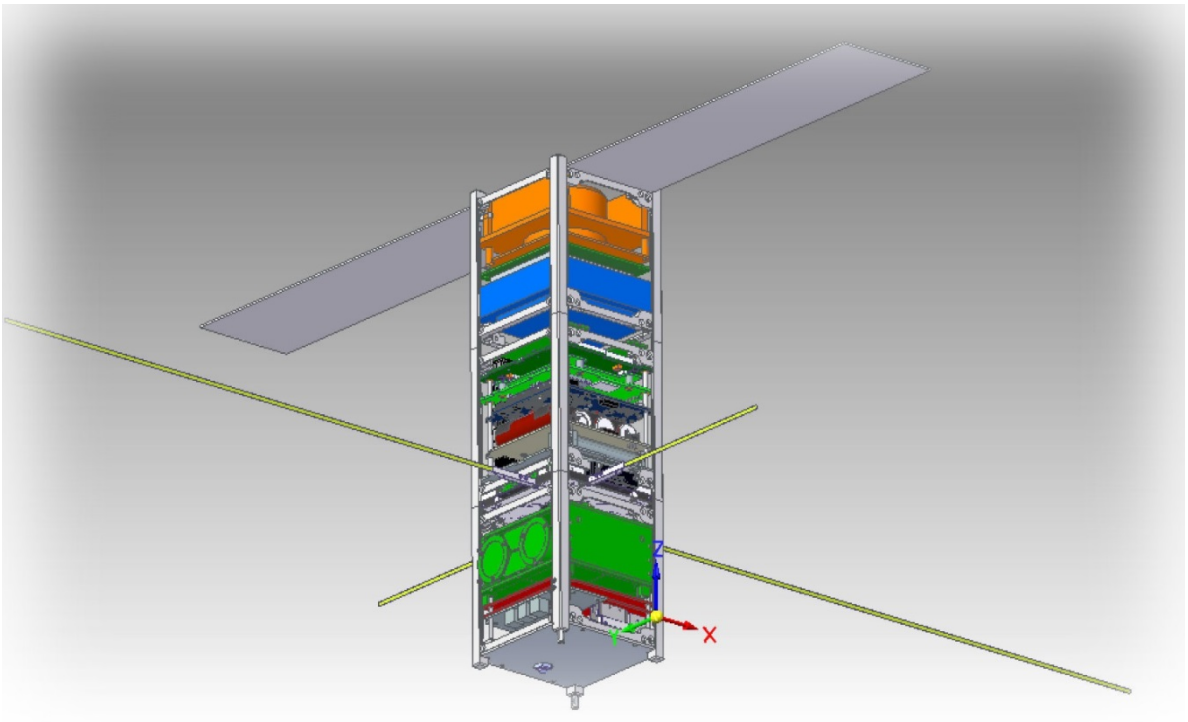
Context I: Space Systems

In this context, bachelor thesis topics are offered within three ongoing space projects: the MIST student satellite, SPIDER research sounding rocket, and the REXUS student sounding rocket experiment.

MIST is a small satellite of the CubeSat class that is widely used by universities around the world for educational and research purposes. The basic subsystems of MIST are procured from suppliers. Students make the overall system analysis and design and will eventually assemble and test the satellite. The launch of the satellite is a couple years away.

SPIDER is a sounding rocket to study electrostatic turbulence in the E region of the ionosphere. The rocket ejects multiple free-flyers that conduct electrical probe measurements in the plasma.

REXUS/BEXUS programme offers European University students and opportunity to design, build and fly their experiment on a sounding rocket, reaching an altitude of 90 km. Several projects have been carried out at KTH, with different objectives, and a new project is initiated targeting the rocket to be launched in spring 2021. During the Spring semester of 2019 design of subsystems for this experiment will be ongoing, with four projects related to it.



Project I1: Estimating the DC magnetic dipole moment on the MIST student satellite

Supervisor: Linda Eliasson (lindaeli@kth.se), Physics KTH, **Nickolay Ivchenko** (nickolay@kth.se), Space and Plasma Physics, KTH

Magnetic moment of satellites introduces a torque, which depends on the relative orientation of the satellite and the ambient magnetic field. This torque must be counteracted by the attitude control system. Minimizing the magnetic dipole moment of the satellite (keeping it "magnetically clean") is a challenge to be addressed in the design.

The MIST satellite subsystems contain some "iron", in the battery casings and the RF shields of the radio. Basing ourselves on discussions with ISIS we have assumed that the residual DC magnetic moment of the satellite is ≤50 mAm^2. This number has been used in attitude control simulations. Even higher numbers have been used to explore the "stability margins" of the control system. Still, there is a lingering concern that the satellite may be "magnetized" by nearby magnetic equipment such as tools. It is therefore interesting to develop a simple system of checking the magnetic status of the subsystems, and potentially to de-magnetize them A fluxgate magnetometer will be provided for such a system.

The specific tasks include:

- Define the procedure for screening the hard and soft magnetization of the parts/subsystems of the cubesat.
- Attempt to estimate the dipole moment of the MIST subsystem stack (unpowered) and also of the battery pack itself with methods outlined above.
- Use another, similar battery cell with steel casing to make experiments concerning how easy it is to magnetize such cells by mistake by using inappropriate tools that are magnetic.
- Develop simple handling rules to avoid magnetizing MIST during integration tests and launch preparations.
- Develop a de-magnetization system and evaluate.

Project I2: Estimating charging on a sounding rocket experiment using plasma simulation

Supervisor: Gabriel Giono (ggiono@kth.se)

Sounding rockets flying inside the ionosphere (100 to 300 km) interact with the ambient plasma, resulting in an electrical charging on the payload's surface. This was the case during the flight of the SPIDER sounding rocket in February 2016. SPIDER flew inside an active aurora, ejecting 10 Free Falling Units (FFUs) each equipped with electrostatic instruments able to measure the electric field and the plasma properties inside the aurora. The FFUs body charged down to -0.8V due to the interaction with the auroral plasma. This affected some measurements, in particular the Langmuir probe for which the FFU body was used a ground reference (i.e. therefore shift to -0.8 V instead of the intended 0 V).
A reflight of the SPIDER sounding rocket is scheduled for 2020. Estimating the payload charging before flight would be a must, which can be obtained by simulation using the Spacecraft Plasma Interaction System software (SPIS).
The project aims at modelling one of the SPIDER FFU with its deployable booms, and estimating the charging for various auroral condition using SPIS.

During this project, the students will:

- Get familiar with Gmsh, a simple CAD software used by SPIS for modelling spacecraft.
- Run plasma environment simulation using SPIS and derive the amount of charging on the spacecraft.
- Investigate the impact of auroral condition (electron density and temperature) on the payload charging.

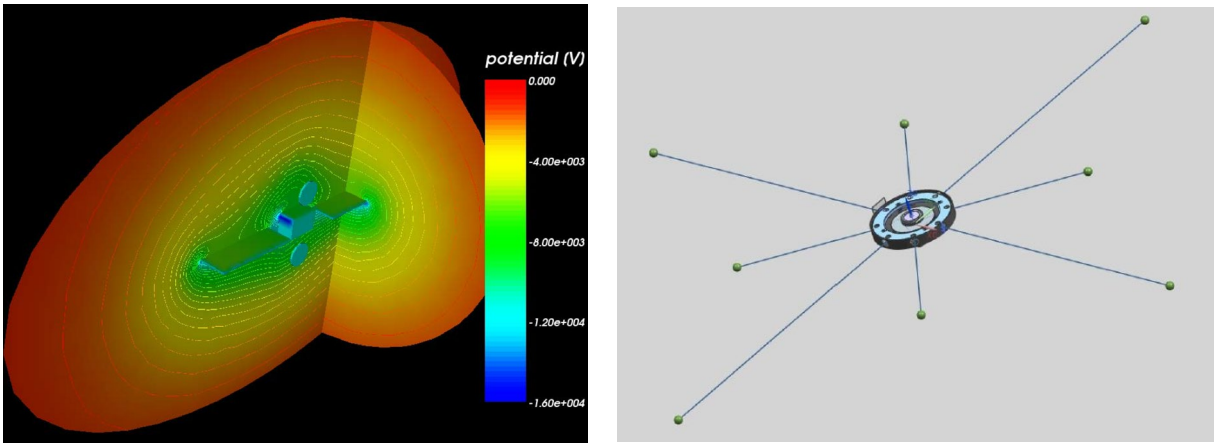


Figure: Left: Example of SPIS simulation of the potential around a spacecraft in geosynchronous orbit. Right: Model of one of the SPIDER FFU with deployable booms.

Project I3: Despin system for REXUS free-flyer

Supervisor: Nickolay Ivchenko (nickolay@kth.se)

The objective of the new REXUS experiment is system level qualification of a dual sensor magnetometer with a deployable boom. When measuring the magnetic field on a satellite, disturbances created by the satellite itself must be minimized. This is achieved by placing the magnetic sensor at a distance from the satellite, which is usually done by means of a deployable boom. The deployable boom will carry two magnetometers, at different distance from the free-flyer body, which allows to remove the satellite-created disturbances, since the disturbance magnetic field falls off with distance in a known way.

The topic of this project is to design and implement a despin sytem for the free-flyer. The free-flyer is ejected from spinning rocket. Deploying the boom on a spinning free-flyer may be dynamically challenging. So, the free-flyer should be stabilized prior to the boom deployment. The requirements on the despin system will be formulated, and a concept of the system will need to be proposed. The objective is to build the system in prototype, as a part of this BSc project, and conduct basic functional testing of it.

Project I4: Power system for REXUS free-flyer

Supervisor: Nickolay Ivchenko (nickolay@kth.se)

The free-flyer of the REXUS experiment, described in the previous project will carry the magnetometer, a data collection system, and the despin system. The subsystems will be powered from a battery, and a power distribution system shall be designed to meet needs of the subsystems. The work will include identifying the needs of the subsystems of the payload in terms of their supply voltages, power drawn. A power budget will need to be compiled for the complete duration of the experiment, which will be an input to the battery selection.

The power system conceptual design will be detailed to the schematics level, using prototypes if needed, to verify the performance. Finally, the layout of a printed circuit board will be prepared, the board soldered, and the system tested to verify it meets the requirements.

Project I5: Ejection system for REXUS free-flyer

Supervisor: Nickolay Ivchenko (nickolay@kth.se)

The topic of this Bachelor thesis relates to the REXUS project described above. The free-flyer shall be ejected from the rocket. The project focuses on the design of the system to hold down the free-flyer during the launch and eject it during the flight.

Several examples of ejection systems exit from previous REXUS experiments developed at KTH. While these solutions will not be directly suitable for the new experiment, primarily due to geometry constraints, they provide useful input for the design of the new ejection system. The requirements on the ejection system will need to be consolidated, and a new design to be developed, prototyped, and finally manufactured and tested.

Context J: Design and testing of novel microwave/antenna technologies

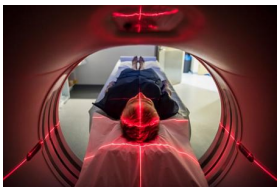
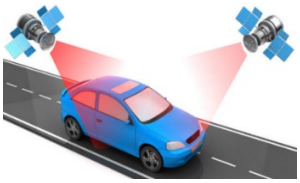
Today, microwave technology is employed in many of our technological devices and they fulfil an essential function in communication systems, intelligent cities, surveillance, medical diagnosis and space observation.

Innovative microwave designs are everyday required for driven-technology companies for their present products. These companies require of 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 basic knowledge for a microwave and antenna design. You will learn how to use commercial software of simulation, which is commonly employed at 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.
Picture4. Car communicating with LEO satellites.

Project J1: 3D printing microwave lens antennas

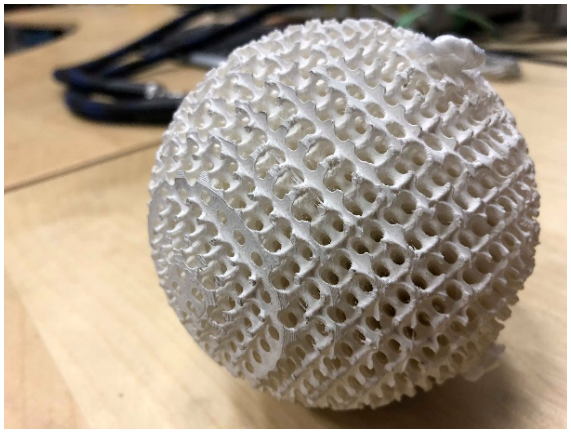
Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Qingbi Liao, qlia@kth.se, and Oskar Zetterström, oskdah@kth.se
Division of Electromagnetic Engineering

Due to the increase in the frequency regime 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 of complex feeding networks. On the other hand, 3D printers are becoming a low-cost and easy tool commonly used in industry to manufacture complex structures. Conventional 3D printers are able to construct dielectric structures such as lenses with low-loss microwave materials.

The purpose of this project is to design and measure a number of lens antennas that exploit the properties of 3D printers.

As a student, you will learn:

- The importance of lenses for future communications systems.
- How to simulate microwave lens antennas with commercial software of simulation.
- How to design basic microwave lenses, and to integrate these lenses in an antenna system.
- How to use a 3D printer with low-loss microwave materials.
- How to measure lens antennas in the antenna laboratory at the Division of Electromagnetic Engineering.



Example of a lens manufactured at the Division of Electromagnetic Engineering by a Master student with a 3D printer.

Students in the antenna lab developing measurements of electromagnetic devices.

Project J2: Experimental validation of the propagation on periodic structures

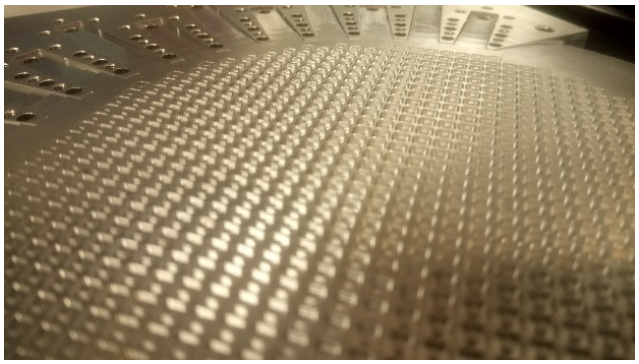
Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Qingbi Liao, qlia@kth.se, and Oskar Zetterström, oskdah@kth.se
Division of Electromagnetic Engineering

Periodic structures are used in common devices of communication systems, radio-astronomy instruments or medical scanners. In the Division of Electromagnetic Engineering at KTH, we have been recently discovered that periodic structures with glide symmetries have extraordinary properties that can be used to increase the bandwidth of operation of microwave devices, such as antennas, and to reduce the cost of millimeter wave components.

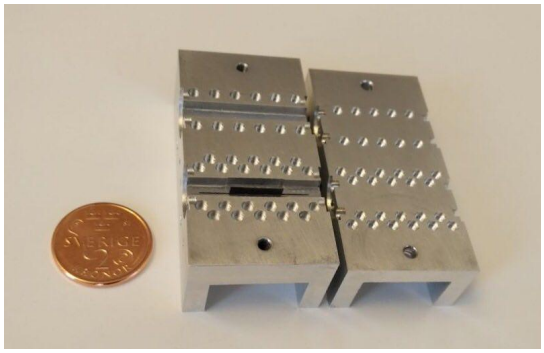
The main goal of this project is to study the properties of a number of electromagnetic devices that are made of glide-symmetric periodic structures.

As a student, you will learn:

- The basic operation of periodic structures, including those with glide symmetries.
- How to simulate periodic structures with commercial software.
- How to design basic microwave components with periodic structures that possess glide symmetries.



Example of a glide-symmetric Luneburg lens antenna designed by a Master student at Ericsson AB in collaboration with KTH.



Phase shifter in gap-waveguide structure made of glide-symmetric holey metasurfaces.

Project J3: Dielectric lenses and reflectors in optical regimes excited by lasers

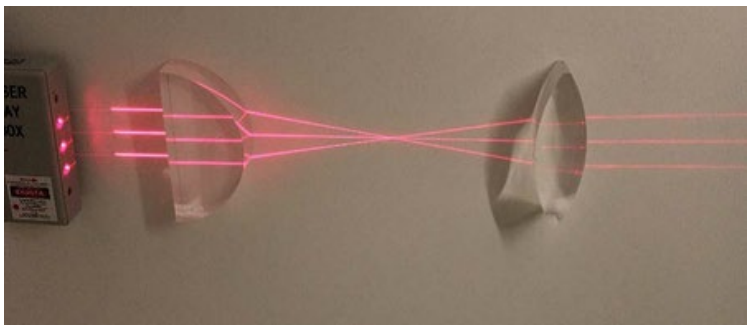
Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Qingbi Liao, qlia@kth.se, and Oskar Zetterström, oskdah@kth.se
Division of Electromagnetic Engineering

Lenses and reflectors are commonly used to increase the directivity of antenna systems. When a lens or a reflector are illuminated by a given electromagnetic feed, the aperture of the total antenna system is increased, producing a directive beam. In order words, lenses and reflectors can be used to focus a plane wave into a point, or to transform a point source into a plane wave.

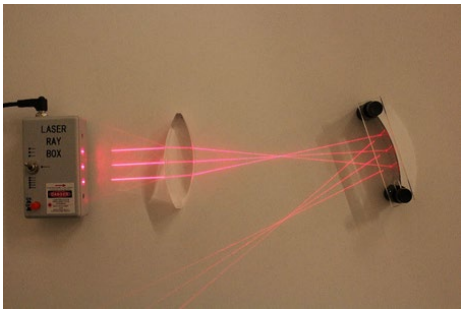
The purpose of this project is to simulate, design and test a number of dielectric lenses and reflectors in the optical regime, which are employed to transform point sources into plane waves or vice versa.

In this project, the student will learn:

- The importance of lens and reflector antennas for future communication systems.
- How to simulate lens and reflector antennas with commercial software of simulation.
- To design a number of lenses and reflectors, i.e. a hyperbolic lens, a Fresnel lens and a Cassegrain reflector.
- To test the designed lenses and reflectors in the Electromagnetic Engineering Lab.



Set up with two convex dielectric lenses at the lab of the Division of Electromagnetic Engineering.



Dielectric convex lens and reflector excited with 3 laser rays at the lab of the Division of Electromagnetic Engineering.

Project J4: Design and fabrication of an optical lens made of transparent liquids

Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Qingbi Liao, qlia@kth.se, and Oskar Zetterström, oskdah@kth.se
Division of Electromagnetic Engineering

Lenses are commonly used to increase the directivity of antenna systems. When a lens is illuminated by a given electromagnetic feed, the aperture of the total antenna system is increased, producing a directive beam. In order words, lenses can be used to focus a plane wave into a point, or to transform a point source into a plane wave.

The purpose of this project is to simulate, design and test a liquid dielectric lens in the optical regime, which are employed to transform point sources into plane waves or vice versa.

In this project, the student will learn:

- The importance of lens antennas for future communication systems.
- How to simulate lens antenna with commercial software of simulation.
- To design a lens made of different liquid material.
- To test the designed lens in the Electromagnetic Engineering Lab.

Artistic representation of a liquid lens.

Project J5: Design a magnetic levitating object for medical diagnosis

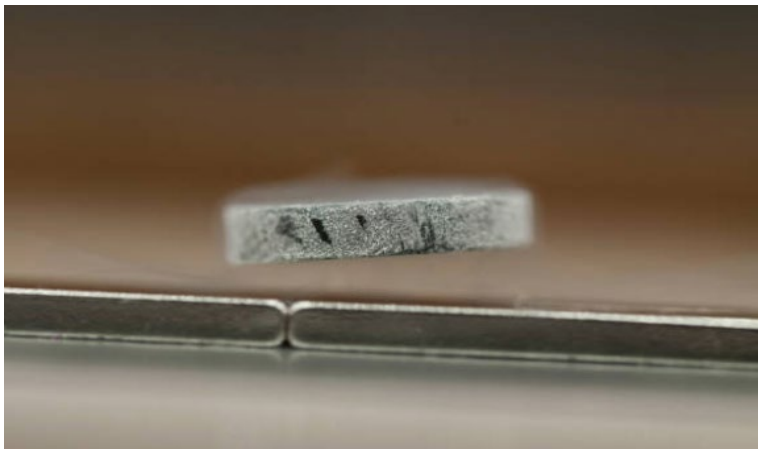
Supervisors: Oscar Quevedo-Teruel, oscarqt@kth.se, Qingbi Liao, qlia@kth.se, and Oskar Zetterström, oskdah@kth.se
Division of Electromagnetic Engineering

When processing medical diagnosis in real environments, some of the optical devices can have deviations based on small defocusing of the lenses and the location of the sample. In this sense, it would be beneficial to modify, electrically the position of the samples with non-invasive methods, such as magnetic levitation.

The purpose of this project is to design and build a prototype that can test the ability to magnetically modify the location of medical samples to avoid errors. The objective of the project is to determine the minimum distance that a sample can controlled with common circuitry.

As a student, you will learn:

- The principles of magnetic levitation.
- How to design and construct a controlled magnetic levitating object.
- Which are the limitations in controlling the levitation of small metallic objects.



Example of a magnetic levitation.

Context K: Electrotechnical multiphysics simulation

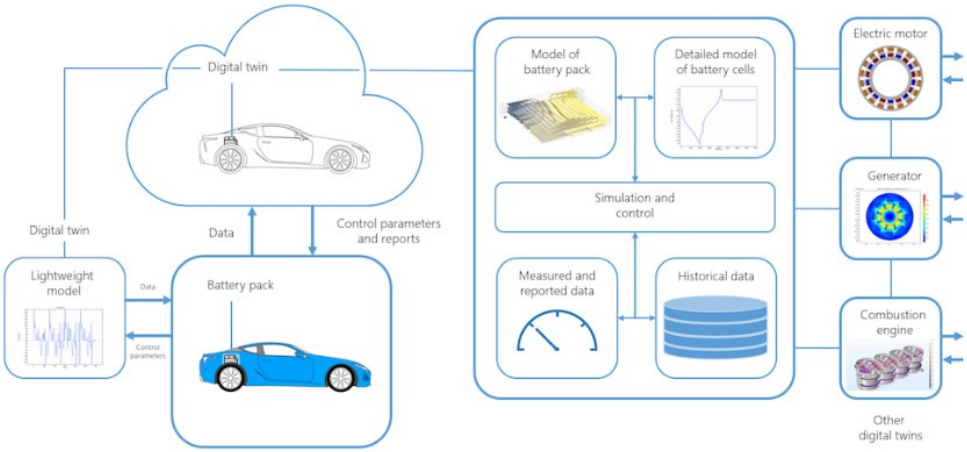


Figure 1. Sketch of the interaction of different processes in the digital twin of an electric car

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.

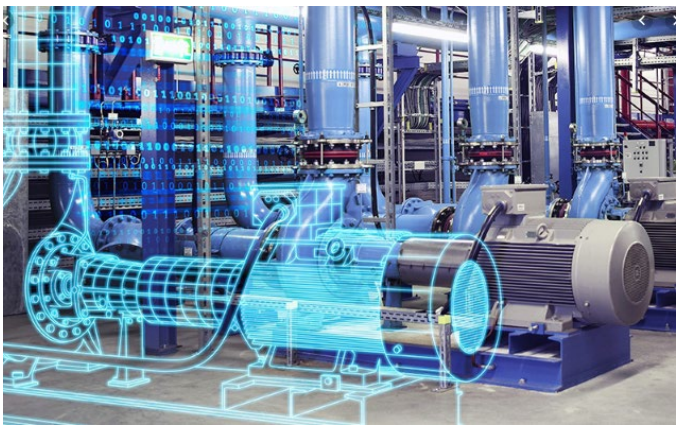


Figure 2. Illustration of a plant with electrical motors and digital twin.

Project K1: Digital twin simulation and construction of a magnetic inductor with an air-gap

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

Magnetic inductors are important components in power electronic devices and electrical systems. They are used in a broad range of applications ranging from high frequency filters, magnetic energy storages, electromagnetic compatibility chokes, magnetic fault current limiters, etc. The design of magnetic inductors is however complicated due to the nonlinear properties of magnetic materials and their stray power losses, the heating of the windings, the magnetic forces between different components and the possible dielectric failure between turns. This complexity is further increased when air-gaps are included in magnetic cores to enable tuning different parameters such as inductance and magnetic losses.
This project is aimed for the students to use a *digital twin* of inductors with air-gapped magnetic core to analyse and perform a design targeting a specific technical specification. The project also includes the construction of the designed inductor and the validation of the simulation results.

During this project, the students will:

- Get familiar with COMSOL Multiphysics and to perform parametric analysis for different design variables.
- Design an air-gapped inductor to reach a defined technical specification.
- Construct an air-gapped inductor following the found design variables.
- Participate in the design the experimental setup and the testing of the inductor
- Compare the experimental results with the simulation results to validate the model

Figure 1. Example of an air-gapped inductor.

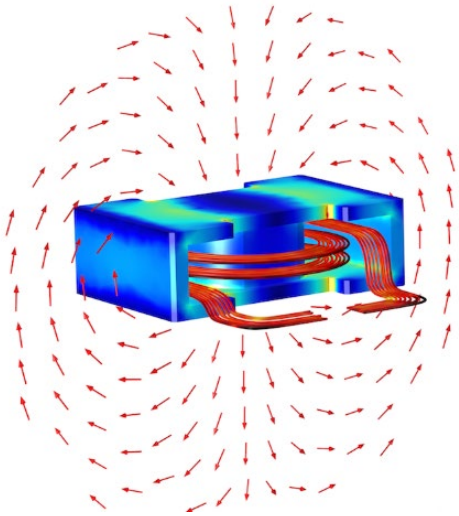


Figure 2. Digital twin of the real inductor.

Project K2: Estimating the risk of lightning strikes to on-shore wind turbine parks

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

Wind energy is an important source of the renewable energy with a rapidly increasing installed capacity. More and more wind parks are installed to meet the growing demands of energy consumption. These wind farms are usually constructed on the top or the ridge of hills, or in onshore and offshore regions where no nearby object has a comparable height. For this reason, wind turbines are vulnerable to lightning strikes, with an increasing risk of damage as their height increase (currently reaching heights larger than 100 m). The estimation of the incidence of lightning strikes to wind turbines is essential in the assessment of the risk of damages, providing information for the cost-benefit evaluation of the entire wind farm. However, field observations have shown that the actual number of lightning strikes to wind farms is several times higher than the estimates obtained using the standard practice.

In this project, the students will extend a new methodology developed at KTH to estimate the risk of lightning strikes of on-shore wind parks. The project will focus on a single on-shore wind turbine and a nearby tall tower in Uchinada-chou, Japan to validate the estimations with field observations.

During this project, the students will:

- Get familiar SLIM (Self-consistent Leader Inception and Propagation model) to simulate the conditions for downward and upward lightning from the considered structures
- Construct the geometry of the wind turbine and the tower for Finite Element Method calculations with COMSOL Multiphysics.
- Collect and analyze data from atmospheric radio sounding meteorological measurements to estimate the seasonal charged cloud base height during thunderstorms.
- Use probability distribution functions to estimate the likelihood of strikes during different lightning seasons
- Investigate the risk of different lightning events affecting the analysed wind turbine and its nearby tall tower.

Figure 1: Photograph of a wind park struck by lightning.

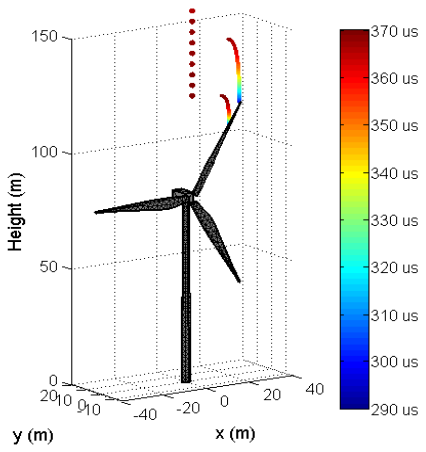


Figure 2: Simulation of lightning strikes to a single wind turbine with SLIM

Project K3: COMSOL App to obtain optical radiative properties of polymers from spectrophotometric measurements

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

Spectrophotometry is a broadly used analytical tool to measure how light is transmitted and reflected from a material (e.g. a polymer or a colored liquid). Although chemists traditionally use this technique to quantify the number of molecules in a sample, it can also be useful for physicists interested in obtaining optical radiative properties (e.g. absorption, scattering and reflection coefficients) of materials used in electrotechnology. However, obtaining optical properties from spectrophotometric measurements require the complex numerical simulation of different diffusive and collimated radiative fluxes within the sample.
In order to facilitate the estimation of optical parameters from spectrophotometry by any scientist or engineer, the project will develop an open-access, intuitive and ready-to-use application interface in COMSOL Multiphysics. The developed App uses as starting point a model already developed at KTH and will interface with a non-expert user to provide relevant input and output options to the specific task at hand.

During this project, the students will:

- Learn fundamental aspects of spectrophotometry in chemistry and physics
- Get familiar with radiative transfer in materials
- Learn how to develop a COMSOL App user-interface and to connect it to a model
- Construct a COMSOL App based on the existing COMSOL model of radiative fluxes within materials
- Use a spectrophotometer to obtain optical properties of a material and interpret the estimated results

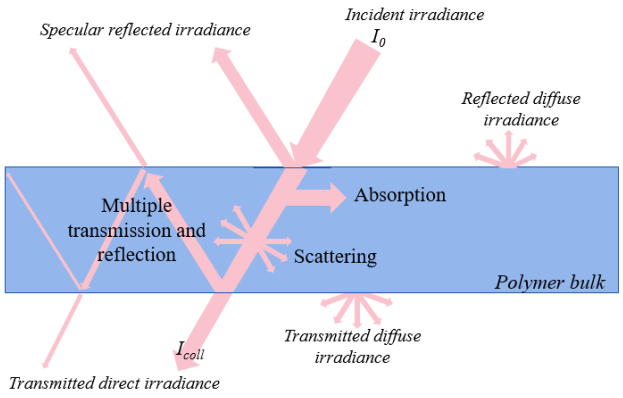


Figure 1: Spectrophotometer to measured transmitted and reflected irradiance. Figure 2: Sketch of the different ways how radiation interacts with a transparent or opaque sample

Project K4: Electrothermal dynamic model for fuses.

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

Fuses (smältsäkringar) are still widely used as protection devices in electric power applications, in spite of the increasing popularity of resettable circuit-breakers. Manufacturers of fuses provide specifications for disconnection times at high current (times up to tens of milliseconds) and for steady values of more moderate current (times of tenths to hundreds of seconds).
In some contexts one might want to judge whether a fuse will disconnect with a particular pattern of non-steady current: for example, highly variable loading with short overloads, or intermittent arcing-type faults with a weak source. This is not possible directly from the manufacturer data: it requires a dynamic model of the fuse, including the metal 'element', the surrounding sand and housing, and both axial and radial heat flows.
The project is based on simulation, using information from fuse dimensions, manufacturer specifications, and our own lab measurements. The aim is to establish what simplest level of modelling can give good results in the time-range of 0.1 s to at least 100 s, such that the actual and modelled times are correct for currents within 10% of the actual. The suggested simulation is Matlab/Simulink, with Comsol multiphysics as an option for alternative or supplementary use. The project will be a good chance to get started with dynamic system modelling and some programming.

Figure 1: Examples of fuse-elements, with sand filler and porcelain housing removed.

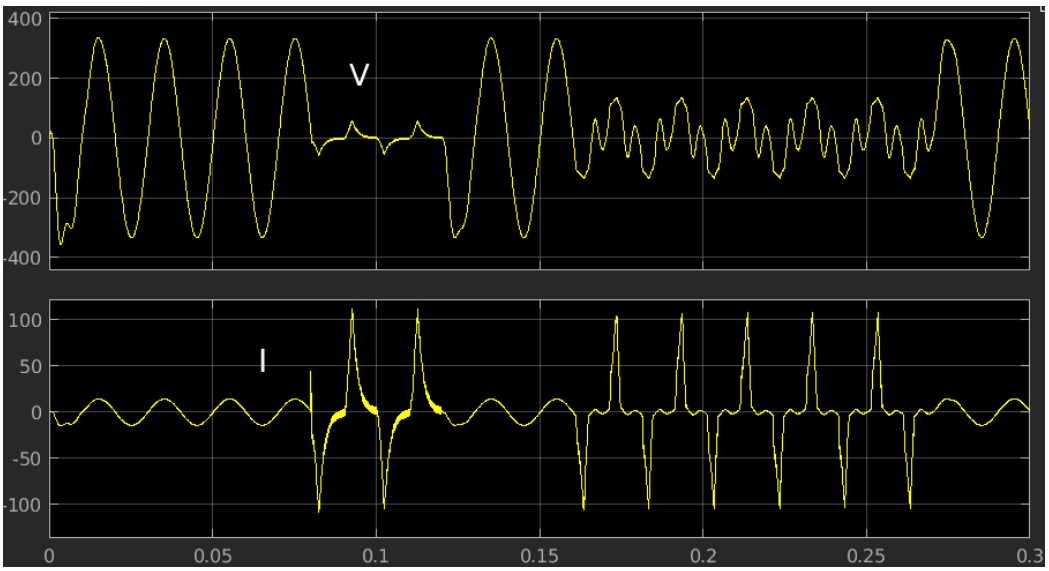


Figure 2: voltage (upper) and current in a simple model of an intermittent fault.

Context L: Artificial Intelligence and the Internet of Things

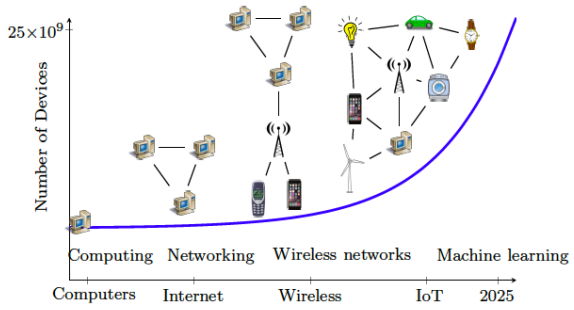


Figure 1: *Four technological revolutions: Computers, Internet, Wireless Phones, and Internet of Things (IoT) or "the all-connected and digitalized world". With future wireless networks and IoT, any system or object that can be connected via communication networks will become "intelligent". An essential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

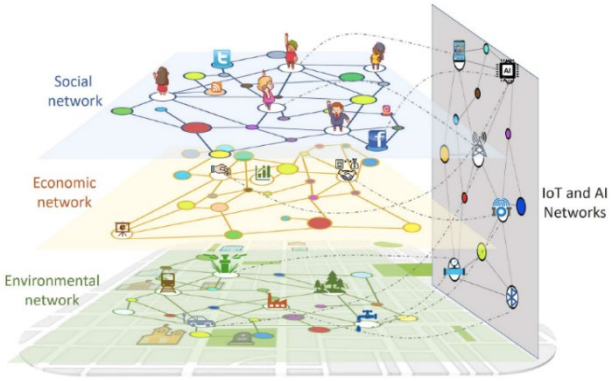


Figure 2: *Machine learning in communication networks with distributed nodes and data sets will face formidable challenges, due to the size of local data sets, limited computation and energy and narrow bandwidth of the nodes, heterogeneity of communication protocols, privacy, and security. Distributed 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 wold'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

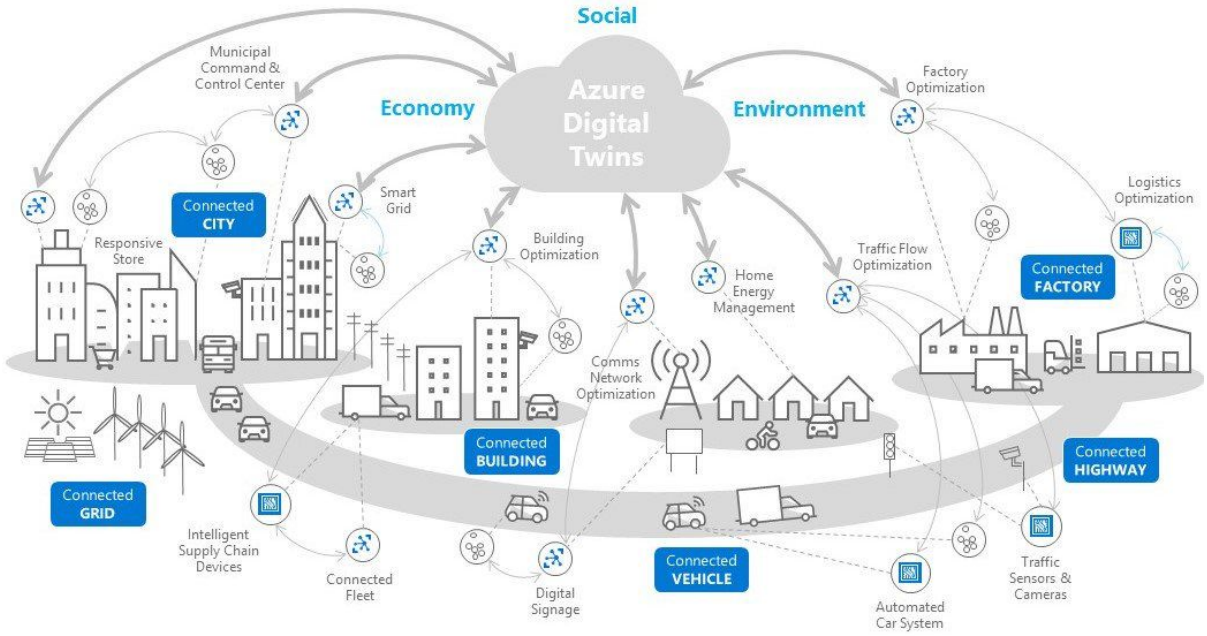
indicate that, in the coming years, IoT systems such as smart grids or smart cities will be mostly served by narrow band IoT. For example, to monitor and control water distribution lines, an IoT network will be underground and underwater, where the nature of the communication channels gives low data 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
- Modeling of a Cyber Attack on an Industrial Control System

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



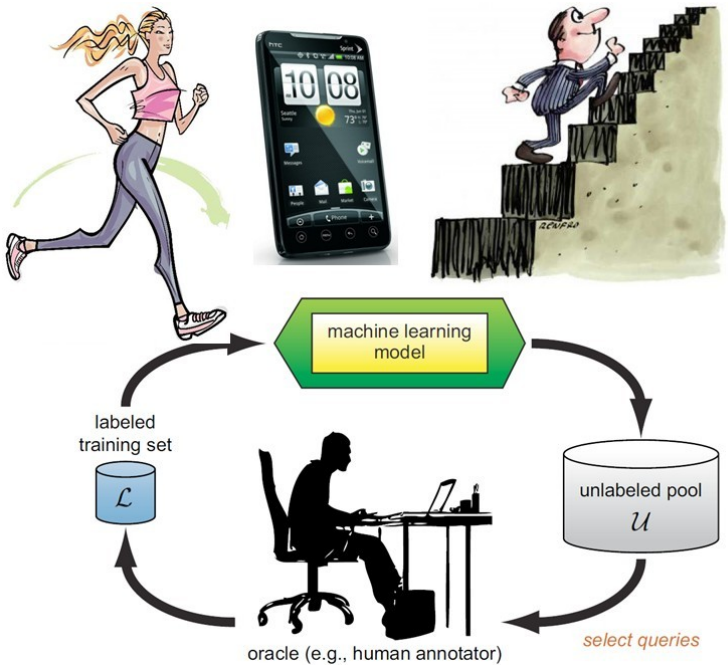
Supervisor: Thomas Ohlson (ttohlson@kth.se), Carlo Fischione (carlofi@kth.se)

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



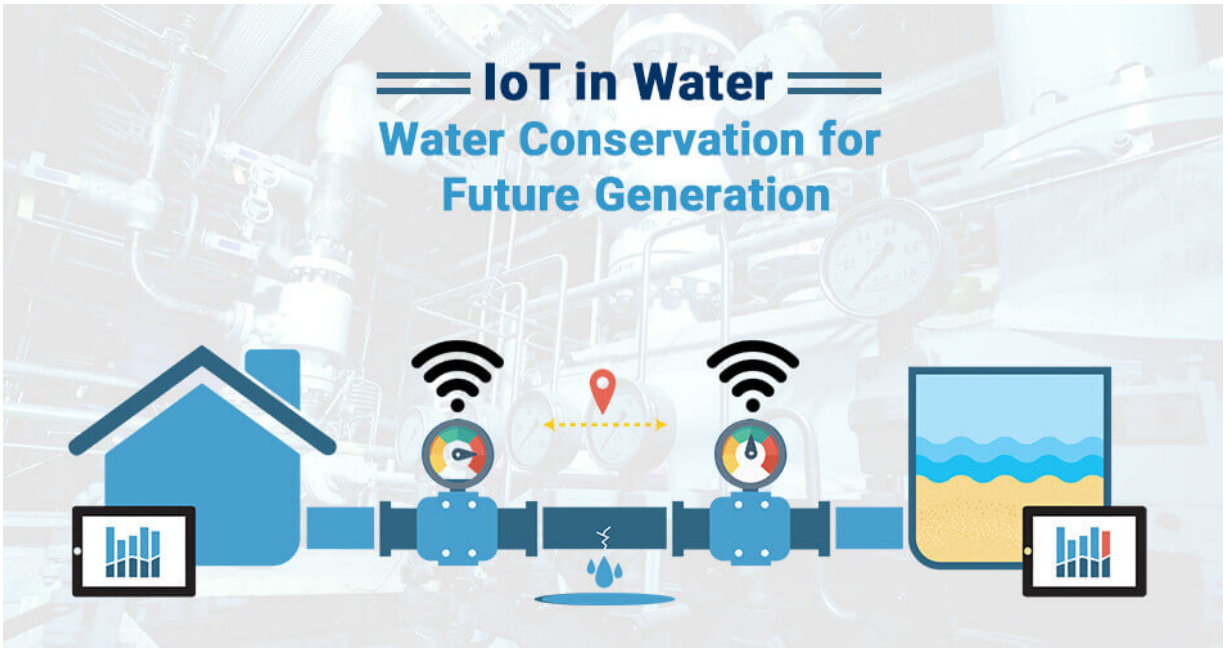
Supervisor: Hossein Shorkri-Ghadikolaei (hshokri@kth.se), Carlo Fischione (carlofi@kth.se)

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



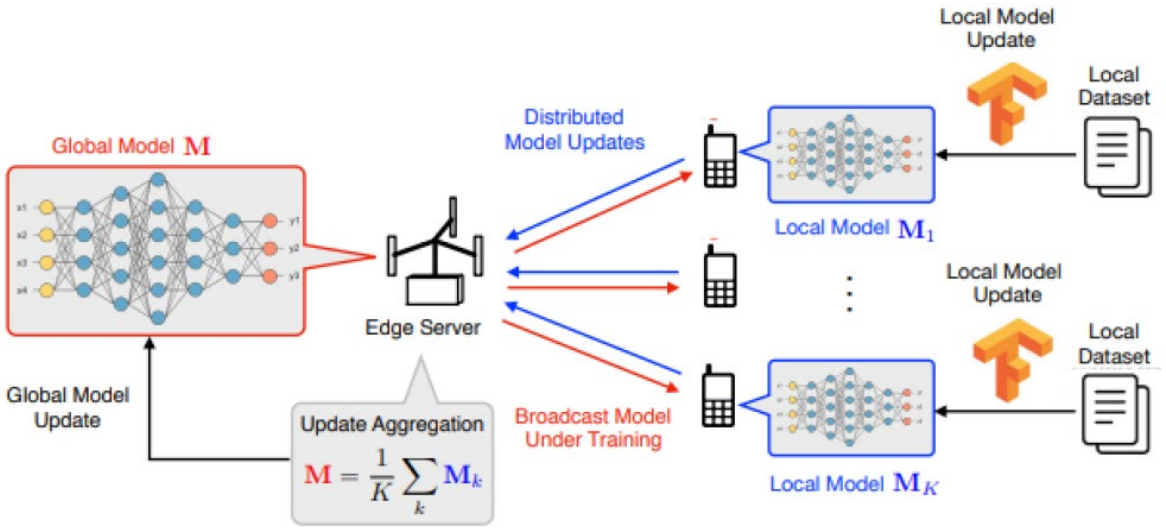
Supervisor: Rong Du (durong@kth.se), Carlo Fischione (carlofi@kth.se)

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), Viktoria Fodor (vjfodor@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

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.

- 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).
Prerequisites: basic statistics, basic programming skills in Python; basic concepts of machine learning.

Literature: Bishop, C. M. "Pattern Recognition and Machine Learning." Springer. 2006; 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)

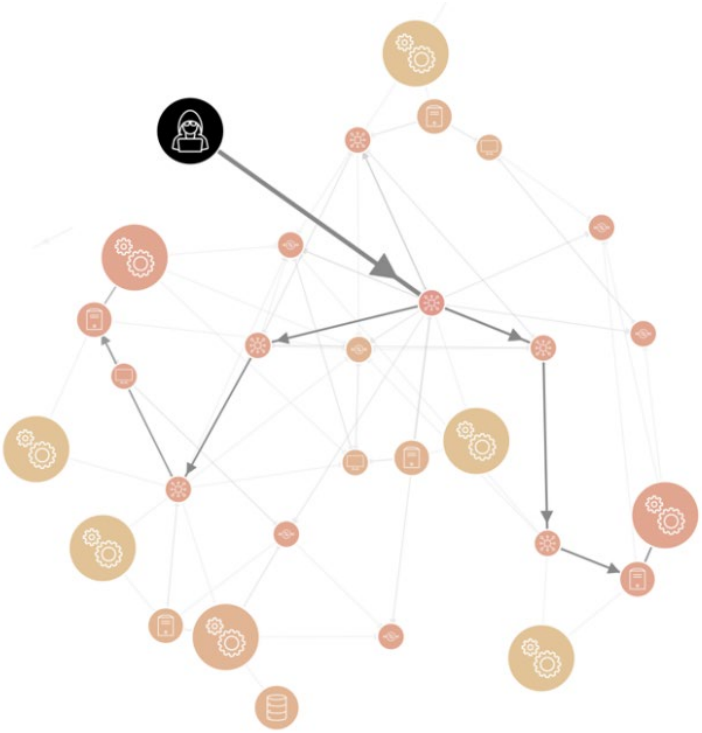
The Internet of Things entails that a plethora of things become connected to the Internet and fitted with sensors and actuators. Many of these things will be low-cost. However, historically, low production cost has not been conducive to high information security. Sayings such as “The S in IoT stands 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: Modeling of a Cyber Attack on an Industrial Control System

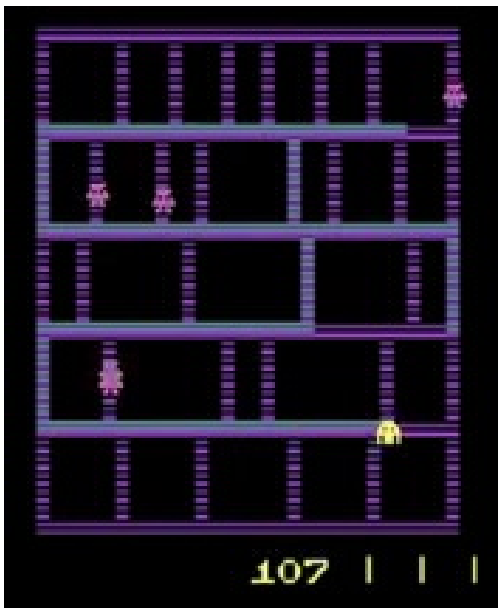
Supervisor: Mathias Ekstedt (mekstedt@kth.se).

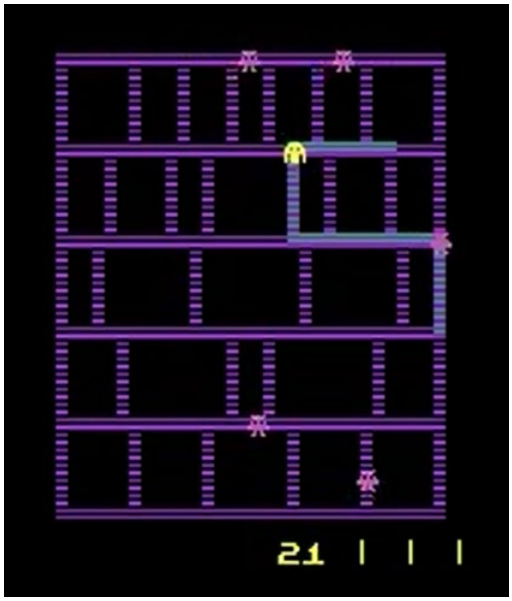
Three times through out the history has critical infrastructures been targeted by cyber attacks; the Stuxnet virus targeted and successfully destroyed equipment in a nuclear enrichment facility in Iran, the Industroyer/Crash override malware forced a large part of the power grid in Ukraine into black-out, and finally the Triton/Trisis attack targeted an oil and gas organization in Saudi Arabia. The latter did not actually succeed, but since it has been verified that it targeted system components that is specifically designed to keep industrial equipment and humans safe it is been considered the scariest.

The aim of this project is to reconstruct what happened in the Triton/Trisis attack. Much of the detail of what happened in the attack is still not known and people are still actively working on reverse engineering the case. This project is focused on collecting and combining information from publicly available material into a consistent whole.

In order to do this the project will employ so called attack graphs which models the steps that an attacker needs to perform in order compromise some end target. The end result should be encoded in the Meta Attack Language (MAL), which is domain-specific language for attack graph modeling.

Project L9: Limits of Deep Reinforcement Learning, are they really learning?





Supervisor: Ezgi Korkmaz ezgik@kth.se

Reinforcement learning (RL) became a popular research area after major advances in deep neural networks (DNNs). Over less than a decade Deep RL achieved to beat human players in their own games [Mnih et. al.(2015), Silver et. al. (2017)]. Yet the outstanding results of Deep RL are inherently vulnerable to adversarial examples. Adversarial examples in DNNs were first observed by [Szegedy et. al. (2013)] and further explanations based on the linearity of the networks have been proposed by [Goodfellow et. al. (2015)]. These works have shown that by adding imperceptible perturbations to the images it is possible to make DNNs diverge from the true labels, consequently affecting Deep RL agenst. The main objective of this project will be testing the limits of deep reinforcement learning agents and finding their vulnerabilities.

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David Silver et al. Mastering the game of go without human knowledge. *Nature* 550.7676 (2017): 354.

Context M: Big Data & AI

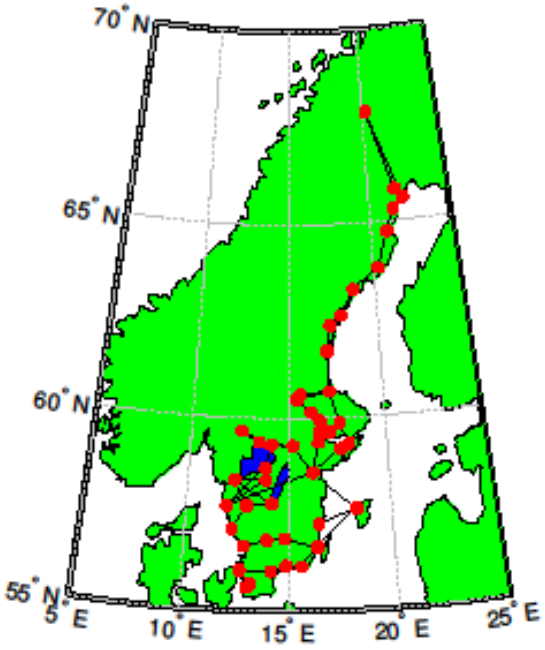
Big data and artificial intelligence are broad topics with huge technological and economical potentials and therefore is of interest in many areas. From an engineering point of view, it is mostly related on how to process data. Currently, information and communication technology (ICT) is penetrating 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 computational statistical inference.

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 machine learning for data over graphs with application to weather data, temporal convolutional networks for computing single base probabilities for DNA sequencing, detection of generative adversarial networks, deep Gaussian processes to model parameters of radio channels, comparison of currently popular neural network architectures, generalization performance of different decentralized learning methods, optimal energy consumption for consumer communities using HMM. Since information processing is quite abstract, all projects require a good mathematical background and solid programming skills.

Project M1: Learning sparse graphs from data

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



A current trend is to collect and store huge amounts of data in almost any instance of our daily lives. The data may be of very different type or being heterogeneous. Sometimes there are no obvious relations or connection between different data or data collected at different instances. Graphs offer a way to describe and explain relationships in such complex datasets. Data is at nodes in the graph and edges or links between nodes describe certain relationships between nodes. This is sometimes referred to as graph signals. Examples of such complex-structured data include data in brain networks, social networks, transportation networks, but it could also be in more traditional time series or image processing applications. To be able to make use of the data for doing "graph signal processing" or "machine learning over graphs" it is central to have this graph description. If the graph is not given by nature it must be learnt from data as a first step. In this project, we are interested in the problem of learning an unknown graph describing relations behind the data. In many facets of the problem it is motivated to select simple graphical models that adequately explain the data. In particular, we are interested in learning a sparse graph, i.e., a graph with a small number of links.

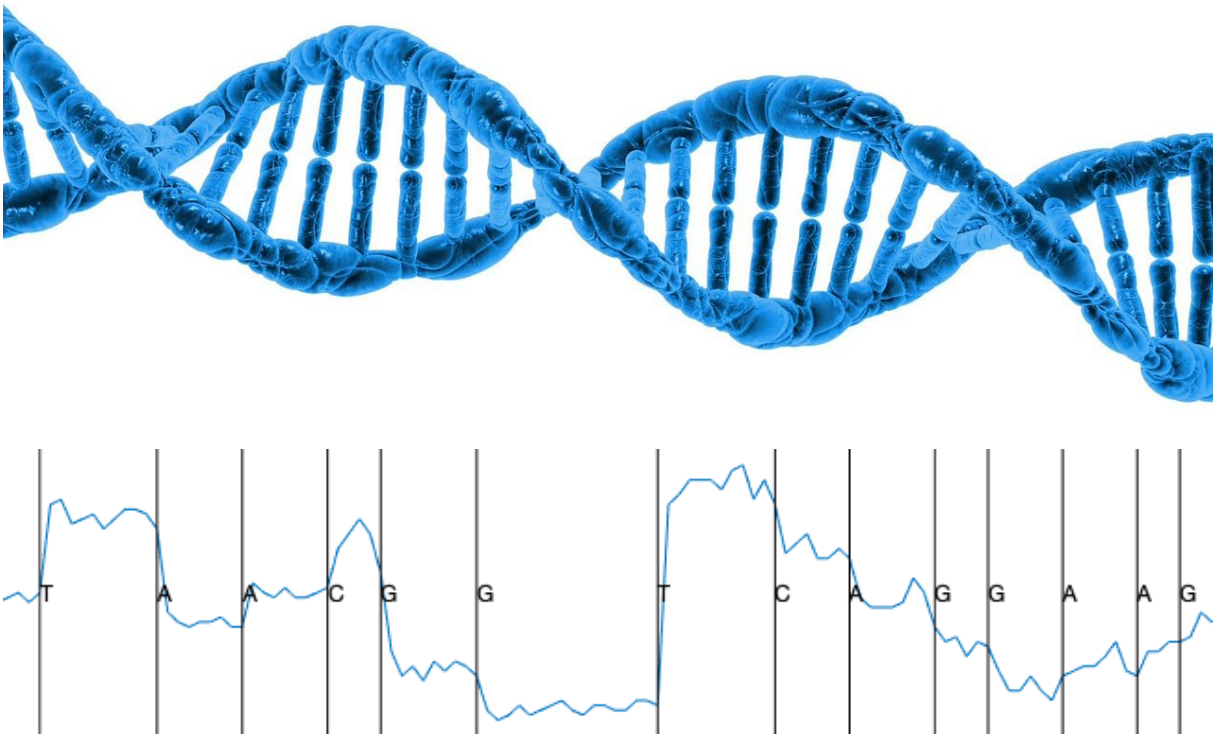
As an example, consider the data set of daily temperatures from 45 Swedish cities from October to December of 2014 [data from SMHI]. The task is to find a graph that shows which cities have similar temperatures. Notice that the graph learning algorithm only has access to the temperatures and not the coordinate locations of the cities. In the figure above we see that "neighboring" cities can be identified from the temperature data. We can also see that cities on the same latitude have related temperatures.

The aim of this bachelor thesis project is to perform a graph learning task similar to the example above based on a certain chosen data set and appropriate data assumptions such as for example smoothness across the graph.

This is a hot topic in research. Please see the recent IEEE Signal Processing Magazine May 2019. For example, "Learning Graphs From Data: A Signal Representation Perspective".

Project M2: Temporal convolution networks for DNA sequencing

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



Next generation 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 bases in perpendicular to the backbone. Either way, the currents are on the order of pico-Ampere, and will despite the use of high precision amplifiers contain a large amount of noise. There is thus a need for signal processing and machine learning for interpreting the measurements.

The proposed bachelor thesis project is with the division of information science and engineering, which is part of a larger research environment funded by Swedish Research Council and dedicated to developing next generation sequencing technologies. The specific purpose of the bachelor thesis project will be to investigate a new machine learning tool called temporal convolutional networks for computing single base probabilities from raw electric reads originating a next generation sequencer developed by Oxford Nanopore. The project is suitable for students comfortable with programming in Python, and with an interest in signals and systems, and its overlap with machine learning.

A high-level description of the overall goals of the research environment for next generation sequencing can be found at https://bit.ly/2FjwEZH

Project M3: True or Faked Data

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

In today's society, we are not only only exposed to faked news in written or spoken form, but also to images, videos or sound recordings that are computer generated but that are more or less indistinguishable from true data.

The goal of this project is to try to device computer algorithms to distinguish between true and faked data. Interestingly enough, such algorithms are used as a part of so-called generative adversarial networks, which are among the most successful techniques used today to create artificial natural-looking images/videos and other data. These generative adversarial networks actually contain two separate parts, one neural network that attempts to generate the data and another neural network that attempts to distinguish the generated data from true real-world data. The former network is trained with the goal to make the latter network fail, whereas the latter network is trained to still be able to determine the difference. Letting these two neural networks compete against each other turns out to be an efficient strategy to teach a computer to generate artificial but realistically looking data.

Implementing a full generative adversarial networks would be too extensive a task for this degree project, so we will focus on one half of the solution, namely the part that attempts to distinguish between real-world and artificially created data. At your disposal, you will have tens of gigabytes of measurements of radio propagation data, in the form of impulse responses, reflecting how a radio signal is affected by attenuation, diffraction, reflections and other physical phenomena, when passing from a base station to your mobile. You will also get access to algorithms to numerically generate artificial radio channel impulse responses. These algorithms are based on channel models that have been developed by human experts, using a combination of theoretic considerations and field measurements.

In your project, you should develop one or several strategies and evaluate their ability to distinguish between real-world and artificially generated data. Your algorithms may be based on machine-learning techniques or your own ideas on what features are interesting to look at, or a combination of both.

Project M4: Modelling Parameters of Radio Channels with Deep Gaussian Processes

Contact: Ragnar Thobaben, ragnart@kth.se, Information Science and Engineering Division

The parameters of radio channels like, e.g., the channel's frequency response (i.e., the amplitude and phase at a given frequency) are usually affected by the randomness of the environment due to moving objects that change how signals are scattered and reflected. Due to the underlying physical phenomena, there is correlation in time and frequency, which affects the performance of communication systems, and randomness that can be used to extract a secret key from the channel used in a security application. Hence, stochastic models of channel parameters are desirable and can be utilized in many different ways.

The goal of this project is to apply the deep Gaussian processes[2] to model parameters of radio channels, to develop new ideas on how these models can be utilized, and to answer questions like the following:

- Can we use generative deep Gaussians models[3] to predict future channel parameters or channel parameters for "neighbouring" channels (e.g., channels that are close in space or frequency)?
- Can we quantify the randomness of the radio environment?
- Can we detect physical phenomena in the wireless environment based on the channel parameters (e.g., presence or absence of a person)?

Answers to these questions can have implication on several use cases like resource scheduling in a communication system, wireless security, and surveillance tasks.

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 a strong mathematical background. Students working in this project will be supported by Ragnar Thobaben. Measurement data from channel responses will be provided. The available USRP software-defined radio platform at ISE can also be exploited in order to collect measurement data with specific properties in order to better match an envisioned use case.

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[2] A. Damianou and N. Lawrence. "Deep gaussian processes." *Artificial Intelligence and Statistics*. 2013.

[3] Z. Dai, A. Damianou, J. González, and N. Lawrence, "Variational Auto-Encoded Deep Gaussian Processes," in Proc. ICLR 2016.

Project M5: Beyond Deep Learning in the Era of Big Data

Contact: 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 M6: Decentralized Methods in Machine Learning

Contact: Ming Xiao, mingx@kth.se, Information Science and Engineering Division

Background: As compared to publicly-accessible data, privately-held data are more relevant and timely for machine learning. These private data are usually stored in individual electronic devices such as smart phones, tablets and computers. Decentralized Machine Learning (DML) protocol is designed to expand the reach to private data and unleash their potential to facilitate machine learning development while protecting data privacy. Decentralized machine learning algorithms will be run on the devices without extracting the data from the devices, which will be kept within the devices. Only the machine learning result will be aggregated with outcomes generated from other devices to form analytics and predictions.

Tasks:

1. Learn the decentralized optimization algorithms, e.g. decentralized gradient descend (DGD) [1], stochastic DGD [2], alternating direction method of multipliers (ADMM) [3] and variants.
2. Implement the decentralized methods on learning different neural network (NN) based models. Compare the generalization performance for learned results on real world dataset.
3. Optionally, propose approaches to improve the performance of decentralized methods, e.g., reducing running time or communication load.

References:

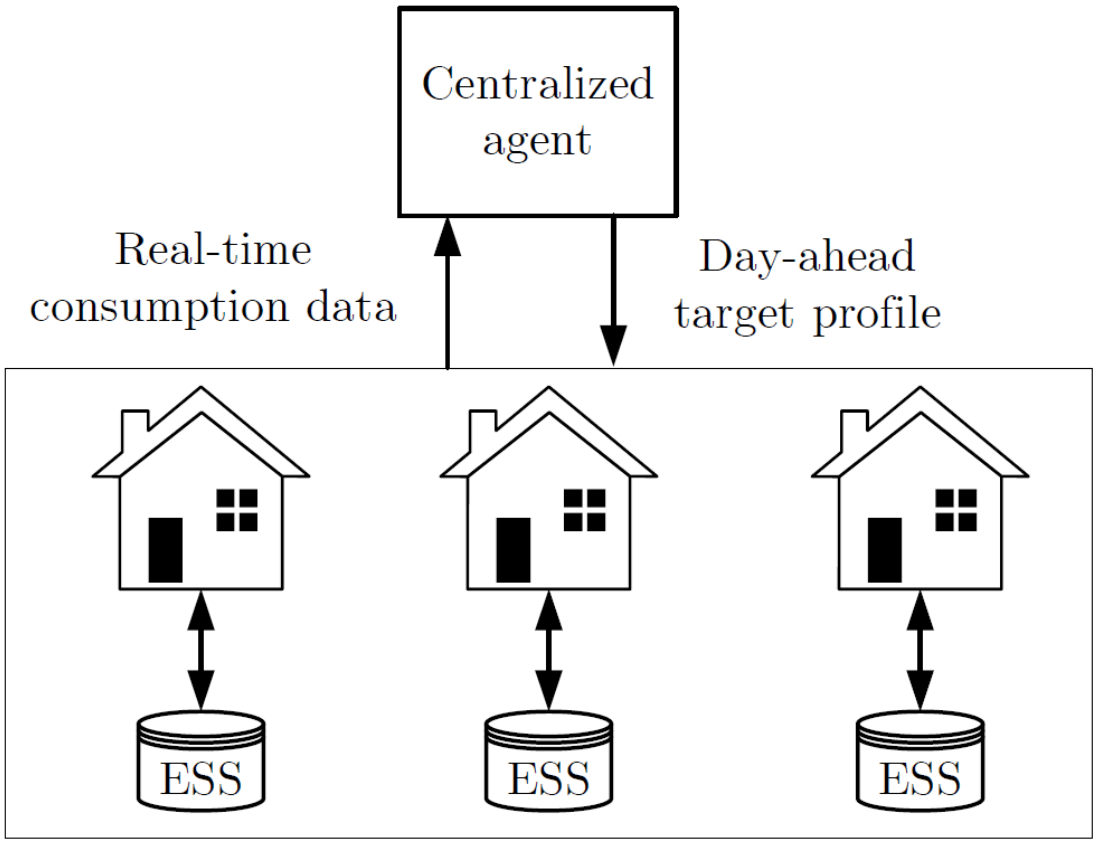
[1]. Yuan, Kun, Qing Ling, and Wotao Yin. "On the convergence of decentralized gradient descent." *SIAM Journal on Optimization* 26.3 (2016): 1835-1854.

[2]. Lian, Xiangru, et al. "Asynchronous decentralized parallel stochastic gradient descent." *arXiv preprint arXiv:1710.06952* (2017).

[3]. Boyd, Stephen, et al. "Distributed optimization and statistical learning via the alternating direction method of multipliers." *Foundations and Trends® in Machine learning* 3.1 (2011): 1-122.

Project M7: Privacy-risk analysis in smart grids with the goal to minimize cost of electricity consumption

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



In smart grids, the energy demands of consumers are recorded in real-time using smart meters. With the fine-grained energy usage data, smart grids can better control the grid fluctuations and facilitate smooth integration of renewable energy sources and storage systems. In this project, we consider a community of users interested in jointly minimizing their cost of electricity consumption from the grid. A centralized agent monitors the energy consumption of users and generates a day-ahead target consumption profile for each user. Further, each user employs an energy storage system to achieve the target profile. In this system, we analyze the privacy-risk of the users when the centralized agent is compromised.

In the first part, we use the available real household consumption datasets and the electricity price datasets to estimate parameters of a hidden Markov model that approximates the system evolution in a stochastic sense. Next, we generate the target-profiles for each user in order to jointly minimize the cost of electricity consumption. Lastly, we implement a simple controller [1] for each user to track the target signal and access the privacy-risk in the system by using hypothesis-testing [2].

References:
[1] G. Kalogridis, C. Efthymiou, S. Z. Denic, T. A. Lewis, and R. Cepeda, "*Privacy for smart meters: Towards undetectable appliance load signatures*," in Proc. 1st IEEE Int. Conf. on Smart Grid Comm. (Smart-GridComm), Gaithersburg, MD, USA, 2010, pp. 232–237.
[2] Pramod K Varshney, "*Distributed detection and data fusion*," Springer Science & Business Media, 2012.

Context N: Automatic bug fixing and self-healing software

General description:

In the projects of this context, 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: Sequence-to-sequence machine learning for automatic program repair

Supervisor: Martin Monperrus, KTH Royal Institute of Technology, EECS/TCS, http://www.monperrus.net/martin/

A lot of automatic bug fixing generation techniques rely on slightly modifying the existing code. The student will devise and evaluate a new repair algorithm that will learn from past diffs, using sequence-to-sequence learning. The planned methodology is as follows: 1) set up a training and evaluation dataset based on diffs 2) devise, implement and assess a new repair algorithm based on this data. The student will perform the experiment by running it on a scientific computing grid.

1. An Empirical Investigation into Learning Bug-Fixing Patches in the Wild via Neural Machine Translation
2. SequenceR: Sequence-to-Sequence Learning for End-to-End Program Repair
3. Benchmark of single-line bugs

Project N2: Chaos Engineering for Microservices in .NET and C#

Supervision: Long Zhang, Martin Monperrus, KTH Royal Institute of Technology, http://www.monperrus.net/martin/

Description: Chaos Engineering [1] is the discipline of verifying resilience capabilities of software systems in production. ChaosMachine [2] is such an approach for microservices implemented in Java. While microservices in the .NET world are conceptually similar, there are a number of technical differences. You will study, design and implement the ChaosMachine for microservices in .NET and C#

1. Chaos Engineering (the book)
2. A Chaos Engineering System for Live Analysis and Falsification of Exception-handling in the JVM

Project N3: Preventing algorithmic DOS attacks with blackbox randomization

Supervisor: Martin Monperrus, KTH Royal Institute of Technology, http://www.monperrus.net/martin/

Description: The goal of this thesis is to study counter-measures to algorithmic denial of service attacks. An algorithmic DOS consists of a input specifically designed by the attacker to trigger the worst case execution of a program [1]. Black-box randomization consists of identifying and injecting randomization points in software, without any knowledge of the application domain and implementation choices. The goal of this thesis is to study the usage of black-box randomization for countering algorithmic DOS attacks. The student will devise and perform a scientific experiment in this context. She/he will read the literature, implement the required software for supporting the experiment, design the inclusion criteria for subjects and run the experiment on a scientific computing grid.

1. Denial of Service via Algorithmic Complexity Attacks
2. Correctness Attraction: A Study of Stability of Software Behavior Under Runtime Perturbation
3. Slowfuzz: Automated domain-independent detection of algorithmic complexity vulnerabilities

Context O: Neural network based brain models

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. Both, theoretical questions as well as tests of the networks' functionality in applications are addressed in the suggested projects.

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

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

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.

Possible project tasks:

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).

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

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.

Possible project tasks:

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.

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

Project O3: Bayesian learning in spiking neural network models

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

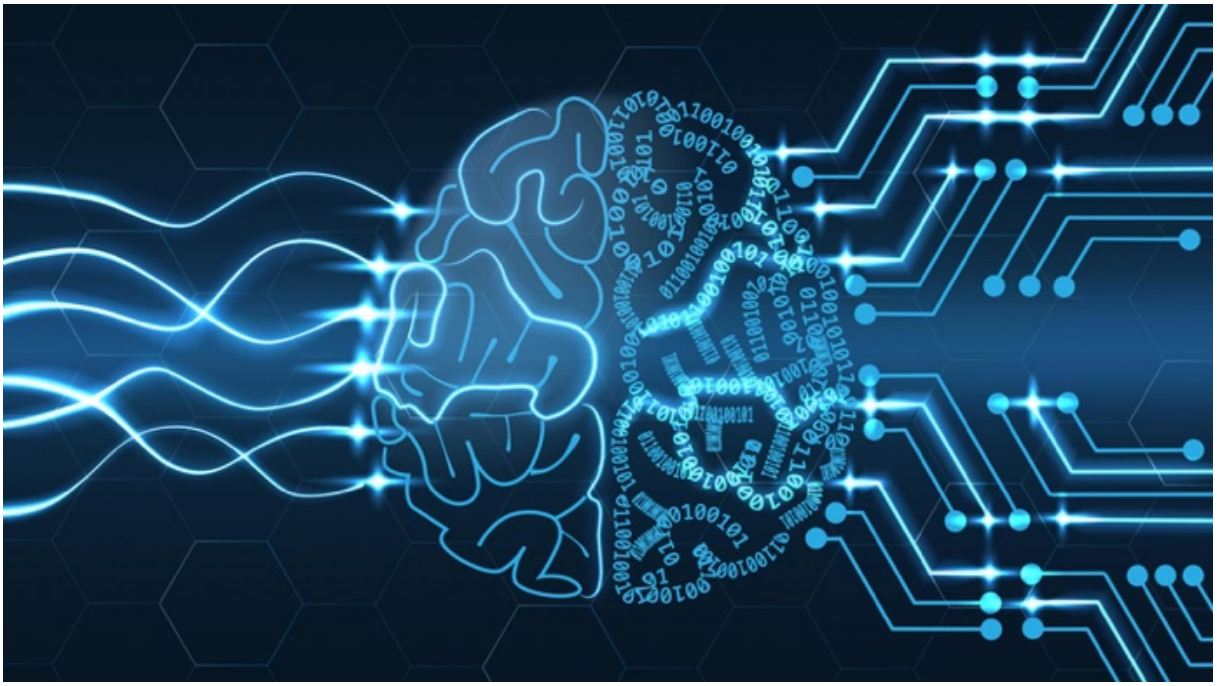
General theme: The theoretical framework of Bayesian statistics is commonly considered as an intuitively attractive model for representing and processing uncertain information in the brain. It has received a lot of attention in computational studies of learning and inference mechanisms underlying brain 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.

Possible project tasks:

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: Multi-Agent Strategic Planning

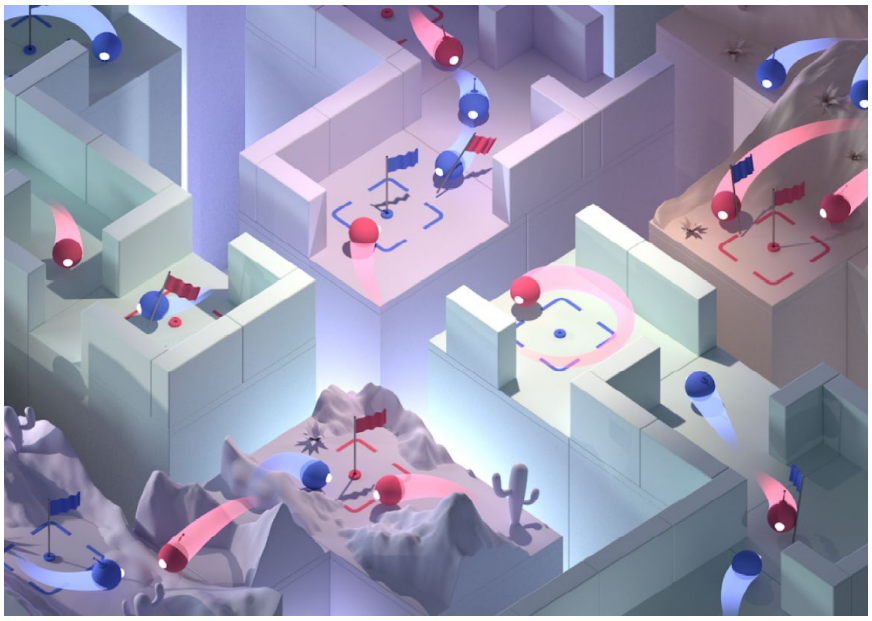
Supervisor: Dilian Gurov (dilian@kth.se)

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: Tactical AI

Supervisor: Mika Cohen (mikac@kth.se)

Keywords: *Deep learning, Reinforcement Learning, Multiplayer games*

During the last few years innovative, at times revolutionary, new strategies are developed in classical strategy games such as Chess, Go, and Shogi, and, since only recently this year, in popular real-time strategy games such as Dota and StarCraft, with the help of tactical AI that are felt to play not like a mechanical machine but as an intuitive and creative master player - only better.

Similar game intelligence will most certainly eventually reach also simulation-based development of military tactics and strategy: we can expect tactics and strategy to be developed with the help of tactical AI that seem to play not like a mechanical machine but as a general – only better.

The proposed projects will take some first steps in this direction and train deep reinforcement learning agents to play two-sided combat games that model decision problems from military science.

Possible project tasks:

- *Pursuit-evasion*. Games of hide and seek, in particular pursuit evasion games, play a prominent role in military science. In this project, deep reinforcement learning agents learn to play hide-and-seek in a testbed from OpenAI (https://openai.com/blog/emergent-tool-use/).
- *Missile allocation*. Missile allocation problems are often analysed as games on a high abstraction level (most often defined by rules as simple as those of classical strategy games like Go, Hex, etc.) In this project, deep reinforcement learning agents learn to play an abstract combat game in which successive waves of air craft attack air defences. The abstract game, described in chapter four of *Combat Modelling* by Alan Washburn and Moshe Kress, is implemented as part of the project.
- *Missile guidance*. There is a long tradition of analysing missile (and air craft) guidance as differential games, abstract games in which the state evolves according to differential equations. In this project, deep reinforcement learning agents learn to guide homing missiles against manoeuvring targets in a simple differential game. The differential game is implemented as part of the project.

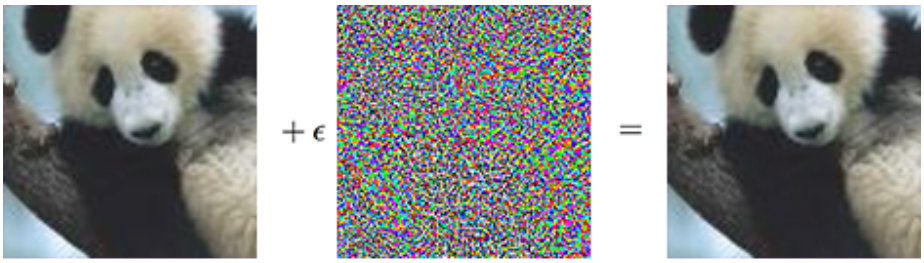
The choice of deep reinforcement learning algorithm will be decided by the student group and supervisor together. A possible candidate is Expert Iteration, a variant of AlphaZero (http://www.nada.kth.se/~ann/exjobb/johan_sjoblom.pdf, code available).

Inspirational reading:

- *Game Changer: AlphaZero's Groundbreaking Chess Strategies and the Promise of AI* (https://www.newinchess.com/game-changer).
- *OpenAI Five* (https://openai.com/five/)

Project P3: Safe and Verified Neural Networks

Supervisor: Mika Cohen (mikac@kth.se)



Keywords: *Neural Networks, adversarial examples, symbolic reasoning*

Spawned by the recently discovered ease of attacking deep neural networks with adversarial examples, there is a growing interest within the AI-community in methods for ensuring that deep neural networks are more robust, safe and interpretable.
Because of their brittle and black box nature, reasoning about neural networks is challenging, making much of traditional software assurance practice ineffectual.
However, symbolic reasoning may offer a way out of the difficulty. The basic idea is to let a symbolic reasoning system, rather than a human, analyse the robustness of the (incomprehensible) neural network. The reasoning system executes the neural network with symbolic formulae as input, propagating formulae rather than concrete values through the network layers, in effect considering a huge (possibly infinite) set of inputs by means of a single pass through the network.
Elsewhere, symbolic reasoning is entering the main stream of software security. E.g., gold, silver and bronze in the DARPA Cyber Grand Challenge was recently won using symbolic reasoning, and Windows, Office, etc. are continuously checked at Microsoft using symbolic reasoning tools, light weight versions of which are now part of Microsoft Visual Studio and Microsoft Security Risk Detection.
In the proposed projects, (automatic) symbolic reasoning tools specialised to neural networks are used to evaluate neural network defences.

Possible project tasks:

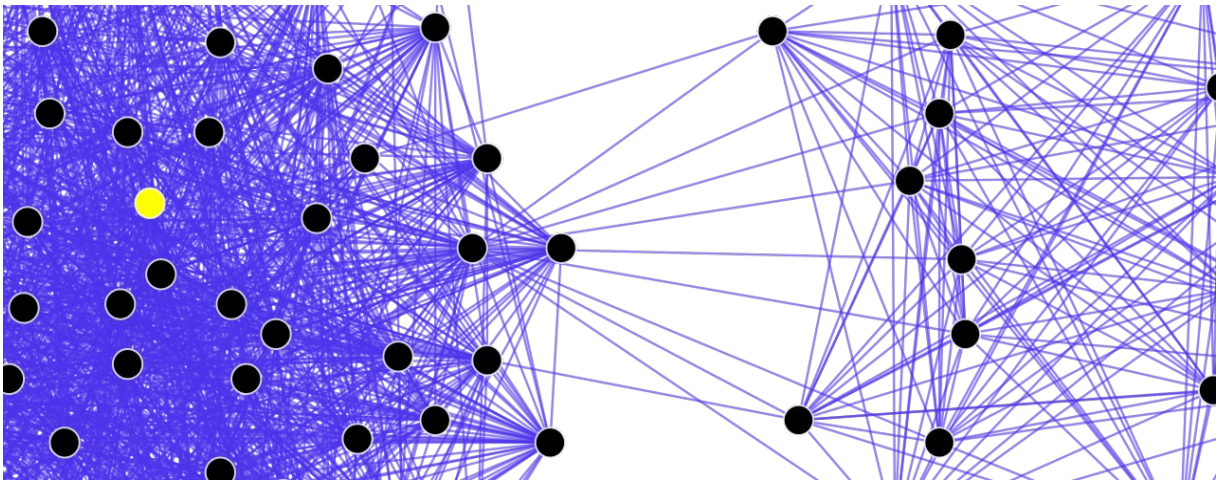
a) *Evaluate neural network defences using abstract interpretation*. Suggested symbolic reasoning system: ETH Robustness Analyzer for Deep Neural Networks (https://github.com/eth-sri/eran).
b) *Evaluate neural network defences using dynamic symbolic execution*. Suggested symbolic reasoning system: DeepConcolic (https://github.com/TrustAI/DeepConcolic).
c) *Evaluate neural network defences using bounded model checking*. Suggested symbolic reasoning system: ESBMC-GPU (https://github.com/LuizHenriqueSena/ESBMC-GPU/).

The choice of network evaluation approach will be decided by the student group and supervisor together.

Inspirational reading:

- *Reliable and Interpretable Artificial Intelligence* (https://www.youtube.com/watch?v=VViHZkIm9pI)
- *Identifying and eliminating bugs in learned predictive models* (https://deepmind.com/blog/article/robust-and-verified-ai

CONTEXT Q: ALGORITHMS: FROM THEORY TO EXPERIMENTS



The projects offered within this context study different aspects of (mostly graph) algorithms with provably performance analysis and experiments.

Project Q1: Learning-Based Dynamic Graph Algorithms

Supervisor: Danupon Na Nongkai, danupon@kth.se

Short description: Can we use machine learning algorithms that can predict the future to develop better algorithms? This question has been actively explores by researchers recently (see [1] and references there in). The goal of this project is to study this question for algorithms that handle graphs that change over time usually called "dynamic graphs" (think of e.g. social networks). Necessary activities are likely be understanding the existing work (e.g. [1]), formulating new questions in the directions above, exploring some existing dynamic graph algorithms, developing new algorithms to answer the newly formulated questions, and theoretically and/or experimentally evaluate the new algorithms. (Warning: This project is not about exploring machine learning algorithms. It is rather the other side, where we explore how to use them assuming some good ones exist.)

[1] Chen-Yu Hsu, Piotr Indyk, Dina Katabi, Ali Vakilian:Learning-Based Frequency Estimation Algorithms, ICLR 2019

Project Q2. Linear Programming Solver

Supervisor: Danupon Na Nongkai, danupon@kth.se

Short description: There are recent theoretical developments on fast linear programming solvers [1,2]. The goal of this project is to explore how well they work in practice. Activities for this project include evaluating the correctness of the existing implementations (note that the algorithm has been coded so you will not start from scratch), experimenting on existing and new data sets, and speed up the algorithms by identifying bottlenecks and coming up with heuristics.

[1] Michael B. Cohen, Yin Tat Lee, Zhao Song, Solving Linear Programs in the Current Matrix Multiplication Time, STOC 2019.

[2] Jan van den Brand, A Deterministic Linear Program Solver in Current Matrix Multiplication Time, SODA 2020.

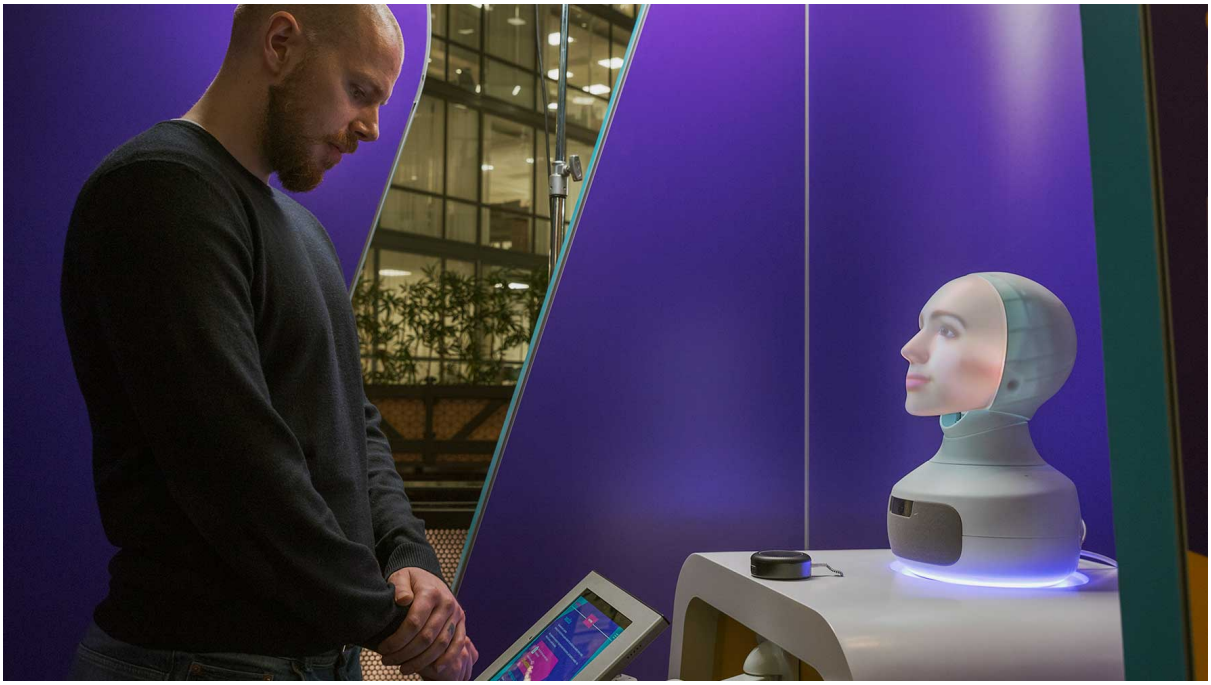
Project Q3. Faster algorithms via new max-flow algorithms

Supervisor: Danupon Na Nongkai, danupon@kth.se

Short description: Max-flow (and min-cost/max-flow) algorithms are primitives in many applications. Recently exciting, faster, max-flow algorithms have been developed (e.g. [1]). One goal of this project is to understand the impact of these new developments in applications. Activities include exploring the new developments, exploring known applications of max-flow algorithms and studying whether the new developments imply anything better for these applications. Note that this project is fairly theoretical (not much experiments).

CONTEXT R: MULTIMODAL SPEECH SIGNAL PROCESSING FOR CONVERSATIONAL ROBOTS

Context coordinator: Jonas Beskow, Division of Speech, Music and Hearing, beskow@kth.se



Spoken interaction with machines in the form of smart speakers and phones is part of our everyday lives, and it is soon expected from advanced devices that we should be able to talk to them. In the field of conversational social robotics, the goal is to build machines that allow for socially engaging face-to-face conversation in real-world environments possibly with multiple users simultaneously.

This poses unique challenges on the speech processing modules of such robots for example when it comes to handling speech from multiple users in noisy environments etc. At the same time, video, array microphones and increasing processing power makes new solutions, e.g. based on deep learning, feasible. This context deals with the low-level processing of multiple input channels, in order to allow for the robot to better understand the situation it is in: Is someone trying to interrupt me when I am spealking? Who (in a group of users) is currently talking? The latter question to be answered using either video or multi-channel audio input. All of the projects will employ deep neural networks, and all of the projects should consider computational requirements and whether deployment of the solution on an actual robot would be feasible.

Project R1: Robust self-voice cancellation based on time-frequency masking

Supervisor: Jonas Beskow, Division of Speech, Music and Hearing, beskow@kth.se

For a conversational system to function smoothly in interaction, it needs to allow for interruption a.k.a. Barge-in, i.e. the user should be able to interrupt the speech of the system by speaking over it. This means that the system needs to monitor the microphone signal also when it is speaking, in order to be able to detect user speech. The problem is that the outgoing robot voice also will be picked up by the microphone(s). Traditionally, acoustic echo-cancellation (AEC) based on adaptive linear filters is used in order to eliminate the system's own speech from the microphone signal. Linear AEC will only work for well-behaved signals and will fail in many real-world scenarios. Using deep neural networks, more robust solutions can be developed. Given representative training data, the network can be trained to output a spectro-temporal mask that can effectively eliminate traces of the systems own voice in the microphone signal. In this project, the students will:

- Propose and implement a basic architecture for DNN-based self-voice cancellation based on time-frequency masking
- Construct a dataset for training the performance of the network, based on existing speech datasets, filtering using room simulation software (e.g. https://pypi.org/project/pyroomacoustics/) as well as a small test set based on own recordings.
- Evaluate the performance of the system both in terms of objective signal measures and in terms of scoring from an automatic speech recognition on the resulting output
- Analyze computational requirements and feasibility of real-time implementation

Project R2: Multi-speaker speech activity detection from video

Supervisor: Jonas Beskow, Division of Speech, Music and Hearing, beskow@kth.se

A conversational robot will in certain settings have to deal with multi-party spoken interaction, where one or more of several people may choose to speak at a given time. For the robot to handle such interactions in a smooth and natural manner, it needs to know who is speaking, e.g. in order to attend that person. This project will attempt to solve this problem from a visual point of view (project 3 will do the same from multi-microphone input)

The goal of this project is to detect speech activity based on a video input, using a machine learning based method. Presented with a video stream containing one or more faces, the task is to detect for each face, at each point in time, the probability of that person speaking or not. There are available datasets (e.g. AVA-Speech https://ai.google/research/pubs/pub47336/) Specifically the participants will:

- Study existing literature on state of the art in visual speech activity detection

- Collect and pre-process training data, possibly and complement with a small test set based on own data.
- Implement and train video-based speech activity solution, based on DNNs (or possibly other machine learning frameworks)
- Evaluate performance, compare against published methods if possible
- Analyze computational requirements and feasibility of real-time implementation

Project R3: Multi-speaker speech activity detection from array microphone input

Supervisor: Jonas Beskow, Division of Speech, Music and Hearing, beskow@kth.se

A conversational robot will in certain settings have to deal with multi-party spoken interaction, where one or more of several people may choose to speak at a given time. For the robot to handle such interactions in a smooth and natural manner, it needs to know who is speaking, e.g. in order to attend the right person. This project will attempt to solve this problem from multi-microphone input (project R2 will do the same from visual input)

This project is about detecting speech activity based on audio readings from array microphone input (2 or 4 channels). Given a spatial direction from the microphone (given as a direction in azimuth and elevation angles) the goal is to estimate the probability of speech coming from that location at a given point in time. Ideally, the system should also be able to ignore its own voice, that can be provided in clean form as a separate input (but also present in the microphone signals in some form)

- Construct a data set for training based by filtering existing speech data through room simulation software (e.g. https://pypi.org/project/pyroomacoustics/), and a small test set based on own array mic recordings.
- Implement and train a DNN-based speech activity detector for (simulated) array microphone input
- Evaluate performance, compare against published methods (if possible)
- Analyze computational requirements and feasibility of real-time implementation