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# TOPICS FOR THESIS / INTERNSHIPS

## ACADEMIC YEAR 2024-25

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# TOPICS FOR THESIS / INTERNSHIPS 2024-25



Applications (CV + transcript of records + cover letter + desired period to begin) must be sent to international@heig-vd.ch

Interns will receive a grant to support financial costs: housing (CHF 600.-/month) + basic expenses (CHF 400.-/month).

Internships last 4 months. Some professors may exceptionally accept shorter or longer ones.

# GEOMATICS, CIVIL ENGINEERING



## VULNERABILITY ASSESSMENT OF BUILDINGS TO DEBRIS FLOW

**Prof. E. Prina Howald**

Debris flow is considered amongst the most dangerous natural hazards today due to the high velocities and heights it can reach. Climate change and the intensification of land use, not suited to natural hazards, are two factors that significantly increase the risk associated with natural hazards. It is therefore more necessary than ever to understand their behavior and to evaluate the danger they represent for the built environment and thus the population.

The aim of this study is to evaluate the vulnerability of different types of building structures to debris flows. In order to carry out this task, it is first necessary to evaluate the intensity of debris flows according to multiple previously defined parameters. Then, it is necessary to develop a general methodology (adaptation of existing methodologies) needed to assess the vulnerability of predefined types of building structures.

**Prerequisites:** Students in Civil engineering and/or environmental engineering with strong interest in Natural Hazards

## PHYSICAL VULNERABILITY ASSESSMENT OF THE BUILT ENVIRONMENT TO ROCKFALL HAZARDS

**Prof. E. Prina Howald**

Global warming and the escalation of land use not adapted to natural hazards are two drivers that greatly contribute to the elevation of the risk related to natural hazards. Thus, it is necessary now more than ever to analysis and evaluate the danger they represent for the constructed environment and consequently for the population. In the field of rock fall hazards, there are several different methodologies developed to determine the hazard risk and to help create hazard maps (zoning).

This work aims toward analyzing of existing methodologies for rockfall risk assessment and their adaptation in the field of physical vulnerability assessment of the built environment.

**Prerequisites:** Students in Civil engineering and/or environmental engineering with strong interest in Natural Hazards

## ADVANTAGES AND DISADVANTAGES OF LOW TEMPERATURE ASPHALT PRODUCTION

**Prof. E. Prina Howald**

Asphaltic concrete is a mixture of aggregate and bituminous liant, hot-mixed at temperatures generally above 150°C. In order to reduce the energy impact of producing these mixes, it is possible to reduce the production temperature by adding chemical additives. The aim of this project is to analyse the advantages and disadvantages of low temperature asphalt production. The project includes an experimental study and a rheological study, part of which will be carried out in the laboratory in collaboration with a building materials laboratory.

**Prerequisites:** Students in Civil engineering and/or environmental engineering with strong interest in road construction

## NUMERICAL MODELLING OF GLACIER MOVEMENTS IN RESPONSE TO CLIMATE CHANGE

**Prof. E. Prina Howald**

Climate change is the leading cause of glaciers thaw in the Alpine environment. Over the last 30 years, it has led to a drastic increase in rock instabilities, landslides, mudflows, and debris flows in the European Alps. The project aims to analyse the risks associated with glacier movements due to climate change. In order to carry out this task, a numerical model will be used to assess the temperature rise on glaciers displacements and its consequences.

**Prerequisites:** Students in Civil engineering and/or environmental engineering with strong interest in Natural Hazards and modelling

## EFFECT OF THAWING ON FROZEN SOIL GEOMECHANICAL PROPERTIES

**Prof. E. Prina Howald**

Climate change is the leading cause of permafrost thaw in the Alpine environment. Over the last 30 years, it has led to a drastic increase in rock instabilities, landslides, mudflows, and debris flows in the European Alps. The aims of this project is to quantify exprimentally the effect of thawing on the geomechanical properties of a reconstructed soil samples. The project include the establishment of a test protocol and laboratory tests.

**Prerequisites:** Students in Civil engineering and/or environmental engineering with strong interest in lab tests

## PHYSICAL VULNERABILITY ASSESSMENT OF THE BUILT ENVIRONMENT TO DROUGHT

**Prof. E. Prina Howald**

Climate change is increasing the intensity and duration of soil droughts due to increased evaporation associated with rising temperatures. One of the effects is the swelling and shrinking of clay soils. Although this problem does not directly threaten human life, it causes significant damage to buildings and structures each year.
The aim of this work is to investigate the impact of long periods of heat on the built environment.

**Prerequisites:** Students in Civil engineering and/or environmental engineering with strong interest in Natural Hazards

## CORRELATION BETWEEN ROCKFALL AND CLIMATE CHANGE

**Prof. E. Prina Howald**

Climate change has an important influence on the increasing frequency of events related to natural hazards. Study on pilot sites of the effect of climate change on rockfall.

The objectives of this study are to characterize the different effects of climate change and to determine the real impacts. In addition, it will be important to participate in the creation of a comprehensive methodology for the risk management and risk mitigation.

**Prerequisites:** Students in Civil engineering and/or environmental engineering with strong interest in Natural Hazards





## SUSTAINABILITY IN THE CONSTRUCTION INDUSTRY

**Prof. M. Viviani**

The research project in which the candidate will work targets enhancing sustainability in construction projects, especially transformation projects, through the use of smart digital twins. These twins are tailored to incorporate crucial information on existing structures, monitoring data, and local suppliers of sustainable products and services. Architects and engineers can leverage these digital twins to evaluate project impacts early in the design phase and optimize designs in line with corporate social responsibility principles. This approach ensures that construction projects efficiently meet societal and environmental obligations.

**Prerequisites:** Knowledge and interest in the following areas: sustainable construction materials, recycling, reuse, BIM, Sustainability in construction industry, Corporate social responsibility, Innovation economy, construction processes

**Duration:** 6 months

**Keywords:** Sustainability in costruction, digital twins, environmental impacts, costruction processes

## BOND STRENGTH OF STRENGTHENING LAYERS

**Prof. M. Viviani**

The research project in which the candidate will work focuses to advance the development of predictive models to ensure the durability of bond strength in advanced strengthening materials like Ultra High Performance Fiber Reinforced Concretes (UHPFRC) and geopolymers. These models will specifically address concerns related to seismic loads and viscous phenomena, which currently lead engineers to rely heavily on mechanical connectors. By enhancing these predictive models, the study aims to mitigate concerns about bond strength evolution over time, ultimately ensuring the long-term effectiveness and stability of these materials, particularly in seismic conditions.

**Prerequisites:** Knowledge and interest in the following areas: Laboratory testing, material science, modeling, structural engineering

**Duration:** 6 months

**Keywords:** Bond strength, strengthening materials, geopolymers, structural engineering

# ENERGY, ENVIRONMENTAL ENGINEERING



## OPTIMIZATION OF ENERGY PRODUCTION FROM BIOLOGICAL WASTE TROUGH ANAEROBIC DIGESTION

**Prof. Dr. R. Roethlisberger**

As the world is facing a growing issue with climate change, alternative non-fossil energy sources are becoming more and more prominent. Among them, anaerobic digestion is a carbon neutral way of converting organic waste into methane, while producing an organic-rich fertilizer. It thus perfectly falls within the concept of a circular economy.

The Institute of Energies has been active for several years in this research field, mainly in process optimisation through cow manure pretreatment as well as enhancement through $CO_2$ injection. The work proposed consists in contributing to further develop the cow manure pre-treatments through optimized grinding, thermal hydrolysis and weak acid attack.

**Duration:** Minimum duration 4 months, preferentially 6 months

**Keywords:** Methanization, anaerobic digestion, substrate pre-treatments, $CO_2$ injection

## EXISTING MULTI-FAMILY BUILDING DECARBONIZATION BY AN OPTIMAL COMBINATION OF RETROFITTING MEASURES AND FUEL SWITCH

**Dr. A. Duret**

Multi Family Buildings (MFB) remains largely non-retrofitted and use mainly fossil energy for heating and domestic hot water (DHN) production in Switzerland. This category of building is therefore responsible for a large share of the Greenhouse Gas emission of the Swiss building stock. The retrofitting rate of those categories of buildings remains too low to reach the CO2 emission reduction national target. In order to address this issue, an applied R&D project has recently been launched to optimize the decarbonization of existing MFBs by combining limited retrofitting actions with heat distribution and DHW production optimization and switching from fossil-based heat producer to Air Source Heat Pump (ASHP).

The proposed internship will directly contribute to the realization of this project. Based on a defined modelling and optimization strategy, the student selected for this internship will be responsible to develop several numerical models:

(1) a dynamic model to generate the building heating demand and the DHW production as a function of weather conditions and taking into account various retrofitting actions,

(2) model of the heating distribution system to calculate the minimum forward temperature to satisfy the heating demand and

(3) a simplified model of an ASHP able to compute the performances as a function of the operating conditions. Those models will then be connected one to each other to evaluate and compare several decarbonization scenarios. The developed method will be tested with at least one case study based on a real MFB.

**Keywords:** Building retrofitting, building decarbonization, renewable heating, numerical modelling and multi objective optimization

## THERMAL ENERGY STORAGE IN DISTRICT HEATING NETWORKS

**Prof. X. Jobard**

The TES4DH project proposes to study the applications of thermal energy storage (TES) with water for district heating (DH) in Switzerland. Three promising applications have been identified:

1) Sectoral coupling with heat pumps or cogeneration plants to flexibilize the production/consumption of electricity.
2) Decentralized TES to support the extension of networks and to increase heat pre-distribution.
3) Centralized TES to increase boiler room capacity and eliminate the use of fossil heat during peak consumption.
TES4DH will quantify the energy, economic and environmental benefits of the proposed applications and optimize their design and operation. Finally, an analysis of the framework conditions and business models will identify the brakes and levers for the implementation of concrete projects.

The proposed internship will directly contribute to the realization of the TES4DH project. The selected student will be responsible to: 1) establish the state of the art of the use, modelling and planning of TES in DH networks. 2) develop numerical models with TRNSYS of the heat production system for one chosen application (depends on data availability and project advancement. 3) evaluate the energy, economic and environmental performances of the application through a case study

**Keywords:** District heating, thermal energy storage, decarbonisation, sector coupling

## LIFE CYCLE ASSESSMENT OF CIRCULAR STRATEGIES AT THE BUILDING STOCK AND PILOT PROJECT LEVELS

**Prof. S. Lasvaux**

This internship is part of an applied research project that analyses the reuse of building components in the Geneva canton with multiple public and private stakeholders. From a typology-based assessment on the reuse potential (“offer” side in the existing building stock) to the analysis of pilot projects (“demand” side) conducted in collaboration with practitioners, the aim is to quantify the LCA of different measures and logistic routes for the reuse of building components. The internship’s work plan will be divided in different activities:

- Estimation of the reuse potential through a typology-based approach including on-site audit on selected buildings and LCA of individual elements for reuse for the “offer” side in the building stock
- Analysis of possible constraints for reuse in terms of logistics for specific building elements (e.g. load bearing ones) when the “demand” does not synchronise with the “offer”.
- From the “demand” side, analysis of real pilot project (at least one) in partnership with local stakeholders and LCA of the building with a particular analysis on the different reuse routes and elements.

**Duration:** Minimum 4 months (preferably 6 months)

**Keywords:** District heating, thermal energy storage, decarbonisation, sector coupling





## INTEGRATING HYDROGEN PRODUCTION AND DISTRICT HEATING FROM A WASTE INCINERATION PLANT

**Prof. M. Capezzali**

Waste incineration plants represent multi-energy generation hubs that can provide large quantities of renewable energy to urban centers. Indeed, those plants can provide thermal energy to district heating networks and industrial sites, while generating baseload electricity for local networks. New solutions are emerging by taking advantage of the high-temperature processes, including production of hydrogen, thermal storage capacities and carbon capture technologies. Hence, urban waste incineration plants will become flexible platforms providing a broad spectrum of energy services to the surrounding urban territories, possibly including production of renewable fuels for mobility and industrial processes, such as ammonia and methanol. Optimized integration of waste incineration plants for the supply of district heating networks will be another major focus.
Within a concrete case of application of the new approach on an urban waste incineration in the Canton of Zürich and then extrapolated to the whole national context, the tasks will be the following:

a. Validate available data on buildings to be connected to future district heating network
b. Quantify buildings demand profiles over different time horizons as inputs for scenarios
c. Simulate future district heating network, both hydrodynamically and energetically, in a python environment
d. Develop scenarios based on available energy flows from incineration plants
e. Calculate KPIs for the different scenarios
f. Lay basis for generalization of approach to other urban waste incineration plants in Switzerland

**Prerequisites:** Interest in Python programming, knowledge in energy engineering and sustainability, passion for renewable energy

**Keywords:** District Heating Networks, Urban Energy Planning, Simulation, Renewable Energies, Waste Valorization

## COMMUNITY MICROGRIDS: TOWARD ELECTRICAL GRID RELIABILITY AND RESILIENCY INCREASE

**Prof. M. Carpita**

A community microgrid is designed to serve the energy needs of a residential neighbourhood, a building complex, etc.; it includes several GFMI and is connected to a distribution grid. Furthermore, community microgrids can be owned and operated by local communities rather than a centralized utility. The interaction of multiple GFMIs in a community microgrid in «standalone» operation modes, as well as the interaction of GFMIs and the power grid in «grid-connected» operation modes, will be studied and tested by building a second proprietary GFMI inverter (with a power capacity in the same order of magnitude than the first GFMI). Other technical risks, including load imbalances and short-circuits of GFMIs in a community microgrid, will be studied. Using GFMIs within a community microgrid will enhance Switzerland’s energy supply’s resilience to external drivers and will participate in laying the groundwork for the implementation of the «Energy Strategy 2050» in an affordable and secure manner.

Overall, the project aims to explore the role of community microgrids in enhancing the reliability and resilience of the grid. A community microgrid co-ordinates several grid-forming inverters (GFMIs) equipped with im-proved damping and virtual inertia, within a local distribution grid in both grid-connected and standalone operational modes. Through simulations and experimental validation, this study will propose a decentralized control strategy for GFMIs within a community microgrid. The project will investigate the advantages and effectiveness of the proposed community microgrid scheme, including improved grid reliability and resilience as well as supporting grid restoration. The project will also examine the technical risks of voltage instability, load imbalance, and short-circuits in both operational modes to deter-mine adequate control measures and protection strategies. However, a reduced student term of reference will be agreed with the candidate, according to his/her time availability and technical background

**Prerequisites:** Competencies in power electronics and Power Systems

## POWER CONVERTER TOPOLOGIES TO IMPROVE THE EFFICIENCY AND LIFETIME OF PEM (AND OTHER) HYDROLYSER TECHNOLOGIES

**Prof. M. Carpita**

Polymer Electrolyte Membrane (PEM) technology is really interesting for electrolyser applications mainly thanks to its ability to operate at high current densities and variable (low) power levels within seconds and with a higher rate of hydrogen production. However, it is emerging that its performances can deeply degrade in a few years. This seems to be mainly due to the current harmonics produced by the power supply on the DC side. Other really important issues are that the power supply must respect AC grid code requirement, together with obtaining reduced costs (reduced CAPEX) and high efficiency (reduced OPEX). Aim of this project is to choose and design an optimal structure of the power converter, concerning both topology and control, for improving both AC and DC side behaviour. Therefore, this will lead to have a high-power quality of the whole system and a more gentle impact on the electrolyser of the power electronics. Moreover, the possibility of operating PEM electrolysers as close as possible to their optimal functioning conditions, independently of fluctuations on the power grid side.
Hence, at a more global level, our project has the following purposes: improving the way the power electronics affect the hydrolyser, enhancing the overall efficiency and reliability of future power-to-gas schemes by using modern power electronics applied to electrolysers, in a similar fashion to variable speed generators in hydro pump-turbines.
For testing the developed principles, a reduced scale demonstrator together with an emulator of the electrolyser will be developed.
The project will be developed in order to solve the following issues raised in the literature:

- Optimal choice of the power converter topology
- Application flexibility
- High level control - AC side impact and ancillary services to the grid:
- Inverter current control - DC side impact:
- Dynamic model of the electrolyser

A reduced student term of reference will be agreed with the candidate, according to his/her time availability and technical background





**Prerequisites:** Basic competences in Power electronics and Control theory

## OPTIMAL DESIGN AND OPERATION OF A VIRTUAL POWER PLANT IN THE VICINITY OF SMALL-SCALE HYDRO POWER PLANTS

**Prof. M. Bozorg**

The project aims at developing optimization model for designing a virtual power plant (VPP) by aggregating small hydroelectric units as well as local photovoltaic, wind power units, storage systems, etc in order to mutually valorize potential flexibilities to participate in electricity markets. The optimal design of the VPP includes: 1) Definition of VPP components (distributed resources); two case studies 2) Definition of yearly scenario of operation (available water, PV production, etc) for the two case studies 3) Optimization of the size and location of resources regarding yearly scenarios with respect to overall potentials for energy and flexibility (ancillary service) provision for the two case studies

**Prerequisites:** Basic knowledge in power systems, renewable energy sources, optimization techniques, and mathematical modelling Experience in programming

**Duration:** 4-6 months

**Website:** https://heig-vd.ch/recherche/projets/smallflex-goms

**Keywords:** Virtual power plant, small hydro, optimization, ancillary services and flexibility market

## DISTRIBUTION GRID ASSET PLANNING UNDER UNCERTAINTIES OF LOAD CONFIGURATION AND FLEXIBILITY PROVISION

**Prof. M. Bozorg**

the objective of this project is to study and develop an asset-planning method for Distribution system Operators that considers the technological risks of the energy transition (e.g., the impacts of EVs, PVs, and Heat Pumps on the grid, like voltage violations, branch overloads, and transformer aging) and the spatial/temporal uncertainties of flexibility provided by prosumers. To this end, an optimization model will be developed in which the decision variables include reinforcement, replacement, and expansion capacity of transformers and branches. The overall purpose is to ensure that the distribution grid is operated securely and economically under uncertainty.

**Prerequisites:** Basic knowledge in power systems, renewable energy sources, optimization techniques, and mathematical modelling. Experience in programming

**Duration:** 4-6 months

**Website:** https://heig-vd.ch/recherche/projets/dig-a-plan-project

**Keywords:** Distribution grid planning, Long-term load scenario, Photovoltaic, EV charging stations

## INTEGRATION OF SMART METER DATA IN DISTRIBUTION SYSTEM STATE ESTIMATION WITHIN A DIGITAL TWIN PLATFORM

**Prof. M. Bozorg**

State estimation methods could be applied to integrate data from smart meters and grid measurement infrastructure to enhance the observability of the distribution network. However, due to the privacy and practical issues, the data are not always available with the same sampling time and recuperation delay.

The aim of this project is to study and analyze the number of smart meter real-time data request necessary to satisfy a desired level of observability at each time step as well as to find an appropriate allocation of smart meter data request among the costumers over time to ensure data privacy constraints. This will be tested within a distribution grid digital twin that has been developed at HEIG-VD.

**Prerequisites:** Basic knowledge in power systems (power flow models)
Basic knowledge in Python

**Duration:** 4 - 6 months

**Website:** https://twindigrid.heig-vd.ch/

**Keywords:** Distribution system, State estimation, smartmeters, data privacy

## INNOVATIVE ENERGY RECOVERY IN NATURAL GAS AND HYDROGEN SUBSTATIONS BY WAY OF IN-PIPE TURBINES

**Prof. M. Capezzali**

Natural gas networks operate at different pressure levels, similar to the voltage levels in electricity networks. Natural gas is transported at high pressures (typically 70 bar) over long distances, before being expanded to 5 bar for local transport, and then to a few mbar for local distribution. At present, the overwhelming majority of high-medium pressure regulators do not recover the energy available at the moment of expansion, and even consume additional natural gas to prevent the pipes from freezing. This therefore represents a potential source of energy through the recovery of «fatal energy».

In the future, the same principle will have to be applied to networks transporting either pure hydrogen or hydrogen blended with natural gas. The proposed study aims at investigating the possibility of generating electrical energy by implementing an integrated turbine (known as an in-pipe turbine) in place of the mechanical expansion valve currently used. The turbine generates electrical energy which can then be valorized as such or in another form, for example by producing hydrogen. This CO2-neutral production, based on an existing infrastructure, can make a contribution to Switzerland's energy deficit, particularly in winter. An application on an existing substation in Western Switzerland will guide the proposed work, with the support of specialized technical personnel from the local utility.

The work is planned in four phases:

- Comparative study of existing in-pipe turbine systems, along with a detailed analysis of the adaptation to the network supply of a Western Switzerland Canton. Possibility of using the turbines for natural gas-hydrogen mixtures at different percentages (typically 5 to 30%)
- Analysis of the interface between high and medium pressure networks. This will involve a detailed analysis of natural gas flows on both sides of the expansion station, taking into account the characteristics of the existing network and its future developments. The possible integration of an electrolyser will also be analyzed (pre-sizing)
- Development of scenarios for valorizing the electricity generated by the turbine: sale of electricity (e.g. to charge electric trucks), injection into the grid, production and various valorizations of hydrogen
- Detailed comparison of scenarios based on energy, environmental and economic indicators

The results will be summarized and critically analyzed in a comprehensive report, including recommendations for the partner utility.

**Keywords:** Energy Networks, Hydrogen, Natural Gas, Energy Recovery

**Prerequisites:** Knowledge in energy engineering, basic fluid mechanics and networks, systemic approach



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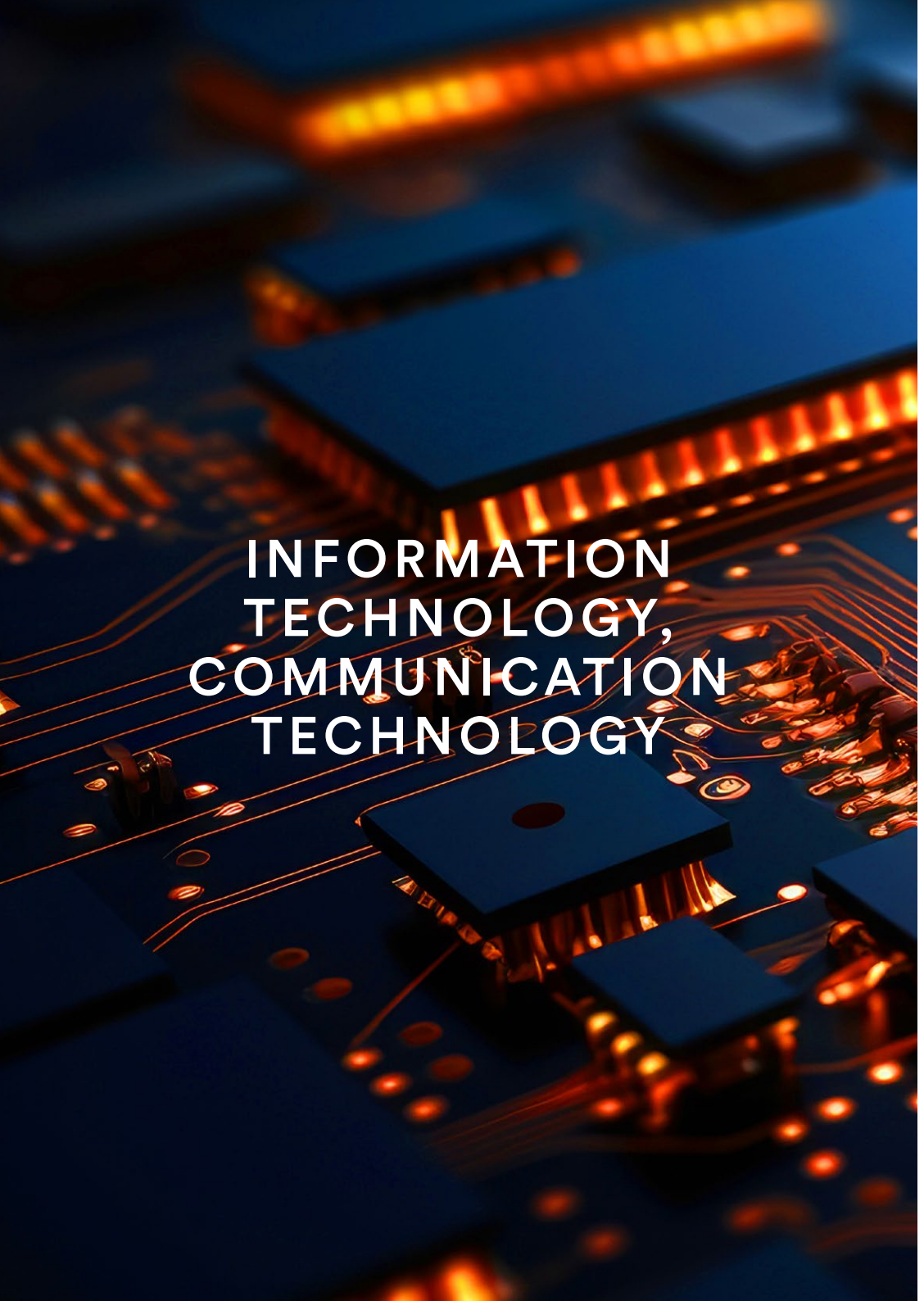

# INFORMATION TECHNOLOGY, COMMUNICATION TECHNOLOGY



## MACHINE TRANSLATION AND LARGE LANGUAGE MODELS

**Prof. A. Popescu-Belis**

The goal of this internship is to study the capacity of recent language models (LLMs) to improve machine translation (MT), either in cases of low-resource language pairs, or where large contexts are needed to translate correctly. The internship can be devoted to evaluation issues, i.e. measuring precisely the types of errors that are most often observed, or to issues related to transfer learning and the capacity to address low-resource languages by using information from better-resourced related languages.

**Prerequisites:** Advanced courses in machine learning (deep learning) and at least one introductory course in natural language processing

**Duration:** 4-6 months

**Keywords:** Machine translation, large language models

## KNOWLEDGE INTEGRATION IN CHATBOTS

**Prof. A. Popescu-Belis**

Chatbots using deep neural networks (such as large language models) have resulted in realistic conversational agents - using written, or sometimes spoken language. However, while these agents are trainable through conversations, it is difficult to connect these agents to external knowledge bases, so that they perform useful tasks, such as question answering or database transactions. The internship will focus on hybrid chatbots, which can access knowledge bases and also have conversational capacities for the social aspects of an interaction. The goal is to compare question answering capabilities, either using the large language model alone, or combining it with a knowledge base.

**Prerequisites:** Advanced courses in machine learning (deep learning) and at least one introductory course in natural language processing

**Duration:** 3-6 months

**Keywords:** Chatbots, large language models, retrieval augmented generation

## EDUCATIONAL GAMING PLATFORM

**Prof. M. Rubinstein**

The objective of this project is the development of an educational tool for students to simulate the process of studying to improve their test scores in a chosen subject. The tool will take the form of a game that combines traditional learning methods (such as exercises and reading materials) and innovative methods (for example virtual labs and AI-based interactions). Another innovative aspect of the tool is the inclusion of the teaching of life skills, such as overcoming procrastination, developing grit, and effective management of the study process.

**Prerequisites:** Software development, game design, AI programming

**Duration:** 3-4 months

**Keywords:** Software development, AI, gaming

## PLANT ELECTROPHYSIOLOGY ANALYSIS AND MODELING FOR PRECISION AGRICULTURE PURPOSES

**Prof. Dr. L. Raileanu**

Environmental alterations trigger changes in the plant's physiological processes, portrayed by distinct variations of its electrical potential. Advanced signal processing and data analysis techniques have enabled the automatic recognition of patterns in the electrical response of plants growing under typical production conditions, allowing an accurate identification of a plant's health status. However, current developments are based on classical machine learning algorithms requiring the extraction of signal features.

The proposed project aims to extend the existing modeling approach by developing a classification framework that will extract features in an automated manner, such as applying deep-learning-based algorithms.

**Prerequisites:** knowledge and experience with signal processing, machine learning, and Python

**Duration:** 4-6 months

**Website:** https://hee-projets.heig-vd.ch/en/projects/140/

**Keywords:** Signal processing, data analysis, deep learning, plants, electrical signal

## FRUIT GROWERS' ADVISORY SYSTEM BASED ON MACHINE LEARNING EXPLORING FRUIT DIAMETER GROWTH AND MICRO-CLIMATE DATA

**Prof. Dr. L. Raileanu**

Commercial orchards increasingly depend on proper irrigation to ensure the highest yields and optimize production quality. Current monitoring tools need higher accuracy, achievable by incorporating plant-based indicators. Tomatoes in greenhouses also show difficulty adapting to the irrigation provided by automatic systems, resulting in physiological damage to the fruit, such as skin «cracking,» and, therefore, important yield losses. The project aims to model the fruit growth from data acquired with fruit dendrometer and micro-climate stations to provide a tool for growers that would help them predict physiological damage of the fruits, i.e., improve the quality of the crops while optimizing harvest timing and reducing water usage.

**Prerequisites:** Knowledge and experience with analysis of time series, machine learning, and Python

**Duration:** 4-6 months

**Website:** https://hee-projets.heig-vd.ch/en/projects/152/

**Keywords:** Time series, machine learning, fruit growth modeling





## HARVEST ESTIMATION THROUGH IMAGE-BASED FRUIT DETECTION

**Prof. Dr. L. Raileanu**

Maximizing the quantity of top-quality fruit is crucial in orchard production, whereas fruit load is a significant factor affecting the quality. Accurate yield estimation is vital for resource optimization and benefit increase. Manual counting is often employed but is time-consuming and prone to errors. This project aims to design and implement a pipeline incorporating image analysis techniques on images from apple trees taken with a smartphone to achieve highly accurate apple yield estimation. Specifically, it involves applying machine learning algorithms to build models that detect apples in images and, therefore, automate fruit counting.

**Prerequisites:** Knowledge and experience with image processing, machine learning, and Python

**Duration:** 4-6 months

**Keywords:** Image processing and analysis, machine learning, fruit harvest

## ELIMINATION OF ARTIFACTS FROM EYE IMAGES USING RAW MRI DATA

**Prof. Dr. L. Raileanu**

Magnetic Resonance Imaging (MRI) is a non-invasive technique providing detailed internal body structure images, which are crucial for diagnosing, treating, and performing surgeries for oculomotor disorders. However, eye motion artifacts in MRI scans remain unresolved, hindering such eye examinations. A recent study uses an Eye Tracker (ET) to address this issue, but it is a resource-demanding task. This project aims to design and implement a pipeline employing data analysis techniques on raw eye-MRI data to automatically detect eye movement-affected acquisitions and classify the data following the gaze direction. This will eliminate the need for an ET to obtain artifact-free images of the eye.

**Prerequisites:** Knowledge and experience with data preprocessing and analysis, machine learning, and Python

**Duration:** 4-6 months

**Keywords:** Data analysis, machine learning, eye imaging

## MALE FERTILITY ASSESSMENT BASED ON SPERM MORPHOLOGY

**Prof. Dr. L. Raileanu**

Semen analysis is considered the cornerstone of male infertility assessment, whereas spermatozoa morphology is one of the fundamental parameters for evaluating sperm quality. Evaluation of the morphology from microscopic sperm images could help reduce the required time and the observer-based variability of the manual analysis currently used as a clinical gold standard. Moreover, morphological abnormalities represent various forms and shapes on different cell parts, making classification challenging. This project aims to use image processing and machine learning algorithms on spermatozoa images to automatically distinguish abnormal from normal cells and classify different abnormal sperm morphology

**Prerequisites:** Knowledge and experience with image processing, machine learning, and Python.

**Duration:** 4-6 months

**Keywords:** Image processing and analysis, machine learning, semen analysis

## ANALYSES OF BACK MOVEMENT DATA

**Prof. Dr. L. Raileanu**

Low back pain is a prevalent symptom and the leading cause of disability worldwide. Using smartphone applications to promote self-management (giving regular advice and prescribing exercises) is essential for improving back pain management. Moreover, using artificial intelligence, personalization could also be achieved.

This project aims to develop a framework for automatically detecting patterns of interest in back movement sequences. Additionally, an adapted resampling frequency to these sequences should be selected and evaluated regarding the quality of motion measurements.

**Prerequisites:** Knowledge and experience with analysis of time series, machine learning, and Python

**Duration:** 4-6 months

**Keywords:** Time series, longitudinal relationship, low-back pain

## SMARTWATCH APPLICATION TO MEASURE BACK MOVEMENT AND COLLECT PHYSICAL ACTIVITY DATA

**Prof. Dr. L. Raileanu**

Low back pain is a prevalent symptom and the leading cause of disability worldwide. Using smartphone applications to promote self-management (giving regular advice and prescribing exercises) is essential for improving back pain management. Moreover, using artificial intelligence, personalization could also be achieved. This project aims to develop a smartwatch application to measure trunk kinematics.

The collected data will be evaluated regarding the quality of motion measurements and transmitted to the mobile application.

**Prerequisites:** Knowledge and experience with mobile programming, data analysis, machine learning, and Python

**Duration:** 4-6 months

**Keywords:** Smartwatch app, data analysis, low-back pain

## SECURE GEOLOCATION SOLUTION ON MOBILE

**Prof. F. Dutoit**

This internship aims to study, design, implement, and evaluate a secure geolocation solution for mobiles. Today, geolocation on smartphones is mainly achieved through GNSS, Wi-Fi positioning, or BLE beacons. Still, none offer a strong guarantee as they can be unavailable or



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spoofable. After completing a state-of-the-art of existing technologies and their availability on mobile platforms, the trainee will propose a solution and realize a PoC. Several approaches are possible to realize this project; one possibility is the design of a BLE beacon integrating cryptographic features.

**Prerequisites:** Android or IOS app development, geolocation

**Duration:** 2-6 months - The scope of this project can be adjusted to accommodate different internship/thesis duration

**Keywords:** Mobile development, geolocation, BLE-beacon, security

## DESIGN OF AN EMBEDDED SYSTEM FOR WHEELCHAIR VIBRATION ACQUISITION

**Prof. R. Mosqueron**

As part of the Walio project, which consists of designing a new generation of electric wheelchairs, we wish to obtain data on the vibrations generated by existing wheelchairs in order to

Prove/motivate the interest of a more stable and technologically advanced solution. Establish a set of reference data for the design of the solution (level of vibration to be damped etc.)

The project consists here in improving and designing elements of the compact and mobile measurement system, easily usable for the acquisition of these data.

The project includes:

- Development and optimisation of the electronic system
- Design of an electronic board (ideally with EMC validation) and the 3D case
- Energy sizing of the system (recharge, battery size etc.)
- Establish an interface for data interpretation, representation and modelling
- Project management: ensure documentation in relation to the design (SysML modelling)

**Keywords:** Health, embedded systems

## VIRTUAL SIM FOR 5G STAND-ALONE NETWORK

**Prof. R. Mosqueron**

As part of these projects, REDS is studying the implementation of a 5G Standalone network (5G SA). To do this, it has a 5G Base Station and various User Equipment (UE -modem connected to Raspberry PI, mobile phone, road, etc.). These UEs currently use basic SIM cards (USIM), the same as those used by operators. The use of these USIMs is not optimal: It requires individual programming, physical access to the EU, … The aim of the project is to study the new generations of cards that are / will be available. These include eSIM (electronic SIM), iSIM (integrated SIM), SW SIM. Once the study has been completed, it will first be a matter of selecting the most suitable type of card. The selection criteria will also be defined during the project. Once the type of card has been selected, a solution, SW and HW, will have to be set up for the use of this type of SIM within the 5G network.
Progress of the project:

- Study of the different types of SIM card
- Selecting a SIM card type
- SIM deployment

**Keywords:** Telecom, embedded systems, 5G

## IMPLEMENTATION OF CLOUD FRAMEWORK INTO EDGE COMPUTER

**Prof. R. Mosqueron**

As part of the development of agriculture in African countries, a distributed edge computer network system could be developed to allow a group of farmers to have access to an intelligent and shared data processing service.

This network would be a private 5G-type base station network where the management would not be done by the mobile telephone operators. AWS and Microsoft have some frameworks include in their cloud functionalities dedicated to agricultural concern. It is possible to integrate this system into edge (cloud) computing to design an architecture capable of operating without having access to the cloud. Internet access is not guaranteed in these countries, it is necessary that access to these computing power can be done anyway.

Specifications:
- System definition
- Implementation of farmbeats in an edge computer
- Development of communications with sensors and user equipment
- Tests and validation

**Keywords:** Cloud computing, Network

## SEAT TILT CONTROL FOR WHEELCHAIR USERS

**Prof. R. Mosqueron**

Within the framework of the Walio project, which consists in designing a new generation of electric wheelchair, we are studying the integration of a stabilisation system for the user of the chair to maintain him/her in an adapted position on a steep slope.
Indeed, in the event of a steep slope or descent/climb of stairs, a person in a wheelchair is in a dangerous situation, it is necessary to guarantee a stable and correctly oriented sitting position to limit the risks to health and safety.

The work consists of:
- Design a system that measures the angular position of the user in real time.
- Detect and display the position and critical tilt points to ensure user safety and anticipate tipping
- Adjust the position in real time according to the tilt and speed of the device.
- Combine this system with an anti-tilt detection system.
- Manage this system with the addition of acceleration and centre of gravity management.

**Keywords:** Health, embedded systems

## MINI 5G BASE STATION FOR EMBEDDED APPLICATION

**Prof. R. Mosqueron**

Through various projects, the REDS institute has set up a private 5G network that can be rapidly deployed at different sites, for example at sporting events.





The solution used is based on 100% Software stacks and SDR cards. Everything is installed in server-type PCs with x86 CPUs.

The aim of this project is to deploy and start up a 5G network in a reduced form factor, with reduced performance based on mini-PCs or cards based on these ARM CPUs.

The use of mini Base Stations will enable a private 5G network to be used in new applications, for example the deployment of a 5G network in a tunnel following an accident to help coordinate the emergency services.

Project progress:
- State of the art
- Test of available solutions
- Implementation
- Tests and validation

**Keywords:** Telecom, embedded systems, 5G

## TRANSMISSION RELAY FOR INDOOR INSPECTION DRONES

**Prof. R. Mosqueron**

Nowadays, technological advances in the field of robotics offer the possibility of deporting the human eye and to act in environments that are inaccessible or difficult to reach by a human.

Flying robots are the safest and most economical solution for scientific and industrial exploration in cramped and buried spaces such as natural wells, tunnels or chasms. This project will focus on the study of different possible solution architectures, as well as the realization of a specific hardware for this application, including the protocols necessary to establish a modular wireless communication between several consumer devices or relays allowing to carry the commands and data. The focus must be on the adaptive aspect of the system to be able to be effective in the context of multiple use-cases and environments. This evolution would be made possible by the use of transmission modules integrating Point-to-Point and Point-to-Multipoint connections, allowing the creation of relay and consumer networks with data rates higher than 25Mbps and a signal quality ensured by the multiplication of devices at necessary intervals and the dynamic configuration of a frequency adapted to the environment.

**Keywords:** Telecom, embedded systems, 5G

## SERIOUS GAMES AND LEARNING ANALYTICS

**Prof D. Jaccard**

At Media Engineering Institute (MEI), AlbaSim «serious games» research group (www.albasim.ch) develops games and simulations for training purposes in fields such as project management, oncology care or medical management of major events. These serious games are available online and used by thousands of students from different universities. The project aims at studying the possibilities of using usage traces in order to improve the quality of both the games and learning. This study includes conceptual, technical, legal and statistical aspects.

**Prerequisites:** End of Bachelor or Master student in Computer sciences or with a background in user experience

## SERIOUS GAMES: USER EXPERIENCE

**Prof D. Jaccard**

At Media Engineering Institute (MEI), AlbaSim «serious games» research group (www.albasim.ch) develops games and simulations for training purposes in fields such as project management, oncology care or medical management of major events. The UI and UX aspects of games are essential. The aim of the project is to test and evaluate the UI and UX aspects of existing games, define possible improvements, implement and assess the effects of those changes.

**Prerequisites:** End of Bachelor or Master student in Computer sciences or with a background in user experience

## VERSATILE GUI FOR OPENCN

**Prof. D. Rossier**

OpenCN is an open, flexible and powerful solution for system control with embedded path planning algorithms and hard real-time control. It has been used to control different kind of machine like 3 or 5 axes milling machines, laser engraver, Pick & Place robot. It can be deployed on different targets (x86, ARM / Raspberry PI 4). The user can control OpenCN though applications running on a distant PC connected through a network connection (Ethernet) The goal of this project consists of developing a new GUI which has the following features:

- Ability to adapt to different machines.
- Can run on multi-platforms
- Clean interface with OpenCN target

**Prerequisites:** Background on C, C++
Embedded systems
Qt and Motion control would be a plus

**Duration:** 4 months

**Keywords:** GUI, remote control, automation

## OPENCN - INTEGRATION OF A PLC

**Prof. D. Rossier**

OpenCN is an open, flexible and powerful solution for system control with embedded path planning algorithms and hard real-time control.
It has been used to control different kind of machine like 3 or 5 axes milling machines, laser engraver, Pick & Place robot.
It can can be deployed on different targets (x86, ARM / Raspberry PI 4).

The goal of this project consists of t adding the support of a Programmable Logic Controller (PLC), IEC 61131-3 standard, to the OpenCN framework. This will allow very high versatility and customization for the user to reach his need.
It consists in adding the support for at least one of the languages defined in the standard. It means the possibility to write code, compile it and execute it in OpenCN target.

LinuxCNC, OpenPLC open-source project can be used as starting point.

**Prerequisites:** Strong C programming knowledge. Motion control would be a plus
**Duration:** 4 -6 months

**Keywords:** Linux, PLC, automation





## OPENCN - VIRTUAL MACHINE

**Prof. D. Rossier**

OpenCN - Virtual machine

OpenCN is an open, flexible, and powerful solution for system control with embedded path planning algorithms and hard real-time control. It is used to control different kind of machine like 3 or 5 axes milling machines, laser engraver, Pick & Place robot.
This framework can be deployed on real targets (x86, ARM / Raspberry PI 4) and virtual targets, QEMU based for development / debug activities. It controls different kind of machine like 3 or 5 axes milling machines, laser engraver, Pick & Place robot. The goal of this project is to develop an interface to simulate comportment of real machines in a virtualization environment.
The initial use-case is to implement the numerical twin of the micro-milling micro5 available in the school.

The use of virtual machine provides the ability to:

- Exploration of new path-planning algorithms
- Simplification of testing of new components
- Demonstrate OpenCN capabilities

We propose to use Gazebo (https://gazebosim.org) as simulator
**Prerequisites:** C programming, simulation, motion control

**Duration:** 4 -6 months

**Keywords:** Digital twin, automation, simulation

## POLYMORPHIC OPERATING SYSTEM, WITH SO3

**Prof. D. Rossier**

The SO3 Operating System has been developed in the REDS Institute from HEIG-VD for >10Y and is intended to be used in IoT products or embedded systems based on ARM CPU family as well as in academic environment. It is a compact, powerful and full featured operating system which can be configured to run as a standalone OS, an hypervisor (AVZ), or a guest OS running on the hypervisor (AVZ). Furthermore, SO3 can be used as “mobile entitiy” (ME) in the Smart Object Oriented framework enabling the migration of entities between embedded devices.

This project proposes to investigate various security aspects in SO3 to make the execution environment more robust, and also to investigate ARM TrustZone technology in this context. A security audit could be made at the beginning of the project to drive the objectives. An important aspect will be to study the impact of security measures on the overall performance of the execution environment.

**Prerequisites:** Background in C and ARM assembly programming, security and operating systems

**Duration:** 4 -6 months

**Keywords:** ARM microcontrollers, security, operating system

## ORCHESTRATION OF EMBEDDED SERVICES IN A HIGHLY SECURE CONTAINERIZED ENVIRONMENT

**Prof. D. Rossier**

Over the last years, the edge computing paradigm turned out to gain an important momentum in the field of embedded systems. Edge computing is a way to perform possibly complex processing in a local embedded system closed to sensors or actuators and to exchange data with a server located in the cloud.

This project will consist in using the lightweight SO3 operating system developed in our Institute to manage some containerized entities which will be deployed in a Linux based environment. SO3 will also be used as hypervisor to manage the interactions between the containerization engine and the SO3 containers based on Docker technology. We will then propose to use micro-python in SO3 containers to deploy custom algorithms in order to monitor and to collect data as well as to partially control the peripheral environment.

The framework could be used by Enterprises who develop critical systems and would like to provide end customers with the possibility to deploy their own algorithms and execution environment.

**Duration:** Minimum duration 4 months, preferentially 6 months

**Keywords:** Orchestration of services, edge computing, Linux, embedded systems

## HIGH PERFORMANCE PYTHON

**Prof. A. Dassatti**

Python is quickly becoming the language of the research community. This is extremely interesting because lowering the entry barrier to science will boost research ideas. On the other and, Python is not the best tool to effectively use the available hardware and obtain the performance usually needed by the researcher. Several attempts do exist to boost Python performances and the scope of this project is exploring the state of the art in the field to quantify benefit and limit of competing solution.

**Prerequisites:** Python, C/C++, GPU, computer architecture
Duration: 2-6 months

**Keywords:** Python High Performance Computing

## SMART STORAGE

**Prof. A. Dassatti**

Data centres demand more and more computation efficiency. Standard CPU are unable to cope with the demand and GPU can only serve specific computation patterns. FPGAs are an attractive technology in this field, but its integration in the data centre infrastructure is not trivial. Smart Storage solutions based on the NVMe protocol are the most promising path in this scenario. In our lab we have developed a first prototype of the technology and this project will focus on extending its functionalities and benchmark it extensively.



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**Prerequisites:** computer architecture, C/C++, basic FPGA a plus, Operating systems

**Duration:** 2-6 months

**Keywords:** Storage, NVMe

## DVBS2X LDPC DECODER

**Prof. A. Dassatti**

LDPC are powerful error correction codes adopted by many modern communication standards. In satellite communication, for instance, DVBS2x use a specific LDPC to protect video transmission from and to space.
In our lab we have a complete Software Defined Radio system implementing the system in software, but the performance of the LDPC decoder are unable to cope with the required data rate for a real-time system. In this project we will develop a FPGA based LDPC decoder and we will test it in a complete radio communication chain.

**Prerequisites:** C/C++, FPGA design experience

**Duration:** Minimum 4 months

**Keywords:** LDPC, SDR

## SMART NETWORK

**Prof. A. Dassatti**

Data centres demand more and more computation efficiency. Standard CPU are unable to cope with the demand and GPU can only serve specific computation patterns. FPGAs are an attractive technology in this field, but its integration in the data centre infrastructure is not trivial. Smart Network interface (NICs) solutions are attractive for offloading many filtering and computation directly at the network attachment point relieving the CPU of many tasks. This project will be based on our 100Gb research prototype and explore the state of the art in the domain with the aim at developing and benchmarking off-loading tasks to an FPGA.

**Prerequisites:** computer architecture, C/C++ programming, basic FPGA knowledge a plus, Operating systems

**Duration:** 2-6 months

**Keywords:** Networking, Hardware

## DEEP-INSIGHTS: EXTRACTING INTERNAL REPRESENTATIONS FROM DEEP NEURAL NETWORKS

**Prof. C. Peña/X. Brochet**

The proposed project is developed in the frame of our XAI (explainable Artificial Intelligence) research activities. Among other lines, we are exploring the development of novel methods for extracting internal representations from trained Deep Neural Networks. Such methods can identify input patterns which are significant for the predictions of a given Deep Neural Network and that may explain how these networks make their predictions.
The specific goal of the student's project will be to investigate, implement, and test such an approach for one of the specific deep network architectures that we are using in our research projects. For instance: 1D convolutional or LSTM networks.

**Prerequisites:** Machine Learning, Deep learning

**Duration:** 6 months

**Keywords:** Machine learning, Deep learning, Explainable Artificial Intelligence

## RULE-DEEP-EXTRACT: EXTRACTION OF RULES FROM DEEP NEURAL NETWORKS

**Prof. C. Peña/X. Brochet**

The proposed project is developed in the frame of our XAI (explainable Artificial Intelligence) research activities. Among other lines, we are exploring the development of novel methods for extracting rules from Deep Neural Networks. Such methods will be able to extract knowledge in the form of hierarchical rule representations to explain how Deep Neural Networks make their predictions while preserving, as much as possible, the prediction accuracy of the neural network.

The specific goal of the student's project will be to investigate, implement, and test an approach for extracting rules from one of the specific deep network architectures that we are using in our research projects. For instance: 1D convolutional or LSTM networks.

**Prerequisites:** Machine Learning, Deep learning

**Duration:** 6 months

**Keywords:** Machine learning, Deep learning, Explainable Artificial Intelligence

## EVO-PERPHECT: ARTIFICIAL EVOLUTION ON NATURAL VIRAL GENOMES

**Prof. C. Peña/X. Brochet**

In the context of developing viral (phage) therapies to fight resistant bacteria, we have developed models able to predict



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interactions between bacteria and phages based only on their genomic sequences. As a next step, in the PERPHECT project we are exploring the use of Artificial intelligence (AI) to produce genetically-engineered (GE) phages that may provide substantial advantages over natural phages in terms of host range, immune system recognition, and environmental stability. To do so, PERPHECT couples a genome-based interaction predictor with a genome generator that has the potential to create sequences very similar to naturally-occurring ones.
The specific goal of the student's project will be to investigate, implement, and test a generative method based on artificial evolution (e.g., a genetic algorithm) operating virtual modifications (evolution) to existing viral genomes. This method could be integrated/coupled with an existing predictive model in order to search for phage genome editions that improve their therapeutical performance.

**Prerequisites:** Machine Learning, Evolutionary algorithms, notions of biology

**Duration:** 6 months

**Keywords:** Machine learning, Deep learning, Bioinformatics, Genomics

## PERPHECT-RL: MODIFYING VIRAL GENOMES THROUGH DEEP REINFORCEMENT LEARNING

**Prof. C. Peña/X. Brochet**

In the context of developing viral (phage) therapies to fight resistant bacteria, we have developed models able to predict interactions between bacteria and phages based only on their genomic sequences. As a next step, in the PERPHECT project we are exploring the use of Artificial intelligence (AI) to produce genetically-engineered (GE) phages that may provide substantial advantages over natural phages in terms of host range, immune system recognition, and environmental stability. To do so, PERPHECT couples a genome-based interaction predictor with a genome generator that has the potential to create sequences very similar to naturally-occurring ones. The specific goal of the student's project will be to investigate, implement, and test a generative method based on Deep Reinforcement Learning to modify existing viral genomes. This method could be integrated/coupled with an existing predictive model in order to search for phage genome editions that improve their therapeutical performance.

**Prerequisites:** Machine Learning, Reinforcement learning, notions of molecular biology

**Duration:** 6 months

**Keywords:** Machine learning, Deep learning, Bioinformatics, Genomics

## MEDIA ENGINEERING INSTITUTE (MEI) – MY SMAPSHOT

**Prof. D. Rappo**

Smapshot is a geolocation tool dedicated to photography. The web platform allows volunteers to position images within a virtual globe in order to locate them in 3D. End users can go back in time, browsing through collections dating from the late 19th century to nowadays.

The platform has been in development since 2017, it will soon contain 200'000 images, many software features, and new extensions are being considered. The following description is one of them.
The goal of this project is to adapt Smapshot for personal usage (uploading trekking pictures, holiday images, etc.). In particular, adapt the backoffice interface to manage import of new images by the user, import location from EXIF, add other metadata, georeference the pictures...
The backoffice main potential features are: user backoffice, admin backoffice / security, deployment.
For the conception phase, you'll have to create wireframe of user interface. MEI can help with this phase.
The development expected is a proof of concept for the fullstack.

**Keywords:** Students must be skilled in web development, the technologies used are VueJS, Tailwind, CesiumJS for the frontend, NodeJS for the backend, PostgreSQL for database, Docker and ansible for Sysadmin

## DRUG MODELS VALIDATION/ADDITION FOR DRUG DOSAGE ADAPTATION SOFTWARE

**Prof. Y. Thoma**

Tucuxi (http://www.tucuxi.ch) is a software that has been developed with the aim of helping the pharmacologists with the adaptation of medical drug dosages. Models for specific drugs are describes in XML files, and cross-validated against a software called NONMEM. This software is used by pharmacologists to generate models from population data. Currently Monolix seems on the rise to replace NONMEM, and is notably used by our partners at CHUV hospital. This project aims at replacing NONMEM with MONOLIX for the validation of the drug models (the framework uses python scripts), and to implement various new models that will be defined at the beginning of the project. These models will then be offered to the community.

**Prerequisites:** Computer science or computer engineering students: python, interest in discovering pharmacology

**Duration:** 4-6 months

**Keywords:** Pharmacokinetics, Python scripting

## FORMAL VERIFICATION OF DIGITAL SYSTEMS

**Prof. Y. Thoma**

When designing digital systems for FPGAs or ASICs, developers usually write testbenches. Formal verification is a new technics that offers the possibility to formally check a design against properties, and to end up with more reliable systems. Proprietary solutions exist, but are very expensive for our partners. SymbiYosys is an open source initiative that allows to perform some formal verification (https://github.com/YosysHQ/sby ). The goal of the project is to select some already existing interesting VHDL designs, to implement properties and assertions to formally verify their behaviour, and to end up with a good comprehension of the possibilities and limitations of the open source option versus the commercial ones.





**Prerequisites:** Computer engineering students or electrical engineering students with background in HDL design (VHDL or SystemVerilog)

**Duration:** 3-6 months

**Keywords:** Digital systems, Verification, formal

## SMAPSHOT - SCIENTIFIC MEDIATION EXPERIENCE

**Prof. S. Lecorney**

Smapshot is an online platform for 3D georeferencing of historical images. Over 250,000 images have been georeferenced by volunteers and are visible in 3D in a virtual globe. In this context, several image archive libraries would like to showcase the project as part of an exhibition for the general public.

The aim of the internship is to design and implement interactive experiences around Smapshot, for example:

- Tutorial on the georeferencing process: Can you georeference this image?
- Gamification: Find the date of this image? Where is this image located (geoguesser)?

**Prerequisites:** Web design, web development (vueJS, REST API)

**Duration:** 2 to 6 months

**Website:** https://smapshot.heig-vd.ch/

**Keywords:** Interactive experience, web, front-end

## CARTOGRAPHIC PORTRAYAL INTEROPERABILITY, FROM OGC STANDARDS TO CONCRETE SOFTWARE IMPLEMENTATIONS

**Prof. O. Ertz / J. Ingensand**

The Media Engineering Institute (MEI) and the Institute of Territorial Engineering (INSIT) do work since ten years in the field of geostandardization. Especially related to cartographic portrayal interorability, currently contributing as active member of the Styles & Symbology Standard Working Group (SWG) at the Open Geospatial Consortium (OGC). In 2019, the OGC Styles And Symbology Model & Encodings - Part 1: Core (in short SymCore) has been released as an implementation standard. It is the basement of concrete cartographic capabilities currently under work in the group (e.g. 2D vector styles extension) at a conceptual level but also at an encoding level (defining a format).

The proposed project wants to contribute to these efforts in different manner:
(1) encode Swisstopo national maps using the emerging SymCore cartographic capabilities (deliverable: encodings and maps to feed the Map Gallery of the SymCore standard documentation)
(2) develop software to transcode from various encoding formats (deliverable: e.g. GeoStyler transcoder)
(3) implement some capabilities of the 2D vector styles extension on the base of an existing cartographic rendering engine (deliverable: Maputnik adaptation)

**Prerequisites:** Software engineering, infography, geospatial data, cartographic design

## E-LEARNING TO TAKE OVER GEOSPATIAL STANDARDS FROM OGC API THROUGH AN EDUCATIONAL SCENARIO ON CLIMATE CHANGE

**Prof. O. Ertz / J. Ingensand**

The Media Engineering Institute (MEI) and the Institute of Territorial Engineering (INSIT) do work since ten years in the field of geostandardization. Recently the research team is involved in the deployment of a centre of competence in this field. One underpinning purpose is also to produce learning material. Therefore, the proposed intership work participates to the development of an e-learning web app aiming to understand and use the latest Open Geospatial Consortium OGC API standards. The idea is to offer an interactive and gamified way to practice them on the basis of an educational scenario that manipulates climate change geodata.

The internship concerns the setup of a simulation platform offering a guided sequence of actions using geospatial APIs (remote sensing, vector and sensor data, custom styling, etc) in order to allow the assessment of the local impact of climate change and to address target measures and indicators to policy makers. It is to put into perspective the usefulness and use of geospatial APIs, all while learning in a practical way how to use these new technologies. The proposed work will be based on some preliminary designed learning objectives and defined didactics extending already existing OGC tutorial modules [5] as well as on an already deployed geodata infrastructure.

The work will follow several phases:

1. Carry out a state of the art to draw up a panorama of knowledge and techniques
2. Specify, design and develop a proof of concept of the intended simulation platform
3. Follow an agile process to implement a first release with the web technologies studied during the first phase and
4. Deploy and test with multiple learners in order to improve and validate the concept.

**Prerequisites:** Software engineering and development with interest in Geographic Information Systems; Interest in e-learning platforms, in educational technologies (EdTech)

## IDENTIFICATION OF LANDSCAPE FEATURES TO SUPPORT THE 3D GEOREFERENCING OF LANDSCAPE PICTURES.

**Prof. O. Ertz / J. Ingensand**

The smapshot.heig-vd.ch platform allows crowdsourcers to 3D georeference historical landscape pictures. In this process the user clicks on points on a virtual globe that are also visible in a landscape picture (e.g. mountain tops, churches, crossroads). Up to now more than 200'000 images have been georeferenced using clicked points and a database of more than 1'000'000 points is available. One goal of this project is to characterize these clicked points using reference data sets (e.g. land cover, openstreetmap, etc) and to train an algorithm to automatically identify these features in landscape pictures that have not yet been





georeferenced. A second goal is to create an interface that suggests these potentially usable control points for non-experiend crowdsourcers: creation of a mock-up; user testing, implementation of a prototype.

**Prerequisites:** Software engineering and development with machine learning skills and interest in Geographic Information Systems & interest in media engineering

## CHARACTERIZATION OF THE HISTORICAL LANDSCAPE USING 3D GEOREFERENCED HISTORICAL PICTURES

**Prof. O. Ertz / J. Ingensand**

The smapshot.heig-vd.ch platform contains more than 200'000 3D georeferenced historical pictures. For each picture the position from where a picture has been taken is known, as well as the three angles that define the direction of the picture. The goal of this project is to use pre-trained algorithms to segment the visible landscape of the pictures into classes – e.g. forest, mountains, buildings. Furthermore the segmented information shall be combined to a 2D map of the landscape by selecting pictures that have been taken during the same period.

One challenge is to handle the occlusion – i.e. if e.g. a building or a mountain covers the landscape behind. The 2D map shall be rendered in a user-friendly web-portal that allows for the selection of the period.

**Prerequisites:** Software engineering and development with machine learning skills and interest in Geographic Information Systems & interest in media engineering

## BIOSENTIERS AUGMENTED REALITY AND OCCLUSION TECHNIQUES

**Prof. O. Ertz / J. Ingensand**

BioSentiers is a project lead by the Media Engineering Institute and the Institute of Territorial Engineering. The purpose is to offer a way to discover biodiversity through a location-based augmented reality mobile application (see biosentiers.heig-vd.ch). That means, given a predefined pathway marked all along its length with points of biodiversity interest, citizens of Yverdon-les-Bains have the possibility to observe them and virtually interact with nature by getting extra multimedia content about various flora and tree species. The proposed work is about a new feature for the front-office AR application to allow object occlusion while exploring the area around the user. In other words, the purpose is to find a solution to avoid the display in the AR scene of points of biodiversity interest which may be hidden by a building in the real environment. The swissTLM3D large-scale topographic landscape model and swissBUILDINGS3D vector based dataset which describes buildings as 3D models may be useful to implement such a feature. The work will follow three phases (1) carry out a state of the art to draw up a panorama of knowledge and techniques on this theme (2) specify, design and develop a proof of concept of the intended feature (3) integrate the occlusion solution so as to release a new version of the AR front-office BioSentiers application.

**Prerequisites:** Background in software engineering and development with interest in augmented reality or in geographical sciences with focus on interactive mapping techniques

## FEDERATED AND COLLABORATIVE LEARNING FOR NANODRONE SWARM

**Prof. M. Zapater**

The Crazyflie 2.1 is a 27-gram nanodrone. In our research institute we have worked on the creation of Artificial Intelligence (AI) algorithms that enable the drone to fly autonomously. The goal is to put together a system for federated and collaborative learning, enabling several Crazyflie drones to fly together coordinately and autonomously.

This project will use the Light House localisation system together with our internal platform for edge-to-cloud communication, to enable each drone to calculate its position and share it to the others, navigating altogether thanks to AI. The student will put in place the system and create the algorithms for federated and collaborative intelligence.

**Prerequisites:** Background on computer science and programming (C, C++, Python) Knowledge on training and deployment of AI algorithms (neural networks)

**Duration:** Minimum 3 months

**Keywords:** Nanodrone, autonomous navigation, artificial intelligence, deep neural networks

## IMPLEMENTING RISC-V VECTOR EXTENSIONS FOR ARTIFICIAL INTELLIGENCE ON THE ROCKET CHIP

**Prof. M. Zapater**

RISC-V is a modern and simple open-hardware processor architecture which is becoming widely used today by researchers, but also in industry. The Rocket chip, created by UC Berkeley, is an open platforms that allows to improve both the hardware architecture and the software around RISC-V processors for low-power embedded systems by synthethesing a processor on FPGA to emulate its behaviour.

The goal of this project is to propose new vector extensions on RISC-V that will be tested on the Rocket chip on FPGA. For this purpose the intern will need to get familiarised with the Rocket platform and development workflow, extending the core and proposing novel extension that will be tested on FPGA.

**Prerequisites:** Background on VHDL/Verilog, FPGAs and computer architecture. Chisel would be a plus

**Duration:** Minimum 3 months

**Keywords:** RISC-V, vector extension, FPGA, rocket chip





## ARRYHTMIA DETECTION USING TINYML

**Prof. M. Zapater**

The goal of this project is to build an arrythmia detection demonstrator using machine learning implemented in an embedded edge device, following the principles of TinyML. For this purpose, the student will need to put together a system able to acquire electrocardiogram (ECG) signals coming from a “patient simulator” and process them accordingly to perform a basic delineation and hearbeat classification for arrythmia detection. The ECG signals will be processed and the ML algorithms will be implemented in a RISC-V based GAP9 evaluation kit board.

**Prerequisites:** C/C++ programming. Python programming. Knowledge on training and deployment of AI algorithms (neural networks). Quantization and pruning of DNNs would be a plus.

**Duration:** Minimum 3 months

**Keywords:** Arrythmia detection, TinyML

## SIMULATING NOVEL AI ACCELERATORS FOR 2.5D CHIPLETS

**Prof. M. Zapater**

The goal of this project is to investigate the most performant and energy-efficient systems for the execution of Artificial Intelligence (AI) workloads on novel chiplet-based architectures. For doing so, the student will need to simulate using gem5 several different accelerators and show the tradeoffs in terms of latency/power for a wide range of AI workloads.

**Prerequisites:** C/C++ programming. Python programming. Knowledge on the gem5 simulator would be a plus

**Duration:** Minimum 3 months

**Keywords:** AI accelerators, gem5, simulation, chiplets

# MECHANICAL AND MATERIALS ENGINEERING



## SELF-ADAPTIVE SAMPLING RATE DATA ACQUISITION SYSTEM

**Prof G. Courret**

The goal of this internship is to contribute to the development of a self-adaptive sampling rate data acquisition system designed for larg band signals. The work will be performed in collaboration a researcher working in our laboratory on the development of a software and firmware dedicated to signal processing and real time analysis. This internship will also participate in the design of the algorithm for compression, analysis and storage of measurement data. Knowledge of signal processing for spatial engineering as well as medical engineering is potentially useful.

**Prerequisites:** Students with previous knowledge from courses in data compression, analysis, storage, signal processing engineering, digital electronics (FPGA-SoC) and Matlab or Octave programming

**Duration:** Minimum 3 months for master students, preferentially 4-6 months; PhD interns 6-12 months

## HYPERSONIC PLASMA IN A LIGHT BULB

**Prof G. Courret**

This internship aims to contribute to a research project dedicated to the study of an acoustic resonance phenomenon in a high-pressure plasma lamp which could be used to measure hypersonic aerodynamic parameters relevant to the design of space shuttle thermal protection systems. Knowledge of non-equilibrium thermodynamics and molecular dynamics of gases is desired.

**Prerequisites:** Students with previous knowledge from courses of power electronics engineering

**Duration:** Minimum 3 months for master students, preferentially 4-6 months; PhD interns 6-12 months

## STERILIZATION WITH COLD ATMOSPHERIC PLASMA

**Prof G. Courret**

The objective of the internship is to take part of the development of a method to sterilize products using a cold atmospheric plasma (CAP). The cold sterilization has several advantages as compared to the traditional thermal treatment such as lower energy consumption and, potentially, a much faster processing time. Knowledge of plasma technologies is desired. In addition, knowledge of microbiology for decontamination would be potentially useful.

**Prerequisites:** Students with previous knowledge from courses on plasma engineering as well as on the physics of weakly ionized gases

**Duration:** Minimum 3 months for master students, preferentially 4-6 months

## SURFACE NANO AND MICROPATTERN ANALYSIS USING LASER TECHNIQUES

**Prof. Dr. S. Schintke**

The research unit COMATEC-LANS (Laboratory of Applied NanoSciences) is active in research on surface coatings and analysis.

Within the study project, the candidate will participate in running research activities of the COMATEC-LANS. In this project we improve our laser system for investigating surface nano- and microstructures. Our system uses angular detection of the scattered light as well as speckle detection from normal incidence. The system is motorised for angular positioning and data acquisition using diode arrays and LabView control, further data recordings are made by a camera.

During the internship you will learn how to work with a laser system and how optical data can be used for quality control of nano- and microstructured surfaces, and for the detection of invisible anti-counterfeit structures. You will test and implement various calibration methods, and create and tests anti-counterfeit structuring. You will compare results for two different laser wavelengths. Our system has a housing for operation, protecting from ambient light, this implies also that measurements are performed in safe laser class 1 conditions. The laser alignment on the samples is currently performed using appropriate goggles, alternatively a camera could be installed for laser alignment in closed system conditions.

Interested engineering students would also have the possibility to focus on improved data acquisition and control (as an alternative to the currently used LabView interface).

**Prerequisites:** The project is best suitable for bachelor or master students in mechanical or microtechnical engineering, physics, materials or surface science, as well as for students in industrial process technologies

**Duration:** Minimum 3 months for bachelor or master students, preferentially 4-6 months; PhD interns 6-12 months

**Keywords:** Laser surface analysis, angular light scattering, test bench development, applied nanosciences for robotics and industrial machines

## FLEXIBLE ELECTRODES FOR BIOSIGNAL MONITORING AND NERVE STIMULATION

**Prof. Dr. S. Schintke**

The research unit COMATEC-LANS (Laboratory of Applied NanoSciences) is active in the field of nano- and microfiber composite materials.
Within the study project, the candidate will participate in running research activities of the COMATEC-LANS. The laboratory has recently developed materials for flexible electrodes for biosignal monitoring from humans and plants, as well as for nerve stimulation. The project aims at conducting further improvements and experiments on soft flexible electrodes.
The project involves process and materials development, electrical material characterization, as well as prototyping and testing of the material and electrode designs for wearable and medical applications.
You will use various printing and coating equipments. Flexible electrodes are also of interest for flexible actuators, or energy storage applications which can be furthermore envisaged. The project is suitable for master or bachelor students with interest in advanced electrical characterizations of novel materials, a good general understanding of general physics or in chemical engineering is expected.





**Duration:** Minimum 3 months for bachelor or master students, preferentially 4-6 months; PhD interns 6-12 months

**Keywords:** Conductive polymer nanocomposites, electrical probing, electrical impedance spectroscopy, prototyping, lab and field tests

## MOTORIZED ATMOSPHERIC PRESSURE PLASMA TREATMENT ON ADVANCED MATERIALS

**Prof. Dr. S. Schintke**

The research unit COMATEC-LANS (Laboratory of Applied NanoSciences) is active in the field of atmospheric pressure plasma treatment of surfaces.

Within the study project, the candidate will participate in running research activities of the COMATEC-LANS.
The aim of the project is to modify surface properties on various biocompatible or bio-sourced nano- or microfiber-based materials. You will generate nano- and microfiber-based materials using electrospinning. You will use our semi-automated motorised atmospheric pressure plasma system (pilot system for industrial in-line nozzles) and investigate the influence of process parameters and treatment paths. You will apply various surface analysis techniques, such as atomic force microscopy and surface wettability analysis. The project is best suitable for bachelor or master students in machine engineering, chemical engineering, material or surface science, applied physics, as well as for students in industrial process technologies.

**Duration:** Minimum 3 months for bachelor or master students, preferentially 4-6 months; PhD interns 6-12 months

**Keywords:** Atmospheric pressure plasma, surface treatment of advanced materials, motorized systems, applied nanosciences

## ARTIFICIAL MUSCLES FOR ROBOTICS APPLICATIONS

**Prof. Dr. S. Schintke**

The research unit COMATEC-LANS (Laboratory of Applied NanoSciences) is active in the field of transparent electrodes.

Within the study project, the candidate will participate in running research activities of the COMATEC-LANS. You will perform design and characterization of soft flexible artificial muscles based on conductive polymer nanocomposites for the use in robotics applications. You will be involved in the prototyping of the muscles, and in adaptions of our test-benches. You will perform lab tests of the muscles in actuation and sensing geometries.
The project is best suitable for bachelor or master students in mechanical, chemical or materials engineering, applied physic, or robotics, as well as for students in industrial process technologies.

**Duration:** Minimum 3 months for bachelor or master students, preferentially 4-6 months; PhD interns 6-12 months

**Keywords:** Conducting soft materials, electro-mechanical actuation and sensing, test-bench developments, prototyping, lab tests

## MOUNTAIN BIKE – RIDER FORCE INTERACTION AND SHOCK BASED DAMPING TESTING MACHINE

**Prof. A. Schorderet**

Former projects have developed the numerical simulation, in situ testing environment and a suspension shock test-bench simulation POC. The simulation results were compared to experimental data for a step-down case. The model assumption that the rider doesn't move with respect to the bike is probably not valid in this case.
The goals of the project are:
1. Develop rider-bike force measurement capability to include rider-bike interaction in the model and obtain a reliable and precise simulation model fitting the experimental in situ data for the step-down and periodic bumps cases
2. Develop an experimental POC (Proof of concept) for the suspension damping testing based on the shock POC

**Prerequisites:** Mechanical vibrations, structural mechanics, mechanical design, force sensors

**Duration:** 4-6 months

**Keywords:** Force sensors, testing, bike dynamics, damping characterization

## MICRO-MILLING REAL TIME QUALITY CONTROL

**Prof. A. Schorderet**

To improve the micro-milling process quality, confocal microscope analysis of machined parts and surface spatial patterns are correlated to the dynamic and vibrational behaviour of the machine. Recent work has made it possible to obtain, during machining, an indicator of the quality of the machined surface by means of machine signals processing. The goal of the project is to apply advanced data analysis of machine signals to define a process quality criterion and provide it in real-time (RT). The algorithms will be implemented on an ad hoc FPGA hardware. Once available, this criterion could be used to implement a very novel process control loop able to guarantee manufactured parts quality.

**Prerequisites:** Dynamic signal analysis, milling process, machine dynamics

**Duration:** 4-6 months

**Keywords:** Micro-milling, process quality, advanced data analysis, machine dynamics

## DYNAMIC OPTIMIZATION OF LARGE HIGH SPEED COREXY 3DP MACHINE

**Prof. A. Schorderet**

The improvement and optimization of dynamic performances of large machines is studied using a large 3DP CoreXY type machine (700x700x600 mm strokes) controlled by OpenCN. The project aims at optimizing the machine's and process dynamics by using structural composite components and specific control algorithms (FIR, optimized Jerk) in the OpenCN framework. The optimal low-cost/high performance solution is sought. The work includes FEA, prototype realization, modal characterization, trajectory optimization schemes development, NC implementation and assessing the machine's performances with the new solutions.





**Prerequisites:** Structural dynamics/ mechanical vibrations, mechanical design, motion control

**Duration:** 4-6 months

**Keywords:** Machine dynamics, optimization, motion control, composite structures

## NANOTECH 1 – ELECTRODEPOSITION OF NANOWIRE STRUCTURES : GROWTH FRONT CONTROL

**Prof. Dr. L. Gravier**

The COMATEC institute develop for years a very accessible technology called "template synthesis", i. e. an electrochemical deposition of nanowires structures in nanoporous polymer thin film. These thin film nanocomposites are mainly used for microscale sensors applications, but also haptic actuators or smart filters. The major challenge of this nanotechnology is the control of the nanowire growth rate, naturally quite inhomogeneous.

The goal of this project is to adapt the existing electrochemical cell to monitor to control the nanowires growth front. The forseen strategy is to achieve homogeneous nanowires electrodeposition via a sequence of deposition-dissolution. Scanning electron microscope images will be used to characterize the growth front control.
A secondary goal is to gather practical data to published the results in a scientific and/or technique journal.

**Keywords:** Microtechnology, nanotechnology, electrochemical deposition of nanostructures

## NANOTECH 2 - NANOSTRUCTURED PIEZOELECTRIC ACTUATOR SENSOR/ ACTUATOR

**Prof. Dr. L. Gravier**

In the frame of the Industry 4.0 research program, a new generation of sensors is needed, to be integrated in micromachines or devices. The project aims at the design and fabrication of a nanostructured thin film pressure sensor, using the nanotechnology techniques mastered in the lab. The actuator properties of these thin film systems will be also characterized. A test bench will be developed, which will be integrated in a technology demonstrator.

**Keywords:** Microtechnology, nanotechnology, thermoelectric power, lock-in detection, micro-thermal engineering

## NANOTECH 3 -NANOSTRUCTURED INFRARED LIGHT SENSOR

**Prof. Dr. L. Gravier**

In the frame of the Industry 4.0 research program, a new generation of sensors is needed, to be integrated in micromachines or devices.
The project aim at the design and fabrication of a small scale infrared light sensor using thermoelectric properties of a nanostructured thin film, using the nanotechnology techniques mastered in the lab. A test bench will be developed to characterize the sensitivity and response time of this sensor, which will be integrated in a technology demonstrator.

**Keywords:** Microtechnology, nanotechnology, IR light sensors

## NANOTECH 4 -FAST TIME-RESPONSE FLOW METER BY NANOTECHNOLOGY

**Prof. Dr. L. Gravier**

In intensive care units, many biomedical devices monitor patients' vital functions. An important parameter is the measurement of respiratory flow. However, this is tricky to measure for premature babies, since their low lung capacity is of the same order of magnitude as the «dead volumes» of conventional monitoring devices. One solution is to install a very small flow meter at the end of the intubation pipe, right at the entrance to the lungs. The goal of this project is to prove the feasibility of such small-scale flowmeter, which will integrate ultra-thin flexible sensors developed by nanotechnology in our lab.

**Keywords:** Medtech, microtechnology, nanotechnology, micro-thermal engineering

## HAPTICS 1 - LOW CONSUMPTION POWER SUPPLY FOR ELECTROACTIVE HAPTIC SURFACE

**Prof. Dr. L. Gravier**

In the frame of the Industry 4.0 research program, a new generation of sensors is needed, to make machine control more and more easy and intuitive for human users. To this purpose, haptic surfaces are request, which allow to a user swift interactions with a machine via the sense of the touch.
This project aims at the design and fabrication of an integrated power supply for electrostatic haptic surfaces, to be plugged to the mains (230 V / 50 Hz) and that deliver an output voltage of about 500 V peak-to-peak at frequencies in the audio range of 20-1000 Hz. This device will power haptic power surfaces, commercial or made in the lab.

**Keywords:** Medtech, Electric engineering, power electronics and control systems, Human-machine interface

## HAPTICS 2 - TEST BENCH FOR UNBIASED CHARACTERIZATION OF ELECTROACTIVE HAPTIC SURFACES

**Prof. Dr. L. Gravier**

In the frame of the Industry 4.0 research program, a new generation of sensors is needed, to make machine control more and more easy and intuitive for human users. To this purpose, haptic surfaces are request, which allow to a user swift interactions with a machine via the sense of the touch. However, current characterization techniques mostly used human fingers, inducing large biases in the results. To overcome this, a device is currently developed in the lab, using an artificial finger for an objective measurement of haptic properties of electrostatic haptic surfaces. This device needs one more step to be finalized.

This project aims at the final improvement of an existing prototype of haptic characterization test bench, and a full characterization of its performances.
A secondary goal is to gather practical data to published the results in a scientific and/or technique journal.

**Keywords:** Medtech, microtechniques, haptic sensors, Human-machine interface





## HAPTICS 3 - AUDIO SIGNALS FOR ELECTROACTIVE HAPTIC SURFACES TO MIMIC TEXTURES SENSATIONS

**Prof. Dr. L. Gravier**

In the frame of the Industry 4.0 research program, a new generation of sensors is needed, to make machine control more and more easy and intuitive for human users. To this purpose, haptic surfaces are request, which allow to a user swift interactions with a machine via the sense of the touch. One interesting outcome is to induce artificial sensation of surface texture – fabrics, wood, rubber… - to the finger tip, via electrovibrations in the audio range. However, audio signals have to be adapted to this purpose.

This project aims at to set a library of audio signal able to induce artificial texture sensations to the finger tip on a commercial electroactive haptic surface. The main effort is to record audio signals of a finger sliding on various surfaces, and to convert them into effective haptic signals via a sound card. The haptic test bench developed in the lab will be used for objective measurements of haptic responses.

**Keywords:** Microtechniques, sound board control, haptic surfaces, Human-machine interface

## INTERESTED?
## CONTACT US!

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