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# TOPICS FOR THESIS / INTERNSHIPS

## ACADEMIC YEAR 2025-26

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# TOPICS FOR THESIS / INTERNSHIPS 2025-26



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 normally last between 5 and 6 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.



GEOMATICS, CIVIL ENGINEERING

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

## SHEAR WALLS IN EARTHCRETE

**Prof. M. Viviani**

The research project in which the candidate will work focuses on advancing the development of structural calculations for load-bearing walls made with Shot-Earth, a novel excavation-earth-based material.

Currently, the different earth-based concretes available on the market are at various stages of development, and progress is being made in detailing their structural applications. Reinforced Shot-Earth has been extensively tested to assess whether conventional structural calculation models used for reinforced concrete (RC) are suitable. Furthermore, models for shrinkage and creep have also been verified.

The aim of this project is to design a residential building with structures made of Shot-Earth and identify the actual challenges that a structural engineer would face when using this material in everyday practice.

**Prerequisites:** Knowledge and interest in the following areas: Laboratory testing, material science, modeling, structural engineering, seismic analyses, structural modeling with FEM software

**Duration:** 6 months

**Keywords:** Structural engineering, seismic analyses of RC structures earth-based reinforced concretes

# 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 optimization 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, preferably 6 months

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

## THERMAL ENERGY STORAGE TO STIMULATE DISTRICT HEATING EXPANSION AND DECARBONATION IN SWITZERLAND

**Prof. Dr. A. Duret**

The TES4DH project aims to explore latent thermal energy storage (TES) applications in district heating (DH). Key areas include:
1. Sector coupling with heat pumps or cogeneration plants to optimize electricity production and consumption.
2. Decentralized TES to expand networks and enhance heat pre-distribution.
3. Centralized TES to boost boiler room capacity and reduce fossil fuel use during peak demand.

The internship will support TES4DH by evaluating one of these applications. The student will conduct a literature review, develop a numerical model of the heat production system with TES, and assess the energy, environmental, and financial impacts of TES integration.

**Prerequisites:** Knowledge in energy system, ideally a first experience in energy system numerical modeling

**Duration:** 4-8 months

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

## ROBUST LIFE CYCLE ASSESSMENT OF BUILDINGS WITH GRANULAR AND SCALABLE DATA

**Prof. S. Lasvaux**

The internship focuses on adapting input data for Life Cycle Assessment (LCA) models of buildings, with an emphasis on environmental impacts, particularly the carbon footprint, and indirect effects related to construction materials and technical installations. The goal is to optimize the carbon footprint of buildings by refining existing databases and aligning them with the needs of various professionals involved in building design (such as architects and engineers). This collaborative

internship provides the opportunity to work with field actors in the French-speaking part of Switzerland and is part of a practical, innovative approach to accurate carbon calculations. The project will also involve international collaboration with a French research laboratory.

The internship activities include defining the specifications for the database, analysing existing data, capitalizing on feedback from case studies and stakeholders, and applying the approach to a reference building based on Swiss regulations (SIA 390/1).

The internship offers hands-on experience in carbon calculation through life cycle analysis of buildings, contributing to a deeper understanding of carbon footprints. Interns will work in a dynamic R&D team, receive personalized guidance, and have the chance to develop key skills while making a meaningful ecological and societal impact.

**Keywords:** Life cycle assessment, circularity, GHG emissions, buildings, data

## PARAMETERIZED LIFE CYCLE ASSESSMENT OF HEAT PUMPS INTEGRATED IN SWISS BUILDINGS

**Prof. S. Lavaux & A. Duret**

The internship focuses on assessing the carbon footprint of heat pumps (HP) in Swiss buildings throughout their entire life cycle, from design and installation to operation, maintenance, and electricity consumption. The mission is part of the LCA-PAC project, which involves the Institute of Energy (IE), industry partners, and public authorities working together to replace fossil fuels with this technology. The goal is to improve the evaluation of decarbonization strategies for heating and hot water production using heat pumps.
The internship involves four main tasks:
1. Data Collection: Gather information on heat pumps, including refrigerant leaks and CO2 emissions of Swiss electricity, in collaboration with industry partners.
2. Development of a Parameterized Model: Create a life cycle model that accounts for design, installation, operation, and maintenance of heat pumps.
3. Application on Case Studies: Apply the model to several heat pumps and at least one full building case study.
4. Analysis and Reporting: Analyse results and produce a detailed report.

The internship offers practical experience in life cycle analysis (LCA) for energy systems, helping to decarbonize building heat production by 2050. Interns will gain valuable skills while working in a dynamic R&D team.

**Keywords:** Life cycle assessment, heat pumps, GHG emissions, buildings, data, parameterized model

## LIFE CYCLE ASSESSMENT OF THE MOST ADVANCED LOW-CARBON AND CIRCULAR BUILDINGS IN SWITZERLAND

**Prof. S. Lavaux**

The internship focuses on assessing the carbon footprint of «low-carbon» and circular buildings that integrate advanced circular, biobased and geosourced materials and strategies. This mission is part of a collaboration with design teams (architects and engineers) in a new National Research Program. Interns will work on pilot projects featuring ambitious low-carbon concepts with design teams.
The internship tasks include:
1. Data Collection: Gather data to assess the reuse potential of construction products and their associated decarbonization impact.
2. Life Cycle Assessment (LCA): Perform detailed LCAs of pilot projects, considering materials, technical installations, and energy consumption.
3. Performance Indicators: Calculate indicators such as material intensity, carbon footprint, circularity, and biogenic carbon storage.
4. Analysis and Reporting: Analyse results, create graphs and visualizations, and share findings with the project team.

This internship offers the opportunity to develop key skills in carbon calculation for buildings using life cycle analysis and advanced simulation tools. Interns will contribute to understanding the carbon footprint of new buildings and the role of reuse in a fully circular approach. Additionally, interns will work in a dynamic R&D team with personalized guidance.

**Keywords:** Life cycle assessment, circularity, GHG emissions, buildings, new low carbon architecture

## 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

## SHORT-TERM POWER DEMAND FORECASTING WITH NONSYMMETRIC ERROR PENALTY FUNCTION

**Prof. M. Bozorg**

Techniques ranging from statistical models to machine learning and AI-based approaches are applied to forecast electricity demand. In terms of data, these techniques rely on historical time series of electricity demand, own generation (photovoltaic etc.), weather conditions and temporal factors (weekday, weekend etc.). Forecast errors in short-term power demand prediction can lead to imbalances between scheduled and actual electricity consumption, especially for day-ahead energy markets.



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Such discrepancies result in balancing penalties imposed by transmission system operators to maintain grid stability. In Switzerland, the transmission system operator (i.e., Swissgrid) employs a balancing group mechanism to maintain grid stability by ensuring that electricity production and consumption are consistently aligned. A balancing group is essentially a virtual energy account managed by a balance group manager, encompassing energy transactions from various energy providers, Distribution System Operators (DSOs), consumers, and traders. Within this context, in collaboration with a Swiss DSO, the objective of this project is to develop a short-term forecasting method that considers a nonsymmetric penalty function. The penalty function should formulate the costs associated with imbalances within a balancing group including the DSO. Such costs are dynamically varying over time and depend on whether the forecast error of the DSO is in the same or opposite direction as the imbalances of other participants of the market as well as other members of the balancing group.

**Prerequisites:** Basic knowledge in power systems and electricity markets, basic knowledge in machine learning and forecasting techniques, basic knowledge in Python

**Duration:** 4-6 months

**Website:**
Balancing mechanism of Swissgrid:
https://www.swissgrid.ch/en/home/customers/balance-groups.html

**Keywords:** Short term forecasting, power demand time-series, machine learning, balancing management, data science

## INTEGRATION OF LOCAL CHARGING STATIONS FLEXIBILITY WITH DISTRIBUTION GRID OPERATION THROUGH A DIGITAL TWIN PLATFORM

**Prof. M. Bozorg**

The main objective of this project is to develop a co-simulation tool to estimate and optimize the flexibilities provided by local charging stations of electrical vehicles for secure and optimal operation of medium and low voltage distribution grids. To this end, on the mobility side, first we estimate the needs and constraints for transport and charging connected at different locations to the grid.

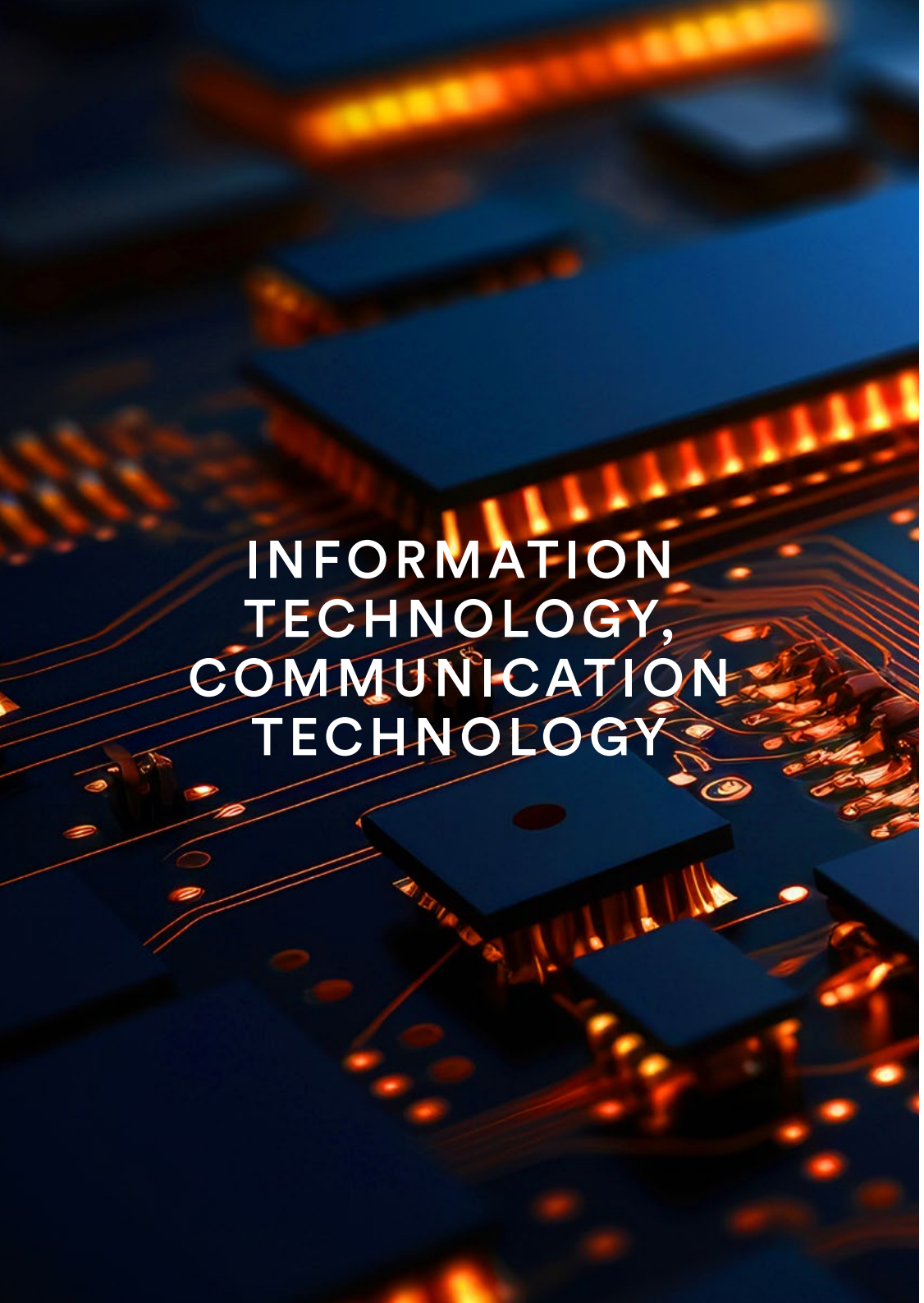
Then, we optimize the use of flexibility on the transport side for different services on the grid side including power balancing, grid operation security as well as reducing the need for grid reinforcement. This will be tested within a distribution grid digital twin that has been developed at HEIG-VD (twindigrid) within a real case of a pilot site in Fribourg, Switzerland in the context of the Smart Energy District project.

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

**Duration:** 4-6 months

**Website:**
Digital twin: https://twindigrid.heig-vd.ch/
Smart energy district project:
https://www.hes-so.ch/smart-energy-district

**Keywords:** Distribution system, EV charging stations, EV management, Grid operation flexibility



# 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

## OPTIMIZING MULTISPECTRAL IMAGE PROCESSING FOR VINEYARD HEALTH ANALYSIS

**Prof. Dr. L. Raileanu**

Drones equipped with multispectral sensors flying over the fields of vine are capturing images that reveal information invisible to the naked eye. This project aims to address two issues:

1) optimizing the generation of orthomosaic images, which involves studying optimization technologies and strategies for generating a large number of orthomosaic images (RGB and multispectral)

2) exploring image analysis and machine (deep) learning techniques for characterizing the health status of the vine plants through generation of health prediction maps.

The development of this project will be realized on several series of multispectral and RGB images acquired on vineyards of between 0.5 and 6 ha.

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

**Duration:** 4-6 months

**Keywords:** Image processing, data analysis, machine/deep learning, vineyards, multispectral images

## ANALYSIS OF EEG SIGNALS FOR PAIN ASSESSMENT AND IMPACT OF PHYSICAL ACTIVITY

**Prof. Dr. L. Raileanu**

Chronic pain is a major public health issue worldwide, not only because of its high prevalence, but also because of the limited effectiveness of available therapies. A targeted therapeutic approach, based on the mechanisms of pain modulation (the ability to adjust the intensity or transmission of a nerve signal), is currently considered a promising way of improving analgesic (painkiller) treatments.

The aim of this project is to study the impact of physical exercise on the experimental pain response, focusing on GABAergic neurotransmission, in order to better understand its involvement in the analgesic effect of exercise. To this end, both the effects of long-term physical training and those of immediate physical exercise will be studied through the analysis of the brain activity recorded using a high-density continuous EEG (64 electrodes, with a sampling frequency of 512 Hz) during experimental painful cold stimulation, while physical exercise consisted of pedaling on a cycle ergometer for 25 minutes, up to 70% of maximum heart rate. Participants' clinical response to pain as well as their demographic characteristics (age, sex, weight, height, etc.) will also be incorporated into the analysis.

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

**Duration:** 4-6 months

**Keywords:** Signal processing, machine learning, EEG

## 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 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

## VIDEO ANALYSIS OF POSTURE DURING FREE WEIGHT EXERCISES

**Prof. R. Mosqueron**

In fitness, some exercises performed by athletes are more dangerous than others for the physical, especially for the back. Free weights are largely responsible for these injuries either because of the load or a poorly performed movement.

The new health centre in Champagne (VD) https://centre-sante.ch/ aspires to become a reference place in the field of health, sport and well-being in the North Vaud region by using technological innovations to improve the monitoring of fitness enthusiasts.
The objective of the project will be to recognize the user of the free weights during these exercises with the help of cameras. These cameras will also be used to calculate the weight put on the bar(s). The user will be able to do these exercises while being analysed in these movements.

The system will therefore be able to analyse his posture during these movements and will be able to tell him if he is doing the right thing or not. This assessment will be transmitted to him on his smartphone by showing him the dangers of his movements on his body and the user can then ask for advice by an explanatory video of the movement to be worked on or by calling a coach from the gym.





In addition, this system will be able to monitor the subscriber's performance as these workouts go on.

Specifications:
- Research of face recognition technologies to recognize the subscriber
- Research of motion tracking technologies
- Weight Analysis
- Movement learning and recognition to recognize «wrong movements»
- Implementing the algorithm
- Development of the application for the Proof of Concept

**Keywords:** Machine Learning, embedded systems, video

## 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

## CHARACTERISATION OF NOISE TO EVALUATE URBAN SOUNDS

**Prof. R. Mosqueron**

In the context of noise reduction in urban areas, this project aims to develop and validate a Proof of Concept (POC) for the evaluation of sound level and the categorization of noise sources. The initial objective is to analyze and identify the acoustic signatures of the different sound sources detected in urban environments.

Once this validation phase is completed, the study will deepen the possibility of characterizing a unique sound signature for each detected vehicle. This analysis will examine whether such a signature can be used to estimate displacement parameters, such as the average vehicle speed.

The project is based on the implementation of sensors capable of collecting data in real time and processing it using signal analysis algorithms and artificial intelligence. By having several sensors, it would become possible to cross-reference information to refine sound recognition and improve the accuracy of estimates.

The analysis tool developed in the framework of this project could contribute to the implementation of innovative solutions for urban noise reduction, helping local authorities to better understand and manage noise pollution. This initiative is therefore part of a process to improve the living environment, protect public health and optimise urban mobility policies.

Work requested:
- Spectral analysis of urban sounds https://urbansounddataset.weebly.com/
- Choosing an audio sensor with the right spectrum

**Duration:** 3-6 months

**Keywords:** Signal processing, machine learning, deep learning, 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

## 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 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.

**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



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**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

## TL-MICROBIAL-GENOMICS: EXPLORING THE USE OF FOUNDATION MODELS AND TRANSFER LEARNING ON MICROBIAL GENOMICS MODELLING.

**Prof. C. Peña/X. Brochet**

The goal of this project is to explore modelling approaches combining the power of foundation models with transfer learning to deal with microbial genomic data in the context of biological classification. These methods will be applied to at least 2 different datasets from our group's research projects.

Context. In the field of biology, from an information point of view, a DNA sequence can be considered as a sequence of specific characters such as 'A', 'C', 'G' and 'T' called bases. It is generally accepted that the information encoded by the DNA is organized hierarchically in blocks of growing complexity (e.g., domains, genes, chromosomes) related directly with biological characteristics and phenomena.

Although different to language, DNA-encoded information has a latent structure that could be exploited by machine-learning algorithms to build predictive models

**Prerequisites:** Machine Learning, Deep learning, notions of biology

**Duration:** 6 months

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

## 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 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

## LABELING OF 3D SCENES SHOWING HISTORICAL IMAGES

**Prof. J. Ingensand**

The smapshot.heig-vd.ch has about 300'000 historical images that have been georeferenced by the crowd. 3D referencing implies that the 3D coordinates of all pixels are known and thereby the development of an algorithm that automatically labels images becomes possible. The idea of the project is to:

1. Conduct a experiment involving citizen with historical images to find out which labels citizen would put on a photo. Deduce labeling rules from the experiment.



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2. Implement an algorithm that automatically places labels (based on available datasets) on a historical photo

3. Test the algorithm with images from smapshot.

**Prerequisites:** Geographical Information Systems (GIS), Development skills (Python, Javascript)

**Duration:** 2 to 6 months

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

**Keywords:** Labeling of 3D scenes, historical images, spatial data processing algorithm, user experiment

## VIRTUAL GLOBE OF THE PAST

**Prof. J. Ingensand**

The smapshot.heig-vd.ch has about 300'000 historical images that have been georeferenced by the crowd in a virtual globe. 3D referencing implies that the 3D coordinates of all pixels are known. The idea of the project is to use existing machine learning algorithms that do an automatic segmentation of a photo (e.g., detection of forests, buildings, etc). Since the dates of most photos are known it becomes possible to map the segmented, extracted information in a virtual globe and thereby to create a virtual globe of the past. The goal is to implement a prototype that allows for navigation in both time and space.

**Prerequisites:** Geographical Information Systems (GIS), Development skills (Python, Javascript)

**Duration:** 2 to 6 months

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

**Keywords:** Virtual globe, Image segmentation, 3D mapping, spatial data processing

## 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

## CREATION AND SIMULATION OF NOVEL GPU MODELS

**Prof. M. Zapater**

GPUs are the most prominent choice when it comes to accelerating artificial intelligence (AI) models. Simulation of GPUs have long been hindered due to the closed-source ISA specifications. In this project, multiple simulation tools will be explored to enable cycle-accurate simulation of GPUs with the goal of simulating the most novel GPUs of the market and understand their benefits and bottlenecks. The preferred choice of the simulator would be gem5 (for the CPU models) and GPGPU-Sim [1] for timing models of the GPU complex, given the current expertise that we have with these tools within the research institute, which will allow us to guide the student closely in all steps of the project.

**Prerequisites:** C/C++ programming. Knowledge of computer architecture (including GPUs) or eagerness to learn. Basic knowledge of the Linux command line.

**Duration:** Minimum 3 months

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

## VALIDATION OF RISC-V CPU MODELS IN THE GEM5 SIMULATOR

**Prof. M. Zapater**

Simulation of Compute Systems is essential for improving their performance. Cycle accurate performance simulation of Compute Systems can identify performance bottlenecks.

However, the simulated models have to be validated against actual hardware. In this project, an Out-of-Order RISC-V CPU model will be validated against in-house OoO CPU emulated on an FPGA. Both the simulated and the emulated system will run Ubuntu distribution (with recent linux version).

The simulator of choice is gem5, given the current expertise that we have with these tools within the research institute, which will allow us to guide the student closely in all steps of the project.

**Prerequisites:** C/C++ programming. Knowledge of computer architecture or eagerness to learn.
Basic knowledge of the Linux command line.

**Duration:** Minimum 3 months

**Keywords:** Gem5, RISC-V, simulation, CPU models

## DEEP LEARNING ARRYTHMIA DETECTION TECHNIQUES ON EMBEDDED PLATFORMS USING EDGE-TO-EDGE WORKLOAD OFF-LOADING

**Prof. M. Zapater**

Cardiovascular diseases represent today one of the most common causes of death. Accurate arrythmia detection requires complex algorithms that are beyond the possibilities of what an embedded platform can execute in real-time.

This project aims at the implementation of workload off-loading techniques in order to run part of a deep learning algorithm in a low-power RISC-V based edge device,





and another part of the same algorithms in a more powerful embedded system (like a NVIDIA Jetson GPU). The goal will be to assess the trade-offs in terms of performance and power, while keeping the accuracy in arrythmia detection. For this purpose, a proof-of-concept platform developed in the REDS institute will be used.

**Prerequisites:** C/C++/Python programming. Knowledge on AI algorithms (DNNs, transformers, others). At least basic knowledge is required on DNNs.

**Duration:** Minimum 3 months

**Keywords:** ECG, Arrythmia detection, AI, deep learning.

## ENHANCING THE ENERGY EFFICIENCY OF AI MODELS VIA WORKLOAD PARTITIONING ON DISTRIBUTED EMBEDDED SYSTEMS

**Prof. M. Zapater**

The goal of this project is to enhance the energy efficiency of AI workloads, by launching them on a set of low-power edge nodes equipped with embedded GPUs, instead of on a high-performance server equipped with a high-end GPU.

To do so, we need to develop software libraries allowing to split CNNs and Large Language Models (LLMs), over a distributed system composed of multiple Jetson Orin Nano boards. Both vertical and horizontal splitting techniques will be investigated, enabling to split a single layer of a certain AI model into several nodes (vertical split) to parallelize the layer execution; as well as to pipeline the execution of the model itself (horizontal split), enabling each node to receive results from the previous model layer, run its assigned layer and forward the intermediate result to the next.

**Prerequisites:** C/C++/Python programming. Knowledge on AI algorithms (DNNs, transformers, others). At least basic knowledge is required on DNNs.

**Duration:** Minimum 3 months

**Keywords:** Embedded Systems, GPUs, AI, CNNs, LLMs.

# MECHANICAL AND MATERIALS ENGINEERING



## SELF-ADAPTIVE SAMPLING RATE DATA ACQUISITION SYSTEM

**Prof G. Courret**

The aim of this internship is to contribute to the development of a self-adaptive sampling rate data acquisition system designed for wide band signals. The work will be carried out in collaboration with our laboratory on the development of software and firmware dedicated to signal processing and real-time analysis. This internship will be involved in the design of the algorithm for compression, analysis and storage of measurement data.

**Prerequisites:** 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, preferably 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.

**Prerequisites:** Courses of plasma physics and thermodynamics

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

## PLASTICS WASTE RECYCLING WITH PLASMA TECHNOLOGY

**Prof G. Courret**

The aim of the internship is to participate in a research and development project related to the recycling of plastic waste. The research team is currently developing a reactor to break down plastic waste into high value molecules using a microwave plasma process. The work is being carried out by a collaborative research team. The internship will focus on experimentation, analysis and parameter optimization of a new laboratory set-up.

**Prerequisites:** Courses in plasma technology and materials science.

**Duration:** Minimum 3 months for Master students, preferably 4-6 months, PhD interns 6-12 months

**Keywords:** recycling, sustainability, environment, climate change, plasma processes, polymers, plastics

## 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, preferably 4-6 months; PhD interns 6-12 months

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

## LASER TECHNIQUES FOR NANO AND MICROPATTERN SURFACE ANALYSIS

**Prof. Dr. S. Schintke**

The research unit COMATEC-LANS (Laboratory of Applied NanoSciences, www.comatec-lans.ch) 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 compare our laser system for investigating surface nano- and microstructures with topographic information from optical profilometer measurements, as well as from atomic force microscopy. Our laser 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. The data analysis is performed using Python.

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, Python could be implemented).

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, preferably 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

## SURFACE MODIFICATION OF BIO-SOURCED NANOFIBER MATS USING ATMOSPHERIC PRESSURE PLASMA

**Prof. Dr. S. Schintke**

The research unit COMATEC-LANS (Laboratory of Applied NanoSciences, www.comatec-lans.ch) 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 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, preferably 4-6 months; PhD interns 6-12 months.

**Keywords:** Electrospinning, atmospheric pressure plasma, surface treatment of advanced materials, automation, applied nanosciences

## 3D PRINTING OF HYDROGEL NANOCOMPOSITES FOR SENSOR APPLICATIONS

**Prof. Dr. S. Schintke**

The research unit COMATEC-LANS (Laboratory of Applied NanoSciences, www.comatec-lans.ch) 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 design and test 3D printing of hydrogel nanocomposites for the use in robotics and environmental sensing applications. You will be involved in developing and choosing printable hydrogel materials, in performing chemical and physical testing of materials properties, as well as in the comparison of several printing processes: You will be involved in dedicated adaption of our 3D printing system and you will perform lab tests on 3D printed hydrogel-based robotic components and environmental sensors.
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, preferably 4-6 months; PhD interns 6-12 months.

**Keywords:** hydrogel composites, material development and testing, 3D printing, test-bench developments, prototyping, sensors

## 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, preferably 4-6 months; PhD interns 6-12 months

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

## SIGNAL PROCESSING OF ROTATING MACHINERY FOR IMPROVED PREDICTIVE MAINTENANCE

**Prof. A. Schorderet**

Industrial rotating machinery, such as machine-tool spindles, motor-pump systems for water treatment solutions, and similar applications, is monitored to minimize component failures as much as possible. The use of both standard physics-based algorithms and machine learning presents promising ways to enhance failure detection capabilities, with the ultimate goal of precisely estimating the time remaining until the next servicing or component replacement.

For both of the aforementioned applications, extensive datasets of test bench and in-situ measured signals are already available from a previous project. The objective is to improve signal processing algorithms by extending failure type detection capabilities, as well as enhancing sensitivity and precision

**Prerequisites:** Dynamic signal analysis

**Duration:** 4-6 months

**Keywords:** Micro-milling, process quality, advanced signal processing

## 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 detection are correlated to machine control signals.





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. But not in real-time (RT). The goal of the project is to improve the advanced signals processing to compute a process quality criterion and provide it in real-time (RT). The developed algorithms could then 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

**Duration:** 4-6 months

**Keywords:** micro-milling, process quality, advanced signal processing

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

**Prof. A. Schorderet**

The improvement and optimization of the dynamic performance of large machines are studied using a large 3DP CoreXY-type machine (700x700x600 mm strokes) controlled by the OpenCN framework. The project aims to optimize both the machine's and the process's dynamics by integrating structural composite components and specific control algorithms (FIR, optimized jerk) within the OpenCN framework, seeking the optimal balance between cost and performance.

The work includes all or a subset of the following tasks: finite element analysis (FEA), prototype development, modal characterization, trajectory optimization scheme development, NC implementation, and performance assessment of the machine 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

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

## 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 PRESSURE 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, force sensors

## NANOTECH 3 - NANOSTRUCTURED MAGNETIC FIELD 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 magnetic field sensor using giant magnetic resistance 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, magnetic field sensors.

## NANOTECH 4 - BLOOD CIRCULATION MONITORING WITH NANOSTRUCTURED MICRO-SENSORS

**Prof. Dr. L. Gravier**

In intensive care units, many biomedical devices monitor patients' vital functions. An important parameter is the measurement of blood circulation. One solution is to install a very small flow meter into blood vessels, as an autonomous implant. 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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