Louvain School of Engineering Research Internships Portfolio for summer 2025

Professors / Mentor	Eng. field	Research project title	project summary
Pierre-Antoine Absil https://sites.uclouvain.be/absil/	**Math. engineering**	**Clustering**	Clustering is a pervasive task in data science. The objective is to develop and test a clustering algorithm based on orthogonal nonnegative matrices, leveraging techniques akin to those that we have proposed in our laboratory for orthogonal nonnegative matrix factorization. The testing will involve both synthetic data and real-life data.
		Optimal state estimation from intermittent measures with application to epidemics	Dynamical systems are broadly used to model many engineering, social, and natural systems. Observability of a dynamical system guarantees the ability to reconstruct its internal state from sparse and possibly intermittent measurements. While observability for smooth systems is a well-studied property, it remains an outstanding question to determine whether the state of systems with intermittent sensor measurements can be reconstructed with the same accuracy as in the classical case. Contact : Pierre-Antoine Absil and Gianluca Bianchin
		Using randomized low-rank linear solvers for structured nonconvex optimization	Many nonconvex optimization problems have built-in symmetries which induce a low-rank structure in the Hessian. The project will use this structure to design fast second-order optimization methods, where the rank deficiency will be exploited in the computation of the Newton direction. Recently developed randomized methods compute a low-rank approximation of a matrix; this enables fast inversion at a cost of O(n r^2) operations, instead of the traditional O(n^3). The project will also study how these low-rank approximation methods interact with iterative methods to solve linear systems (Krylov methods).
Frederic Crevecoeur https://uclouvain.be/en/research-institutes/icteam/biomedical-engineering.html	**Biomed / Math Engineering**	**Adaptive control model of human reaching movements**	Recent results in sensorimotor neuroscience have suggested that humans use adaptive neural control to correct for unexpected disturbances during reaching movements. These results have been established based on behavioral data of movement kinematics and surface recordings of muscles activity and validated in a computational model that considered an approximation of the nervous system. It remains how several properties of the motor system constrain the adaptive control strategies. In this project we aim at studying the impact of limb geometry, neural noise and sensorimotor delays on adaptive control models to study the stability margins of human motor control. The modeling results may potentially be confronted to data collected in the lab.

Laurent Delannay https://uclouvain.be/en/research-institutes/immc/members-0.html?id=1183	**Mechanical Engineering**	**Hydrogen effect on ductility of Al alloys**	Aluminium alloys are interesting candidate materials for H storage but, just like many other metals, they are susceptible to H embrittlement. In this project, laminate composite samples produced by accumulative roll bonding will be used as "micro- laboratories" so as to investigate the influence of diffusible H on dislocation- mediated plasticity. Tomography and electron microscopy observations will be used to assess model predictions of microscopic strain heterogeneity and crystallographic texture development.
Laurent Delannay https://uclouvain.be/en/research-institutes/immc/members-0.html?id=1183 and **Benoit Delhaye** Benoit Delhaye (delhayeben.github.io)	**Biomedical Engineering**	**Modeling fingertip biomechanics during oblique loading**	The sense of touch allows us to perceive the physical properties of the objects and interaction forces during manipulation. Tactile perception relies on sensors, the mechanoreceptors, that transduce the local skin deformations into neural signal transmitted to the brain. While the response properties of the mechanoreceptive afferents under normal loading have been extensively characterized, much less is known about those properties under tangential loading. This is because of the complexity of the finger geometry and mechanics, and the complexity to make faithful measurements of its deformations during tangential loading. The goal of this project is to get insight into fingertip deformation during oblique loading through modeling. An existing finite element model of the fingertips will be improved to faithfully simulate tangential loading. If you are potentially interested, please contact first: benoit.delhaye@uclouvain.be
Juray De Wilde https://uclouvain.be/en/research-institutes/immc/imap/process-intensification-for-the-development-of-eco-efficient-processes.html	**Chemical & Material Science Eng.**	**Reducing CO2 emissions of hydrogen/syngas production by Steam Methane Reforming (SMR)**	One of the important steps in the production of base chemicals and synthetic fuels from natural gas is the conversion of methane into synthesis gas, a mixture of CO and H2. Different processes exist, but Steam Methane Reforming (SMR) is the most widely used. The reactions are strongly endothermic, and energy is supplied by burning fuel in a furnace in which the SMR reactor tubes are suspended. The furnace is an important source of CO2 that is difficult to capture because it is mixed with N2. The project focuses on various ways to reduce CO2 emissions of SMR. Research includes experimental work and detailed modelling and simulation. For more details please contact: juray.dewilde@uclouvain.be
		Ammonia cracking in the context of hydrogen storage	Ammonia is regarded as an interesting storage medium for green hydrogen that is produced when there is excess power. The project aims at studying the recovery of hydrogen by ammonia cracking. Catalyst, kinetics and reactor design are studied by a combination of detailed experiments and modelling. For more details, please contact: juray.dewilde@uclouvain.be

Juray De Wilde https://uclouvain.be/en/research-institutes/immc/imap/process-intensification-for-the-development-of-eco-efficient-processes.html	**Chemical & Material Science Eng.**	**A new process combining CO2 adsorption/desorption and methanation for neutralizing CO2 emissions when excess green energy**	The project aims at developing a transient process that allows to store CO2 when insufficient green energy is produced, and NG is used for power production and to convert that stored CO2 back into methane when excess green energy is available by producing green hydrogen and methanation of the CO2. Aspects studied include the catalyst and kinetics and reactor design. For more details, please contact: juray.dewilde@uclouvain.be
Samuel Poncé www.samuelponce.com	**Physics & Material Science Eng.**	**Accelerated calculations of carrier mobility in semiconductors and resistivity in metals.**	Drift carrier mobility describes how charged carriers propagate in a material and is therefore an intrinsic crucial information for material characterization. Thanks to recent numerical advances, the transport of charge can be computed from first principles via the solution of the Boltzmann transport equation without empirical or experimental parameters, making them predictive. The goal of this project is to implement spline interpolation of the solution of the Boltzmann equation to speed up the time to solution and to perform realistic calculations in simple semiconductors. The student will acquire basic knowledge of first-principles calculations and the physics of charged transport. This project can open to the further realization of a doctoral work. Having done the class LMAPR2451 on atomistic and nanoscopic simulations or following the class during the thesis will be very helpful. The master thesis will be done in collaboration with Dr. Francesco Macheda (La Sapienza, Rome). Review on the topic: Reports on Progress in Physics **83**, 036501 (2020)
Gian-Marco Rignanese https://perso.uclouvain.be/gian-marco.rignanese/	**Physics & Material Science Eng.**	**Generative Approaches to Materials Design**	In materials science, the traditional trial-and-error discovery process (including synthesis and characterization of each candidate structure) solely based on luck and intuition is doomed to failure. In the last decade, materials science has entered the era of (big) data-driven science. This revolution needs to be fully embraced to explore the huge combinatorial space of possible materials. Indeed, ML approaches can be used not only to speed up the prediction of the properties of a structure, but more importantly to suggest interesting new structures with the targeted functionalities (inverse design). In particular, the generative approach is an unsupervised learning method to encode a high-dimensional space into a continuous vector space (or latent space) of low dimension. It is then possible to generate new data using knowledge embedded in the latent space. This approach is extremely promising for images (see, e.g., StyleGAN for faces) but it is only in its infancy for materials design. This project aims to investigate its possibilities for materials design.

Julien Hendrickx https://perso.uclouvain.be/julie n.hendrickx/publi.html	**Math. Engineering**	**Open Multi-Agent systems**	Multi-agent systems consist of a set of similar entities (robots, vehicles, sensors, animals, human beings) interacting with each other and their environment without the intervention of any central controller. Multi-agent systems have been the focus of many studies over the last 10-15 years. Almost all results available on multi-agent systems concern « closed systems »: n agents are present at time 0, and one analyze their asymptotic behavior when $t \to \infty$. However, many applications naturally involve open multi-agent systems, where agents can arrive and leave during the process. Think of cars entering a city, or of computers/smartphones waking up or being shut down in a network. Besides, robustness to the disappearance of agents and adaptation to the arrival of new agents are often cited among the most important properties of multi-agent systems.
		Learning From Pairwise Comparisons	In recent works we have developed new ultra-efficient learning algorithms for two problems where the data have a hidden network structure (see below). They are based on solving weighted log-least square problems that are linear with respect to the values to be learned but highly nonlinear in the data. These algorithms run in a time nearly linear with respect to the size of the data, and achieve fundamental lower bounds in terms of asymptotic precision, up to some multiplicative constant.
		Towards bounding the success probability of machine learning classifiers	Machine learning and deep learning are increasingly used in numerous applications requiring classification. For this purpose, the standard approach is to train a statistical model that is next tested on fresh samples. A success probability can then be estimated in order to quantify the quality of the classifier. Concretely, this success probability typically increases with the amount of training data. However, training complex models on large data sets can be computationally intensive. A recent line of works therefore aims at developing new tools in order to bound the success probability of certain classifiers so that even after training the model on a small dataset, it is possible to evaluate the remaining potential of the model with more training data (and therefore the interest to spend more time in training).

Julien Hendrickx https://perso.uclouvain.be/julie n.hendrickx/publi.html		**Advanced optimization techniques for real-time control**	The goal of this master thesis is to adapt and test recent optimization methods to the real-time control of dynamical systems. Control problems can often be formulated in term of optimization. The traditional approach consists in considering the trajectory x as a function x(u) of the input signal u (and the initial condition) and to minimize a cost function J(x(u),u), representing both the quality of the trajectory and the cost of the control action. A more recent alternative approach consists in minimizing the cost of the inputs u and the trajectory x under the constraint that they satisfy the physics of the system: Minu J(x,u) s.t. x, u consistent with initial conditions and physics of the system. This constraint is complicated but linear when the system is linear. Efficient algorithms have recently been developed to solve that class of problems, see e.g. [1]. They consist in dualizing the "physics" constraint and using then a purely dual-type gradient method. The dual objective function is typically separable, so the dual problem can be solved efficiently. One can then reconstruct an approximate primal solution.
Laurent Jacques http://laurentjacques.gitlab.io	**Math. Engineering**	**Deep Inverse Techniques Applied to Interferometric Imaging Models**	Project keywords: inverse problem, computational imaging, lensless imaging, compressive sensing, interferometry, radioastronomy Requirement: - prerequisites in numerical linear algebra and machine learning - knowledge in convex and non-convex optimization techniques - good programming skills in Python/Pytorch Contact L. Jacques (laurent.jacques@uclouvain.be) for more details.

Pascal Jacques https://uclouvain.be/en/research-institutes/immc/ongoing-research-projects.html and https://uclouvain.be/en/research-institutes/immc/imap/high- performance-metallic-alloys.html	**Math. Engineering**	**Additive manufacturing**	Additive manufacturing (AM) is increasingly considered as a key manufacturing technology of tomorrow's society. It covers various technologies that have in common the addition of material in successive layers in order to build parts based on sliced 3D computer-aided design (CAD) models. The AM technologies make possible the production of complex near-net shape parts. Our research group is focusing on metal additive manufacturing, and more particularly on the Laser Powder Bed Fusion technology, with two L-PBF machines available in our lab. All the equipment necessary for the production and handling of powders is also available, together with advanced characterisation facilities (for chemical, microstructural, and mechanical characterisation). Depending on the skills and motivations of the trainee, the project could focus on one or several of the following aspects: Design and implementation in our L-PBF machines of new metallic alloys, e.g. Ni-, Ti-, Fe-, or Al-based alloys; Ensuring reliable comparison and transfer between the two L-PBF machines; Advanced characterisation of L-PBF parts focusing on a specific issue, e.g. chemical and microstructural modifications during the L-PBF process or during post-treatments, etc. Possibility to host several students for an internship on this topic.
Pascal Jacques https://uclouvain.be/en/research-institutes/immc/ongoing-research-projects.html and https://uclouvain.be/en/research-institutes/immc/imap/high- performance-metallic-alloys.html	**Chemical & Material Science Eng.**	**Thermoelectric devices & energy harvesting**	Thermoelectricity is a solid-state technology that allows direct conversion of heat-to-electricity that has a great potential in several applications such as Aerospace, Waste Heat Recovery or Energy Harvesting. However, its use and development remain rather confidential since state-of-the-art materials are expensive. That's why research in our group focuses on the development of cost-effective solutions including new thermoelectric materials, innovative modules designs and working prototypes integrating these new developments. Depending on the skills and motivations of the trainee, the project could focus on one or several of the following aspects: Optimization of microstructure and thermoelectric properties of new Heusler compounds, Development and characterization of thermoelectric modules based on new Heusler compounds, Design, modelling and experimental prototyping of thermoelectric systems for practical applications. Possibility to host several students for an internship on this topic.

Pierre Schaus https://www.info.ucl.ac.be/~pschaus/	**Computer science/Computer Engineering**	**Modeling Language for solving large scale dynamic programs using decision diagrams and a-star based algorithms**	You will design and developing a novel solution for modelling and solving discrete optimization problems through dynamic programming and decision diagrams. Your role involves contributing to the creation of a specialized modeling language/API, akin to PDDL in planning or MiniZinc in constraint programming, tailored for decision-diagram-based optimization. References: https://github.com/xgillard/ddo https://didppy.readthedocs.io/en/stable/
Raphaël Jungers https://perso.uclouvain.be/raph ael.jungers/content/home	**Math. Engineering**	**[Theoretical computer science, mathematics, theoretical research]** **Cerny's conjecture and the synchronizing probability function**	The famous Cerny conjecture has been an open problem since the early 60's in Automata and languages. See [1] for an introduction. Roughly speaking, it postulates a small (quadratic) upper bound on the time needed to locate an autonomous agent in a network by open loop control. Despite its very simple formulation and huge interest from the scientific community, little progress has been made. Recently, a new approach mixing optimization with game-theoretic concepts has been proposed, and this approach has proved useful to prove bounds on quantities related with the conjecture. The student will implement several variants of the function and compare their behaviour on various kinds of automata. If the student is interested in theoretical research, several open questions/conjectures might be investigated. [1] Gonze, F., & Jungers, R. M. (2016). On the synchronizing probability function and the triple rendezvous time for synchronizing automata. SIAM Journal on Discrete Mathematics, 30(2), 995-1014.
		[Control Theory, Data Science, Probability] **Data-driven control of complex systems**	Suppose that you want to control a complex system (or a computer process), whose model is unavailable, or way too complicated to analyze with classical methods (think of a simulink model of a plant in your next job, with components ranging from lookup- tables, proprietary software, nonlinear functions, delays, human-in-the-loop, etc). Something you can probably do is to simulate it, or let your system run for some time, and collect data on its behaviour. But, even if it behaves well when you're there to monitor it, does it mean that it will *always* do so? What if it runs in another regime, which you did not have time to test? (if your model has 1000 variables or more, this is most probably going to happen.) It has recently been shown [1] that by combining geometrical properties of the system with probabilistic optimization techniques, one can indeed derive firm bounds on the behaviour of the system. The goal of this project is to implement the recent results obtained and generalize them to other settings in control. [1] Berger, G. O., Jungers, R. M., & Wang, Z. (2021, May). Chance-constrained quasi-convex optimization with application to data-driven switched systems control. In Learning for Dynamics and Control (pp. 571-583). PMLR.

Raphaël Jungers https://perso.uclouvain.be/raph ael.jungers/content/home		**[Control theory, AI, Machine Learning]** **Learning to Control:** **Implementation of new control techniques in Julia**	The engineered systems surrounding us are increasingly hard to control. Not only the complicated interaction of the physical processes with the machines that control them, but also specifications (cyber-security, safety, privacy, resilience, resource-efficiency, decentralization) are more and more complex, and critical. In the framework of the ERC-supported project L2C, we are creating a new paradigm for smart symbolic control and implementing it in Julia [1]. The student will contribute to the platform by implementing one of our newly published algorithms. [1] https://dionysos-dev.github.io/Dionysos.jl/dev/
Philippe Lefèvre http://perso.uclouvain.be/philip pe.lefevre/ **And** **Benoit Delhaye** Benoit Delhaye (delhayeben.github.io)	**Biomedical Engineering**	**Tactile perception and fingertip skin mechanical properties assessed by robot-controlled stimulation.**	The sense of touch allows us to manipulate objects with exquisite dexterity. The tactile receptors in the skin acquire information about the mechanical interactions between the fingertip and the objects during manipulation by transducing local skin deformations. This information is essential for the fine coordination of the prehension forces. However, what information is provided to the brain by the tactile system during manipulation and how the brain uses this information to coordinate finger forces remains unclear. This project will aim to quantify the perception of tactile stimuli delivered by a robotic platform. To that end, we will use a custom-made robotic platform able to apply controlled tactile stimuli to the fingerpad over transparent material while we assess the perception and/or discrimination performance of the participant. At the same time, images of the fingerpad will be recorded from multiple cameras through the transparent surface, and image processing will be used to quantify the 3-D deformations of the fingertip. We will assess the degree to which skin deformation and age-related changes in skin properties influence tactile perception.
Philippe Lefèvre http://perso.uclouvain.be/philip pe.lefevre/ **And** **Benoit Delhaye** Benoit Delhaye (delhayeben.github.io)	**Biomedical Engineering**	**Influence of local fingertip deformation on haptic force control**	The sense of touch allows us to manipulate objects with exquisite dexterity. The tactile receptors in the skin acquire information about the mechanical interactions between the fingertip and the objects during manipulation. This information is essential for the fine coordination of the prehension forces. However, what information is provided to the brain by the tactile system during manipulation and how the brain uses this information to coordinate finger forces remains unclear. To shed light on these questions, this project will assess the effect of local skin stretch generated by a particular device (i.e. Latero) on the active production of lateral forces. In particular, we will assess if local stretch can influence the force actively perceived by a participant or bias the production of a memorized force.

Benoît Legat https://blegat.github.io/	**Math. Engineering**	**Accelerating energy optimization**	This project focuses on creating a GPU-accelerated optimal power flow solver leveraging CUDA and NCCL to address the growing complexity of energy systems driven by renewable integration and microgrids. Traditional CPU-based solvers struggle with scalability as models become larger and more intricate, limiting their ability to handle modern power flow optimization challenges. Modern HPC infrastructure is increasingly tailored for deep learning, with powerful GPU clusters optimized for parallel computations and fast inter-GPU communication. By utilizing the parallel processing capabilities of GPUs and enabling multi-GPU communication, this project seeks to unlock new levels of efficiency and scalability, allowing for faster and more accurate solutions to large-scale optimal power flow problems. The outcome will enable better utilization of renewable energy and support the transition to smarter, more sustainable energy grids.
		Faster quantum simulation through symmetry and low-rank techniques	This project aims to enhance the scalability and precision of symmetry reduction techniques in quantum many-body systems through a refined analysis of the group actions inherent in quantum mechanics and the low-rank structure of the associated optimization problems. Ground-state properties, a central challenge in quantum physics, are often studied using semidefinite programming relaxations to provide certified bounds on observables. However, scaling these methods to larger systems—crucial for delivering meaningful insights to physicists—leads to extremely large and computationally demanding optimization programs. To address this, it is vital to exploit the problem's symmetries and low-rank structures, enabling efficient computation and extending the applicability of these methods to significantly larger system sizes.
		Large scale solver for polynomial optimization	This project focuses on developing a solver for polynomial optimization, the low-rank structure of the solution using the Burer-Monteiro factorization, and the acceleration of polynomial operations in the Chebyshev basis through Fast Fourier Transform (FFT). The Burer-Monteiro approach not only reduces the dimensionality of the optimization problem but is also highly amenable to parallelization, making it ideal for distribution across a GPU cluster to efficiently handle large-scale instances. The Chebyshev basis enables efficient representation and evaluation of polynomials, and applying FFT accelerates the computation of polynomial operations, further enhancing performance. The combination of these techniques allows for the scalable and fast solving of high-dimensional polynomial optimization problems, making it suitable for a range of applications in quantum physics, machine learning, control theory, and signal processing.

Patricia Luis Alconero https://uclouvain.be/en/researc h/recipe/professor-patricia-luis- alconero.html	**Chemical & Material Science Eng.**	**In-situ methanol removal from transesterification mixture of glycerol and dimethyl carbonate by reactive pervaporation**	Glycerol carbonate (GC) is a valuable product of transesterification reaction between glycerol and dimethyl carbonate (DMC) in the presence of basic catalyst sites. As the reaction mechanism is reversible, the thermodynamic equilibrium can be shifted towards the product if the by-product methanol (MeOH) is removed, resulting in the beneficial reaction intensification. Produced GC is usually recovered by a conventional distillation, which is further complicated by the formation of an azeotrope between the reagent DMC and the by-product MeOH. Thus, alternative solutions must be found to reduce high energy consumption required to break the azeotrope. Pervaporation may offer a considerable process improvement, providing a feasible tool for efficient and simultaneous separation of MeOH vapor from the reaction mixture.
Patricia Luis Alconero https://uclouvain.be/en/researc h/recipe/professor-patricia-luis- alconero.html	**Chemical & Material Science Eng.**	**CO2 revalorization by crystallization using membrane distillation- crystallization**	Climate change has been a major concern since the past half century and becomes an emergency today. Therefore, minimizing our environmental impact through CO2 capture has become essential. However, the current technology used to capture CO2 from industrial gasses is extremely energy intensive and the captured CO2 is stocked underground with no further revalorization. This is why new ways of capturing and storing/using CO2 have been investigated. This leads to the cornerstone of the project that is ongoing in the group: to use membrane-based technology and more precisely membrane contactors in order to minimize energy consumption while obtaining pure crystals of (bi)carbonate salts. This solution would tackle the main problems of the current capture technology: membrane contactors could minimize the energy consumption and valorise the CO2 as (bi)carbonate crystals instead of storing it underground.
		Development of biocatalytic membranes containing ionic liquids for CO2 capture	The economy estimations clearly highlight the future societal reliance on fossil fuel supplies. This will result in further global warming. Several global warming mitigation strategies propose the CO2 capture and geological storage and utilization (CCSU) as a reliable approach. Currently, the most industrially recognized technology for CO2 capture is gas absorption using amine aqueous solutions. However, several drawbacks are associated to the use of amines. Among the different alternatives, the use of membranes has received a lot of attention since they present several advantages such as direct product flow, low footprint, lower energy requirements and straightforward scale-up. This thesis will be focused on the development of advanced membranes for CO2 capture. These membranes merge two important strategies: i) application of room temperature ionic liquid-based materials as the membrane structure, and ii) biomimicking the Nature via the use of enzymes (carbonic anhydrase) integrated within the membrane to enhance the capture of CO2.

Patricia Luis Alconero https://uclouvain.be/en/researc h/recipe/professor-patricia-luis- alconero.html		**Enzymatic capture of CO2 for further revalorization**	The continued increase in the atmospheric concentration of CO2 due to anthropogenic emissions is leading to significant changes in climate, with the industry accounting for one-third of all the energy used globally and for almost 40% of worldwide CO2 emissions. Fast actions are required to decrease the concentration of this greenhouse gas in the atmosphere, value that has currently reaching 400 ppm. Among the technological possibilities that are on the table to reduce CO2 emissions, carbon capture and storage into geological deposits is one of the main strategies that is being applied. However, the final objective of this strategy is to remove CO2 without considering the enormous potential of this molecule as a source of carbon for the production of valuable compounds. Nature has developed an effective and equilibrated mechanism to concentrate CO2 and fixate the inorganic carbon into inorganic or organic material by means of enzymatic action. Mimicking Nature and take advantage of millions of years of evolution should be considered as a basic starting point in the development of smart and highly effective processes.
Patricia Luis Alconero https://uclouvain.be/en/researc h/recipe/professor-patricia-luis- alconero.html	**Chemical & Material Science Eng.**	**Life cycle assessment (LCA) project for a CO2 capture process- Remote simulation using SimaPro software**	The objective of this project is to assess the environmental impact (mainly concerning CO2 emissions) of a new process for producing carbonates from CO2 emitted by combustion gases using membrane technology. A life cycle analysis is proposed as the methodology to be followed, and the results will be compared with the current state of the art (CO2 capture using amines).
		Neuro-symbolic artificial intelligence	AI has witnessed significant progress in recent years. In particular the quality of output generated by generative Deep Neural Networks has increased significantly in the last 10 years. However, a weakness of DNNs is that *how* these models work is not transparent; they require significant resources; and the output of these models does not meet any quality assurances. More traditional forms of AI, such as rule-learning, decision tree learning and constraint programming offer tools that can help to solve these weaknesses. This has led to the development of the field of *neurosymbolic AI*, which aims to combine neural networks with more traditional forms of symbolic AI. In this project in discussion with the promoter a challenge will be identified in how to combine neural networks with symbolic AI. Possibilities include: how to use constraint programming to ensure that the output of a DNN meets predefined requirements; how to combine rule-learning with DNNs; how to combine decision tree learning with DNNs; approaches for using DNNs to solve optimization problems; and more, based on the state-of-the-art at the moment of the project start.

Siegfried Nijssen https://www.info.ucl.ac.be/~snijssen/	**Computer science**	**Radio channel characterization in dense and heterogeneous cellular networks using advanced ray-tracing techniques**	Radio channel characterization is a key issue in wireless communications. However, given the dramatic increase in terms of capabilities of wireless systems, e.g. data rate, quality of service etc., the accurate relationship between radiowave propagation and system performance is getting more crucial, in particular to design optimal network topologies. As measurements are generally costly and time consuming, channel models are widely used for this purpose: empirical, statistical and deterministic models are different approaches. Typically, the latter, being based on the electromagnetic properties of the propagating waves, relies on a Ray-Tracing (RT) method. RT is a geometric optics-based technique aiming at evaluating the paths followed by rays as they interact with the environment (in both outdoor and indoor scenarios). At the same time, the variable user density/network topology should also be accounted for, which is not per se compatible with the RT philosophy (…)
Claude Oestges **https://uclouvain.be/fr/reperoires/claude.oestges**	**Electrical Engineering**	**Performance Trade-offs and Designs for Dual-Function RADAR/Communication Devices**	Both RADAR and communication systems use the frequency spectrum with the following objectives specific. On the one hand, communication systems are used to transmit information between a transmitter and a receiver usually not co-located. If the transmission coexists with other systems, The transmitted signal contains elements (frequency code/signature) that make it possible to differentiate from the interfering signals. On the other hand, RADAR systems are deployed for the detection of targets and the estimation of parameters such as distance, speed and angle of arrival of these targets. In a configuration Mono- static, the RADAR system consists of a transmitter co-located and synchronized with a receiver. The transmitter produces a signal containing predefined elements in order to comply with the following constraints defined for the RADAR system.
		Reconfigurable Impedance Surfaces for 5G wireless networks	Phased arrays are already in use in 5G communication systems to create beams towards users and improve the network throughput. However, phased array technologies are energy-consuming and only provide a limited control over the effects of shadowing in urban propagation. In the subject proposed here, Reconfigurable Impedance Surfaces (RIS) will be studied in the form of metasurfaces. RISs are reconfigurable structured reflectors distributed on the walls in a city with the aim of redirecting rays in a non-specular and controlled manner the incident electromagnetic waves. Doing so, the RIS enables to "engineer" the channel transmittance in order to improve a given performance (capacity, interference, etc.). The proposed study consists of combining a propagation modeling of the channel (from a base station to a mobile user), based on a ray-tracing tool, with a proper design of reflective metasurfaces, so as to improve a given performance metric (capacity, interference, etc). On the one hand, the metasurface will be modeled as a spatially and temporally modulated surface impedance, the latter can be realized with a dense array of sub-wavelength patches printed on a grounded slab. The metasurface reconfiguration will be made possible through the usage of variable reactive loads protruding from the ground

			plane. On the other hand, the wireless channel will be modelled by means of a ray-tracing tool (see an example below), enabling to estimate the number of propagation paths between the transmit base station and the mobile receiver/user, as well as their directional characteristics (how much separated are the paths in the direction-of-departure domain ?).
Claude Oestges **https://uclouvain.be/fr/repertoires/claude.oestges**		**Impact of scintillation on free-space optical satellite communications**	Optical radiowaves used for Earth-Space optical communications (Free-Space Optics, or FSO) in the atmosphere suffers from several impairments, such as absorption, attenuation by clouds or rains, and scintillation. Scintillation is described as temporal and spatial variations of the received intensity of a wave owing to turbulence in the propagation medium. Indeed, fluctuations of pressure, temperature and humidity in the atmosphere leads to fluctuations of the refractive index which induce scintillation. A well-known example of the scintillation effect is the twinkling of star that can be observed in a clear night sky. At UCLouvain, the phenomenon of scintillation for optical waves can be studied in diverse respects. Commonly, the intensity of the refractive index fluctuations is characterized by the Cn2 parameter, named refractive index structure constant, for which several models have been developed. Such models can be theoretical or empirical, but recent trends are to consider numerical weather prediction (NWP) simulations to determine atmospheric quantities and try to derive the associated Cn2 profile. Possible fields of research include review and application of common Cn2 models at the locations of potential FSO ground-based stations, study of scintillation effects in the boundary layer, development of Cn2 models and comparison with seeing measurements, numerical simulations of scintillation effects, ...

Claude Oestges **https://uclouvain.be/fr/repertoires/claude.oestges**		**Numerical study of channel flows of granular suspensions**	Granular suspensions are defined as two-phase mixtures of macroscopic particles immersed in a fluid. They are routinely encountered in natural phenomena and engineering applications, ranging from transport of powders and grains in process industries to drug-delivery systems. However, many questions regarding their dynamics remain open. This notable restrain can be attributed to the rich phenomenology and complex behavior that granular suspensions exhibit. In this internship we propose a numerical study of channel flows of granular suspensions in a channel based on two-phase flow modelling. To this end, a series of parametric studies will be conducted with respect to the material properties and flow conditions, in order to quantify their effects on the velocity and particle concentration across the channel.
Miltiadis V. Papalexandris https://sites.google.com/site/mvpapalexandris/	**Mechanical or Chemical Engineering**	**Numerical simulation of charge build-up in turbulent flows of dielectric liquids**	Flow electrification during transport of dielectric liquids constitutes a major safety hazard. More specifically, at sufficiently high Reynolds numbers and for low- conductivity fluids such as liquid hydrocarbons, the thickness of the hydrodynamic boundary layer can become comparable to that of the electrical double layer. In turn, this leads to increased transport of electric charges away from the wall region and towards the bulk of the flow. The transport charges is further enhanced due to turbulent mixing. However, quantitative information on the underpinning mechanisms of this phenomenon is still lacking. In this internship we propose the study of the phenomenon of electrification of turbulent flows in square ducts via direct numerical simulations. The simulations will be performed via an in-house parallel flow solver.
	Mechanical Engineering	**Large-Eddy Simulation of turbulent thermal convection induced by an internally heated porous medium**	Thermal convection is a classical phenomenon in fluid mechanics: it is driven by buoyancy forces that result from fluid density variations due to thermal gradients. In this internship we propose the numerical study of turbulent convection induced by an internally heated porous medium. The main motivation for this study comes from the need to better understand the phenomena occurring in the early stages of a loss of cooling accident in storage pools of spent nuclear fuel, such as the one in Fukushima 2011. The study will be based on Large - Eddy Simulations (LES). According to this approach, the mass, momentum and energy equations are spatially filtered. In this manner, the large turbulent scales of the flow are directly resolved, whereas the effect of the small, unresolved turbulent scales is taken into account via appropriate sub-grid models. Different heat loadings will be considered, and the emerging turbulent structures and turbulence statistics will be compared.

Miltiadis V. Papalexandris https://sites.google.com/site/mvpapalexandris/	**Mechanical Engineering**	**Nano-, micro-, macro-mechanics of materials (metals, polymers, coatings, composites, hybrids), both experimental and modelling**	Several possible subjects regarding the nano-, micromechanical behaviour of materials can be considered relying on nano-, micro-mechanical test methods and modelling: - Thin freestanding film materials behaviour determined based on a versatile UCLouvain patented MEMS based on chip test method. This method, which is working for more than 10 years but still under continuous development, allow testing materials as thin as single graphene layer and measure the elastic, plastic, creep and fracture properties with possible electrical or thermal couplings. The technique is amenable to direct in situ TEM analysis. - Polymer based composites and other classes of hybrid materials behaviour determined at the level of constituents and interfaces based on nanoindentation, AFM, nano DIC, in situ SEM testing, combined with finite element simulations. - Advanced metallic alloys behaviour determined based on nanoindentation, AFM, nano DIC, in situ SEM testing, combined with finite element simulations, and mechanistic link with macroscopic response. Contact the professor for more details : thomas.pardoen@uclouvain.be
Thomas Pardoen https://uclouvain.be/en/directories/thomas.pardoen	**Chemical, Mechanical & Material Science Eng.**	**Process intensification of water electrolysis for low-cost and high- rate green hydrogen production**	The production of hydrogen from water electrolysis is an essential process in the decarbonisation of the global economy. Hydrogen plays an important role as an energy carrier, storing energy from renewables and liberating it when needed. It can be used in sectors which are difficult to electrify, such as long-distance shipping transport and heavy industry. It can also be used for long-term energy storage and also as feedstock for the industry. Among all the technologies for green hydrogen production, alkaline water electrolysis is the most promising one in terms of cost ($/kW), since it does not need noble metals. Nevertheless, cost is still the main barrier for the entrance of green hydrogen in the market. Our research is focused in the improvement of the electrolyser performance by the use of a forced electrolytic flow and high-surface 3D electrodes. The goal of the project is to intensify hydrogen production by the morphological and topological optimisation of such high-surface electrodes and by the optimization of the electrolyser design. Contact the professor for more details : joris.proost@uclouvain.be

Joris Proost https://uclouvain.be/fr/repertoires/joris.proost	**Chemical & Material Science Eng.**	**Silicon-on-Insulator (SOI) MOSFET technology for RF and millimeter-wave devices and circuits fabrication, etc.)**	3 research projects: - TCAD (Silvaco) simulations of advanced RF SOI transistors (high frequency performance, self-heating, substrate effects, ...) - EM (HFSS, CST) of advanced passive structures on Si-based substrates - IC design (Cadence) of passive circuits on advanced RF SOI technologies keywords: micro- and nanoelectronics, high frequency, wireless communication, low power electronics, 5G, 6G, THz, clean room
Jean-Pierre Raskin https://sites.uclouvain.be/RF-SOI-group/team/jeanpierreraskin/ and **Dimitri Lederer** https://sites.uclouvain.be/RF-SOI-group/team/dimitrilederer/	**Electrical Engineering**	**Characterisation of the thermal conductivity of nanomaterials using the 3- ω technique**	The measurement of thin-film thermal conductivity is vital in microelectronics, as it enables the thermal properties of materials used in the manufacture of electronic devices to be characterized. This measurement reflects a material's ability to conduct heat, and plays a crucial role in the dissipation of heat in electronic devices. By measuring thin-film thermal conductivity, engineers and scientists can optimize the design of electronic devices to improve their thermal performance and avoid overheating problems. These measurements are also important for understanding how materials behave when subjected to high temperature conditions, which can help prevent failures in electronic devices. Among the measurement methods, the 3-omega method is a very versatile technique that can be applied to solids of different dimensions (solid, thin film or nanowire). As well as being fast and simple, this method has the advantage of being localised (to measure the variation in thermal conductivity on inhomogeneous materials). The principle of the 3-omega method is to heat a sample with an alternating current at a frequency ω (the excitation frequency) through a micro-resistor produced by microfabrication. The heating, which does not depend on the direction of the current, has a frequency of 2 ω. The response of the sample is measured at the third harmonic of this frequency, i.e. at 3ω. This third harmonic is measured using a detector and is directly proportional to the thermal conductivity of the sample. In this work, the student will be required to further develop a measurement setup, as well as design models for extracting the thermal properties of nanoporous materials, a major potential candidate for tomorrow's RF electronics. As part of their work, students will have the opportunity to work on the Winfab microfabrication platform. In this way, the student will participate in the development of high-performance RF substrates based on porous silicon, a promising innovation from the UCLouvain laboratories.

Jean-Pierre Raskin https://sites.uclouvain.be/RF-SOI-group/team/jeanpierreraskin/	**Electrical Engineering**	**Improving paper-based reverse electrodialysis for energy generation from saline water**	The objective of this master thesis is to improve a portable battery for powering miniaturized sensors or biosensors. These batteries are made from paper and work on the principle of reverse electrodialysis from salty water. This electrochemical phenomenon allows the generation of energy from a salinity gradient. Its main advantage is to use a resource accessible both environmentally and economically and not discharge any toxic waste. Nevertheless, pumping is necessary to maintain constant energy generation. The capillary properties of the paper allow to avoid the energy cost linked to the pumping and to make the device portable. This technology has been mastered within the laboratory, but several improvements are possible depending on the student's preferences. It can be the design of a power conditioning circuit, physical simulation, microfabrication, or even life cycle analysis for the selection and implementation of components to reduce the environmental footprint. The subject is also open to all proposals from the student. Video of popularization carried out of the subject realized within the framework of a competition: https://www.youtube.com/watch?v=j9vpUeSkiSc
Jean-Pierre Raskin https://sites.uclouvain.be/RF-SOI-group/team/jeanpierreraskin/	**Electrical Engineering**	**Integration of magnetic nanoparticles in electromagnetic biosensors**	This research project aims at designing and manufacturing (lab scale) handheld sensor required for the detection of harmful bacteria present in various aqueous media. Such sensors to measure the quality of drinking water in remote areas, disease in urine or contaminations of milk in the agro-industry. Magnetic nanoparticles are used as “labels” for the presence of bacteria, enabling detection through changes in permeability and coercivity. This master thesis focusses on the integration of nanoparticles in the detection system. According to the student preferences and background, the focus can either be on optimization of the nanoparticle structure (size, coating) in order to maximize the signal-to-noise-ratio (SNR), on characterization of the nanoparticle magnetic properties to elaborate proper calibration and quantification of their magnetisation. The students are invited to tackle ethical and sustainable questions linked to the research project in at least one chapter of their master thesis.
Jean-Pierre Raskin https://sites.uclouvain.be/RF-SOI-group/team/jeanpierreraskin/	**Electrical Engineering**	**Development of an electromagnetic reader for nanoparticle detection**	This research project aims at designing and manufacturing (lab scale) handheld sensor required for the detection of harmful bacteria present in various aqueous media. Such sensors measure the quality of drinking water in remote areas, disease in urine or contaminations of milk in the agro-industry. Magnetic nanoparticles are used as “labels” for the presence of bacteria, enabling detection through changes in permeability and coercivity. This master thesis focusses on the improvement of the electromagnetic transducer. According to the students’ preferences, the focus can either be on the design of a differential sensor with planar electrodes, or on the interfacing and amplification (e.g. lock-in) of the signal extracted from a planar hall effect device.

Jean-Pierre Raskin https://sites.uclouvain.be/RF-SOI-group/team/jeanpierreraskin/	**Electrical Engineering**	**Design of silicon-integrated waveguides and circuits for THz applications**	At sub-mmWave frequencies (>300GHz) resistive losses become unacceptably high in RFICs and it has become clear that the feasibility of CMOS-based sub-mmWave circuits will require alternative modes of signal propagation than current metal-supported transmission lines. Our lab therefore explores other propagation means based using silicon-integrated waveguides (WG) which are fabricated using micro-maching processing techniques. We also investigate the design, modeling and fabrication of (sub)-mmWave circuits based on WG components. The work will therefore focus on one or several of the following research aspects (to be discussed with interested students): design and simulation of optimized Si-integrated WG and circuits (filters, couplers, metasurfaces, THz sensor, ...), fabrication of test structures in UCLouvain's cleanroom (Winfab), electrical characterization and modelling.
Dimitri Lederer https://sites.uclouvain.be/RF-SOI-group/team/dimitrilederer/	**Electrical Engineering**	**Surface reconstruction with alpha-shapes**	Alpha shapes have been introduced by Edelsbrunner, Kirkpatrick & Seidel in 1983 [1] as a family of piecewise linear simple curves in the Euclidean plane associated with the shape of a finite set of points. The main application of alpha-shapes is the reconstruction of objects which have been sampled by points. For instance, a 3D- scanner provides points on the surface of a human-being or so. The objective here is to use alpha-shapes for reconstructing complex CAD models that are not watertight. The concept of alpha-shape is strongly connected to Delaunay triangulations and the prospective student will have access to a highly efficient open source that computes 3D triangulations [2].
Jean-François Remacle **https://www.hextreme.eu/**	**Mechanical Engineering**	**Impact of timing-synchronization & hardware non-idealities on sensing**	Future wireless applications require both communications and sensing on a single platform. In this context, the convergence of communications and sensing attracts research interests to benefit in terms of both spectrum efficiency and cost-effectiveness. Along with several other research tracks, IMEC is active in research for radar, wireless communication, and JSAC which are expected to play a significant role in defining 6G and beyond services. Hardware non-idealities, if left uncompensated, degrade communication and sensing performance. Additionally, in a distributed JSAC system, timing-synchronization among different nodes of the network is essential for sensing. The requirements to mitigate the effect of hardware non-idealities are different for communication than for sensing. Therefore, it is important to investigate the impact of hardware non-idealities for JSAC and find solutions which take into consideration both the functionalities. Similarly, it is also important to tackle the timing-synchronization issue for distributed sensing to recreate physical environment (or objects in the radio channel) in the digital domain. Aim of the thesis: The aim of this thesis is to investigate the impact of hardware nonidealities such as from the Power Amplifier, variations in the carrier frequency, IQ imbalance etc., and timing–synchronization on sensing functionality in a JSAC system. The work is expected to use

			existing models for different hardware non-idealities and timing-synchronization techniques and their suitability for JSAC using simulation. This thesis will be completed in collaboration with IMEC in Leuven. An internship at IMEC is recommended before and/or during the thesis.
Luc Vandendorpe **(with Jérôme Louveaux)**	**Electrical Engineering**	**Performance analysis of the Orthogonal Time Frequency Space Modulation in 6G networks**	While the first 5 generations of mobile communication systems have primarily concentrated on the data communications functionality, the objective of the designers is to provide other services than communications with 6G networks. Among those the sensing and the positioning of "objects" in the environment is one of high importance. Sensing is the operation by means of which one detects targets which are "passive", in the sense that they don't send any particular signal to help the sensing operation. Targets can be pedestrians, bicycle riders, car, etc) moving in streets (with all due respect of anonymity) and the purpose is not only to detect them but also to position them. Sensing is useful to achieve an "image" of the environment. There can also be cooperative targets sending dedicated signals to enable their positioning (their detection is trivial in this case). It is typically the case of users in the mobile network. The sensing and positioning require obviously the transmission of a radio signal. The multi-function nature of future 6G networks, where communications and sensing has to be delivered, has led to the new paradigm of joint positioning, communication and sensing (JPCAS), and there are other acronyms, such as Integrated Communications And Sensing (ISAC), etc. In a nutshell the objective is to provide both communications and radar-type of services. Moreover, these two services can be operated on the same carrier frequency, and also with the same hardware. This enables us to save on the spectrum and on hardware. If the same waveform is used by the two functions, the design of these waveforms is of primary importance. For the 3rd to the 5th generation, the orthogonal frequency division modulation has been selected. While it is still a strong candidate for 6G, a new one has appeared in the literature, under the name Orthogonal Time Frequency Space Modulation. For sensing and positioning, the parameters of interest are the range, angle and Doppler (velocity) of targets. OTFS utilizes the delay-Doppler (DD) domain for data multiplexing, which mirrors the geometry of the scatterings comprising the wireless channel. A tutorial on OTFS can found at https://arxiv.org/pdf/1910.01896.pdf. The goal of this thesis is to investigate the potential of OTFS for JPCAS and design statistical signal processing algorithms to estimate the parameters of targets in networks operating JPCAS. This work should lead to analytical developments, simulations and even measurements if the students are interested.

Luc Vandendorpe **(with Jérôme Louveaux and Claude Oestges)**	**Electrical Engineering**	**Carrier and timing Synchronization for multistatic active and passive radars**	Radar systems are deployed to observe an environment, decode where there might be targets and infer some parameters of the targets such as their position and their velocity. For years, the dominating configuration has been the so-called “monostatic” radar, composed of a single co-localized pair of one transmitter (TX) and one receiver (RX). The recent emergence of distributed setup, named multistatic and composed of multiple RXs no longer collocated with the one or several TXs, has raised multiple new challenges. More specifically, like in all communications systems, it is of uttermost importance to “synchronize” the signal, that is using a “coordinated” timing information and carriers which are frequency and phase synchronized. This requirement is trivially fulfilled in the monostatic setup (since the clocks and carriers generated by the TX are readily available for the RX) but requires dedicated effort in the multistatic setup. This synchronization task is of particular importance for the seminal modulation format (signal generation) called “Frequency Modulated Continuous Wave” (FMCW). This modulation offers the ability to achieve high resolution estimation while sampling at a rate much lower than the bandwidth of its transmitted signal, hence yielding to efficient low-cost radar systems. This excellent property is obtained by demodulating the received signal with the one currently transmitted by the TX, instead of a constant frequency. This specific demodulation process is, however, very sensitive to the above-mentioned synchronization! The synchronization problems can be solved by distributing the clock and carrier of the TX to the different RXs. This solution however requires expensive and inconvenient RF cables between the TX and all RXs (a wireless solution has yet to be conceived, also coming with its own pros and cons). On top of the practical limitations associated with the use of the RF cables there are even setups where this solution is impossible, such as passive radars which opportunistically exploit the communication signal generated for instance by an WIFI or a cellular access point to locate targets. The access point generates a communication signal which is diverted for a detection and parameter estimation objective. In such a case, the access point is not collaborating at all with the different RXs. An original synchronization method has recently been investigated in the Communication Systems Group (COSY) and enables to avoid the synchronization between the TX and the RXs. The RXs must however be synchronized with each other. Another potential solution does not even require this last constraint by synchronizing local oscillators at each RX level. The goal of this Master Thesis project is to confirm these new methods by means of computations, simulations and experimental validations using dedicated radar systems recently developed in the ELEN Telecom's lab. More information can be obtained from Prof. C. Craeye (Christophe.craeye@uclouvain.be), L. Vandendorpe (luc.vandendorpe@uclouvain.be) and G. Monnoyer

			(gilles.monnoyer@uclouvain.be). The student or students should be motivated by the design and experimental validation of RF communication systems. This master thesis combines some mathematical, software and hardware aspects. The emphasis on one or more of them is left to the student(s) choice depending on their interest. Related papers : https://ieeexplore.ieee.org/abstract/document/9037593 https://ieeexplore.ieee.org/abstract/document/10424003 Gilles Monnoyer's Thesis [see Ch. 2 and Ch. 6] : https://dial.uclouvain.be/pr/boreal/object/boreal:280107
Luc Vandendorpe **(with Christophe Craeye)**	**Electrical Engineering**	**Prediction-based Propagation in Constraint Programming**	This topic consists of an evaluation of the potential of having propagators based on machine learning predictors. The constraint targeted is the AllDifferent ("The alldifferent constraint: A survey" by WJ Van Hoeve, 2001), a very well-known and well-studied constraint in CP. The idea would be to design a graph neural network trying to predict which edges of the bipartite graph representing the matching of variables/values could be removed, i.e. which values to remove from the domains. Using these predictions as an oracle, the ML-based propagator would decide which values can or not be removed while still checking if the solution in the building does not violate the constraint. The goal of this method is not to be exact (there will probably be true solutions removed), but to see if such a propagator can obtain some solutions faster and thus help tackle bigger problems. This is motivated by the fact that sometimes only one solution is needed by the user or needs a good but not necessarily optimal solution.
Hélène Verhaeghe **https://hverhaeghe.bitbucket.io/**	**Computer science engineering (Artificial Intelligence)**	**CPMpy Python Interfaces to MiniCP and MaxiCP Solvers using GraalVM**	The goal of this project is to design and implement Python interfaces for the miniCP and MaxiCP solvers (both in java) through CPMpy, utilizing GraalVM for interoperability. This integration aims to enhance the accessibility and usability of these solvers within the Python ecosystem, promoting their adoption for solving complex CP problems.

Aude Simar **https://uclouvain.be/fr/repertoires/aude.simar**	**Mechanical Engineering and Material Science Eng.**	**Combined use of 4D X-ray Computed Tomography and in-situ loading for the failure mechanisms in 3D printed self-healing metal structural alloys**	Failure mechanisms in metal structural alloys and in composites have been extensively investigated during the last decades followed by development of new hybrid or architectured materials or materials with self-healing capabilities. Different aspects of the damage process have been described along with numerical models of the failure mechanism. However, the mechanical behaviour and failure mechanisms responsible for cracking and final failure within 3D printed complex metal structures i.e. Aluminium or Titanium alloy-based scaffolds, are still poorly understood. The understanding and modelling of their failure mechanisms call for a dynamic micromechanics-based approach with many physical inputs and still remains difficult to quantify experimentally. 3D X-ray tomography will be combined with in situ tensile testing to characterize their behaviour.
François-Xavier Standaert **https://perso.uclouvain.be/fstandae/publications.html**	**Electrical Engineering**	**Embedded security & privacy**	Contact the professor for more details (fstandae@uclouvain.be)
		Cryptography	Contact the professor for more details (fstandae@uclouvain.be)
Jean-Christophe Charlier **https://perso.uclouvain.be/jean-christophe.charlier/**	**Physics and Materials Science Engineering**	**Modelling carbon nanostructures, 2D materials and novel Moiré systems using ab initio techniques**	The scientific interests of my group are centered on theoretical condensed matter physics and nanosciences, covering the areas of electronic, structural, dynamical, magnetic and optical properties of crystals and reduced-dimensional solids (i.e. graphene, novel 2D materials, van der Waals heterostructures including Moiré superstructures), as well as their quantum transport properties. The main objective is to explain and predict the properties of these nanomaterials using first-principles theories and computational physics. During the master thesis, a collaboration with Prof. Pablo Jarillo-Herrero (MIT) could be envisaged. Contact the professor for more details (jean-christophe.charlier@uclouvain.be)
Denis Flandre **https://orcid.org/0000-0001-5298-5196**	**Electrical Engineering**	**ML-based plugins for the open-source reverse engineering tool Ghidra**	Ghidra is an open-source tool for the reverse engineering and decompilation of binary excutable files. When you reverse engineer a binary, many tasks are repetitive. Fortunately, Ghidra's plugin system allows to write powerful plugins in Java and Python to automate such tasks. The goal of this project is to explore how simple machine learning techniques (that can be run locally on the computer of the user) can be used to learn task automations from previous user activities.
Ramin Sadre **https://perso.uclouvain.be/ram**	**Computer science/ Computer Engineering**	**Security of IoT and Industrial Control Systems**	Please contact the professor if you are interested in the security of IoT and Industrial Control Systems, in particular in the detection of network attacks against such systems.

in.sadre/		**Secure-by-design smart environments**	We built a platform called HubOS allowing designers of applications for smart homes to build these applications in a private-by-design fashion, and to allow users to decide in what context and under which circumstances the sensitive data of their sensor and appliances can be accessed and used by these applications. HubOS supports WebAssembly binaries to offer near-baremetal performance for advanced applications, e.g., based on IA. Many topics around smart homes, programming models, security, and performance are possible. Feel free to contact the professor if interested.
Etienne Rivière https://cloudlargescale-uclouvain.github.io	**Computer science/** **Computer Engineering**	**Blockchain infrastructures**	The group is part of a network of researchers, funded among others by the Ethereum foundation, laying out the network and distributed systems aspects of next generation blockchains. For instance, we built the new service discovery mechanism of Ethereum, and we developed very-fast dissemination processes for Data Availability Sampling, a new form of consistency checking for high-performance blockchain consensus. Many topics around the performance and scalability of such systems, or on their security, can be discussed. Get in touch with the professor to know more.
		Deployment of applications across edge and cloud using multi-site-aware service meshes	Cloud infrastructures are increasingly distributed, combining large data centers with smaller ones close to the users and accessible with lower latency. While programming in the cloud is easy thanks to high-level resource management, deployment models, and data storage and processing, the same cannot be said of this distributed infrastructure (the cloud/edge continuum). The CLSC group explores techniques for abstracting the complexity of distributed cloud infrastructure, including through adaptation techniques and the use of service meshes that hide the complexity of distribution from the business logic of the application. Many topics are possible in this direction, e.g., data visualization techniques, optimization, service mesh implementations, containers orchestration, data consistency models, etc. Get in touch with the professor to know more.
Laurent Francis https://orcid.org/0000-0003-4683-3916	**Electrical engineering**	**Simulation of porous silicon as a SERS substrate**	Porous silicon decorated with plasmonic nanoparticles is an interesting candidate for Surface Enhanced Raman Spectroscopy (SERS). In this project, COMSOL Multiphysics simulations and transfer method models will be used to investigate the influence of the substrate on the Enhancement of the Raman signal. Some optical measurements and electron microscopy observations will be used to assess the model predictions.
Cristel Pelsser https://cristel.pelsser.eu/	**Computer science/** **Computer Engineering**	**DNS in a Box**	As a simplification, DNS is sometimes called the phone book of the Internet, because its purpose is to map domain names to IP addresses. This makes the DNS a critical service, where any outage has the potential to be very costly. The status of DNS as a critical service has made the maintenance of a state-of-the-art name resolution service challenging. Adding to the challenge is the increased complexity

			induced by four decades of incremental improvements to the protocol. Worse, misconfigurations do not always cause obvious problems immediately: consequences range from problems going unnoticed until the service enters a degraded state; inconsistent data served to different users; or partial or total outages. Finally, without proper understanding of the intricacies of DNS, there is little hope of diagnosing problems with DNS correctly. The objective of this work is to build an environment where practitioners can gain hands-on experience with DNS and *propose meaningful training scenarios.*
Cristel Pelsser https://cristel.pelsser.eu/	**Computer science/** **Computer Engineering**	**The effect of traffic engineering on BGP path changes**	The number of messages observed in BGP varies largely across observation locations and times. In BGP a new advertisement replaces the information previously announced for the same prefix. This renders the protocol very scalable. However, when a network wants to tweak to paths to/from its network or traversing its network, changes are often observed in BGP. This means that other networks bear the cost of one network's Traffic Engineering (TE) objectives. Researchers have tried to determine when networks perform some flavor of TE. Here we want to discover and classify the patterns of consecutive paths that can be observed following TE actions in BGP.
Cristel Pelsser https://cristel.pelsser.eu/	**Computer science/** **Computer Engineering**	**Supporting multiple cores in RIOT**	RIOT is a popular open-source operation system for the Internet of Things (IoT). It supports a wide range of IoT devices and microcontroller architectures. However, at the moment, it does not provide support for Simultaneous Multi-Threading. In this thesis, the student will add the support for multiple cores to RIOT OS. The topic is suitable for students with knowledge in computer architecture and systems. https://github.com/RIOT-OS/Tutorials
Cristel Pelsser https://cristel.pelsser.eu/	**Computer science/** **Computer Engineering**	**A method to map content on the Internet topology**	The Internet is a rich source of information for decades. However, we lack a method to determine how content is reached and how content access evolves over time. Content used to be exchanged over peer-to-peer networks then moved to caches managed by Content Distribution Networks. These CDNs are now widespread. Further networks consolidate to form a restricted group of hyperscalers. In this work, we will provide a methodology to collect the location of content (hostname, host Institution, provider AS) and pin this content on a model of the Internet topology. We'll develop the set of tools necessary to collect this information over time. We will pay attention to the fact that the method and tools are robust to changes.

Gianluca Bianchin https://gianlucabi.github.io/	**Mathematical Engineering / Optimization**	**Methods to design optimization algorithms using internal models**	A time-varying optimization problem is: minimize_x f(x,t) where t denotes time or iteration, and f(x,t) is a loss function to be minimized. The loss function is parametrized by time t and thus it varies dynamically with time. This problem emerges in learning and control problems where functions to learn change dynamically over time. Our objective is to construct optimization algorithms that seeks to compute and track optimal points that solve this optimization problem. The main idea in this internship is to use optimization algorithms that use an internal model of how the cost changes with time. The expected outcomes are an analysis of the algorithm and to show that, in order to track the critical points, the optimization algorithm needs to incorporate an internal model of the time variability. References:G. Bianchin and B. Van Scoy, "The Internal Model Principle of Time-Varying Optimization," arXiv preprint, aug. 2024, (arXiv:2407.08037)
Gianluca Bianchin https://gianlucabi.github.io/	**Mathematical Engineering / Control / Optimization**	**Model predictive control via online optimization**	Model predictive control (MPC) is a control method that relies on solving an optimization problem at every time step and using the solution to this optimization as an input to the system. In classical MPC, it is assumed that the optimization solver is sufficiently fast so that a control action is readily available within a very short time. Unfortunately, in practice, evaluating the model predictive control law is often computationally demanding. It requires solving an optimization problem in real-time, which is challenging in case the problem is large. The objective of this thesis is to investigate the use of first-order optimization methods to solve MPC problems. At every control update, only one iteration of a first-order gradient method is performed, while the next update is warm-started using the solution of the previous one. This leads to an approximate control law, and the objective is thus to study under what conditions such an approximate law works in practice.
Tom Barbette Tom Barbette - Tom Barbette	**Computer science/ Computer Engineering**	**eBPF-accessible TCP Stack in the Linux Kernel**	The Linux Kernel's networking stack is robust but increasingly complex as new protocols and features expand its data structures. Packets pass through numerous functions, hooks, and filters, many of which are unused, causing unpredictable branches and CPU cache misses. Technologies like eXpress Data Path (XDP) address this by allowing small eBPF programs to run directly at the driver level, bypassing much of the networking stack. AF_XDP further enables raw data I/O without constructing sk_buffs. However, XDP programs lack access to Kernel features like the TCP stack. We modified the Linux Kernel to enable access from eBPF to the TCP stack. In his

			internship, we propose to deploy a pre-built eBPF programs that excludes unused features, resulting in optimized data structures and minimal runtime overhead. The main use-case is to enable iPerf to run at very high-speed even on slower ARM limited platforms as most of the data can remain in Kernel space. This project requires proficiency in C and operating systems, with the potential for significant research contributions and publications.