

Topics offered to students by other
master's programs

TARGET PROGRAM

EM – Computer Engineering

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : Chemical & Materials engineering - M-IRMAE

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPs laboratory, ULB.

4. Reporting

- ☐ Weekly meetings with the supervisor(s) to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczymalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Number of topics	2

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Plenoptic encoding of holograms with gaussian mixture models

Program : Electrical engineering - M-IRELE

Description

Context:

Holography represents the frontier of visual technology. By encoding the full wavefield of light (capturing both amplitude and phase information), it holds the potential to be the ultimate display system. Unlike traditional stereoscopic screens, holographic displays can perfectly reproduce all natural visual cues, including continuous parallax and physically accurate focus cues.

However, realizing this potential comes with a significant hurdle: computing holograms requires complex wave-optics rendering, making it highly computationally intensive. To make high-end holographic displays practical, particularly for next-generation augmented and virtual reality (AR/VR) systems, the field needs fundamentally novel algorithms and data representations.

Recently, 3D Gaussian mixture models, such as 3D Gaussian splatting, have revolutionized standard scene representation, enabling highly efficient, high-quality rendering. Yet, these existing models are natively designed for ray-based optics and are not directly adapted to the complex, wave-based requirements of holographic rendering.

The primary aim of this thesis is to bridge this gap. The student will develop novel algorithms and data structures using multivariate Gaussian components to create compact, adaptive plenoptic representations specifically tailored for holography. By encoding light fields into these sophisticated mixture models, this research seeks to drastically optimize the computational pipeline, bringing real-time, high-fidelity holographic rendering one step closer to reality.

Research activities and goals:

The first challenge is to bridge the gap between geometric optics and wave optics. The student will develop novel 3D Gaussian mixture representations specifically adapted for holography. This requires moving beyond traditional rendering by accounting for ray-to-wave conversion and incorporating complex-valued amplitudes to accurately model light interference patterns.

Moving from theory to practice, the student will implement an extended rendering framework. This software pipeline will be responsible for translating the newly developed, complex-valued Gaussian mixture representations into holograms.

The developed algorithms will be rigorously evaluated. First, the student will test the framework within a simulated holographic rendering pipeline to benchmark computational efficiency and image quality. Finally, the research culminates in physical validation: the student will deploy their holograms on an in-house holographic display prototype, directly observing the real-world performance and optical characteristics of their plenoptic encoding approach.

Expected Student Profile:

- Strong programming skills (Python, C/C++, GPU programming is a plus)
- Familiarity with 3D graphics is recommended
- Interest in experimental physical research and evaluation (visual and optical testing)

References and further reading:

Zhan, Yicheng, Dong-Ha Shin, Seung-Hwan Baek, and Kaan Aksit. "Complex-Valued Holographic Radiance Fields." ACM Transactions on Graphics (2025). doi: 10.1145/3804450

David Blinder, Tobias Birnbaum, Tomoyoshi Ito, Tomoyoshi Shimobaba. The state-of-the-art in computer generated holography for 3D display[J]. Light: Advanced Manufacturing 3, 35(2022). doi: 10.37188/lam.2022.035

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2725/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Rodolphe Valicon De Soete (Rodolphe.Sasha.Valicon@vub.be)

Perceptual optimization of 3d gaussian splatting for high-fidelity rendering

Program : *Electrical engineering - M-IRELE*

Description

Context:

3D Gaussian Splatting (3DGS) has recently emerged as an efficient representation for real-time novel view synthesis, offering a compelling alternative to traditional neural rendering techniques. By representing scenes as collections of Gaussian primitives, 3DGS enables high-quality rendering with significantly reduced computational cost. Despite these advantages, most existing approaches rely on pixel-level distortion losses, such as L1 or SSIM, during training. These losses are poorly aligned with human visual perception and often result in overly smooth reconstructions that fail to preserve fine textures and structural details. Recent work has demonstrated that replacing such losses with perceptually motivated alternatives can substantially improve visual quality, with human studies showing strong preference for perceptually optimized models over standard approaches. This highlights the importance of designing training objectives that better reflect perceptual quality, rather than relying solely on traditional image fidelity metrics.

Although perceptual losses have shown promising results in improving 3DGS reconstructions, their design and integration remain relatively unexplored. It is still unclear which perceptual distortions are most suitable for 3D Gaussian representations and how these distortions affect both visual quality and model efficiency. In addition, while improvements are often validated through subjective studies, there is limited understanding of how perceptual gains relate to objective metrics and compression efficiency in 3DGS frameworks.

Research activities and goals:

Objectives: The goal of this thesis is to investigate perceptual optimization strategies for 3D Gaussian Splatting and to analyze their impact on rendering quality. The work will focus on studying different classes of distortion losses, including pixel-based, perceptual, and distribution-based losses, and evaluating their effectiveness in preserving fine details and textures. Particular attention will be given to losses inspired by human perception, such as those based on feature statistics or distribution matching. The thesis will also examine how perceptual optimization affects model characteristics, including the number of Gaussians, rendering efficiency, and compression performance. A secondary objective is to analyze the relationship between perceptual improvements and both objective metrics and human preference, using subjective evaluation as a validation tool.

Methodology and Expected Contributions: The research will involve implementing and integrating different loss functions within a 3DGS training pipeline. Experiments will be conducted on standard datasets to compare reconstruction quality across different optimization strategies. The evaluation will combine objective metrics, such as LPIPS and DISTs, with controlled subjective comparisons to assess perceptual quality. Additional analysis will focus on efficiency-related factors, including model size and rendering performance.

This thesis is expected to provide a systematic analysis of perceptual optimization in 3D Gaussian Splatting and to identify effective loss functions for improving visual quality. It will contribute to a

better understanding of the trade-offs between perceptual fidelity, computational efficiency, and compression, and provide practical insights for designing perceptually optimized 3D rendering systems.

Expected Student Profile:

- Strong programming skills (preferably Python, and familiarity with PyTorch or similar frameworks)
- Basic knowledge of computer vision and/or machine learning
- Familiarity with 3D graphics or rendering is a plus, but not strictly required
- Interest in experimental research and evaluation (including perceptual assessment)

References and further reading:

Kerbl, Bernhard, et al. rd gaussian splatting for real-time radiance field rendering." ACM Trans. Graph. 42.4 (2023): 139-1.

Zhang, Richard, et al. "The unreasonable effectiveness of deep features as a perceptual metric." Proceedings of the IEEE conference on computer vision and pattern recognition. 2018.

Ghildyal, Abhijay, et al. "Non-Aligned Reference Image Quality Assessment for Novel View Synthesis." Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. 2026.

Ozyilkan, Ezgi, et al. "Drop-In Perceptual Optimization for 3D Gaussian Splatting." arXiv preprint arXiv:2603.23297 (2026).

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2721/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Saeed Mahmoudpour (Saeed.Mahmoudpour@vub.be)

Hologram generation via deep learning for 3D holographic display systems

Program : Electrical engineering - M-IRELE

Description

Context

Holographic displays have the potential to become the highest-quality type of 3D display system, as they account for all visual cues by reproducing the full wavefield of light, including both amplitude and phase information. Hologram generation for 3D holographic displays is often done using inverse optimization methods. These methods provide accurate results, but they require many iterations to converge, making the process slow. This thesis investigates the application of deep learning models to reduce the computational time required for hologram generation in a specific type of 3D holographic display.

Research activities and goals:

The student will first study image-to-image deep learning architectures, our hologram generation methods, and our holographic display prototype in our lab. A dataset based on random data will be generated using our forward light propagation model. This dataset will then be used to train different architectures of deep learning models, and their performance will be evaluated using non-random 3D scenes. The work includes programming, working on the optical setup, reviewing literature on computer-generated holography, designing new models for light propagation, and implementing new optimization algorithms.

References and further reading:

Manuel Montoya, Yunfeng Nie, and David Blinder, "Computer-generated holography using the generalized Van Cittert–Zernike Schell propagator," *Opt. Lett.* 51, 2084-2087 (2026)

Huang, L., Chen, H., Liu, T. et al. Self-supervised learning of hologram reconstruction using physics consistency. *Nat Mach Intell* 5, 895–907 (2023)

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2720/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Manuel Montoya (Manuel.Montoya.Zuluaga@vub.be)

Eye-tracking technology for next-generation 3d holographic displays

Program : *Electrical engineering - M-IRELE*

Description

Context:

Next-generation 3D holographic displays are poised to advance fields ranging from entertainment and healthcare to advanced manufacturing. By actively shaping the optical wavefront, these displays can accurately render 3D objects with all natural depth cues. However, achieving this level of precision requires tiny pixels (on the order of the wavelength of light), which inherently necessitate exceptionally high overall pixel counts. Consequently, the immersiveness of these displays, quantified by their space-bandwidth product (SBP) [1], is fundamentally constrained by the immense hardware demands. Because rendering high-resolution holograms requires massive computational resources, SBP remains highly expensive. Optimizing SBP utilization efficiency, specifically by integrating real-time eye-tracking with advanced multiplexing techniques [2], offers a viable pathway to practical digital holography. Developing and evaluating this integration forms the primary objective of this thesis.

Research activities and goals:

This thesis bridges theoretical optical principles with applied systems engineering. Foundationally, you will study the core mechanics of digital holography. Multiplexing expands the effective viewing angle and viewing volume (eyebox) by rapidly adjusting display parameters, leveraging the human eye's persistence of vision.

While current systems rely on static multiplexing, this project aims to implement dynamic multiplexing. By using real-time gaze feedback, the system dynamically allocates computational resources to the user's direct line of sight, thereby maximizing the display's effective SBP. The primary deliverable for this project is a functional proof-of-concept holographic display capable of actively steering light directly to the viewer's pupil in real-time, responsive to continuous eye-tracking data.

From an engineering perspective, we will use a state-of-the-art eye tracker (e.g., a Tobii with 6 Degrees of Freedom) for precise head and gaze tracking. The technical work involves significant software development: interfacing hardware, processing tracking data with minimal latency, and dynamically adjusting the software rendering pipeline to drive the hardware. You will be supported by a team of senior researchers in this highly novel area. Because the integration of active eye-tracking in holographic displays is largely unexplored, this project presents a strong opportunity for scientific publication.

Expected Student Profile:

- Good programming skills (MATLAB or Python, C/C++)
- Enthusiasm for hands-on engineering of next-generation display technologies
- Interest in experimental physical research and evaluation (visual and optical testing)

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2732/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Raees Kizhakkumkara (Raees.Kizhakkumkara.Muhamad@vub.be)

Compressed radiance fields coding for memory-efficient representations and rate-quality trade-offs

Program : Electrical engineering - M-IRELE

Description

Context

Neural radiance field methods, including approaches such as 3D Gaussian Splatting, have significantly advanced the state of the art in novel view synthesis and 3D scene representation. They enable highly realistic rendering from sparse observations, but this quality comes at the cost of substantial memory usage and computational complexity. These limitations become particularly critical in scenarios that require real-time performance or deployment on specialized visualization systems such as light-field displays.

Research activities and goals

Research Objectives: This thesis focuses on developing efficient compression strategies for radiance field representations to reduce memory requirements while preserving visual fidelity. Rather than treating compression as a purely technical problem, the work will explicitly consider the trade-offs between compression rate and perceived quality. Evaluation will play a key role throughout the project. In addition to standard objective metrics such as PSNR, SSIM, and perceptual measures, the thesis will place particular emphasis on perceptual quality assessment in a 3D context. Using a light-field display system available for experiments, the student will investigate how compression artifacts affect depth perception, visual comfort, and overall realism. This aspect is especially important, as artifacts that appear minor in 2D projections can become significantly more noticeable in 3D visualization.

Methodology and Expected Contributions:

The research will involve designing and evaluating compression techniques for radiance field representations, with experiments conducted across different datasets and compression settings. Both objective metrics, such as PSNR and SSIM, and perceptual measures will be used for evaluation. Subjective experiments will be conducted to assess the impact of compression artifacts in realistic viewing conditions.

This thesis is expected to contribute to the development of memory-efficient radiance field representations and to deepen understanding of the relationships among compression, perceptual quality (Rate-Distortion tradeoff), and visualization conditions. The outcomes will support the design of compression methods that are better aligned with human perception, particularly in the context of advanced 3D display systems.

Expected Student Profile:

- Strong programming skills (preferably Python, and familiarity with PyTorch or similar frameworks)
- Basic knowledge of computer vision and/or machine learning
- Familiarity with 3D graphics or rendering is a plus, but not strictly required
- Interest in experimental research and evaluation (including perceptual assessment)

References and further reading

Kerbl, Bernhard, et al. "3d gaussian splatting for real-time radiance field rendering." *ACM Trans. Graph.* 42.4 (2023): 139-1.

Zhang, Richard, et al. "The unreasonable effectiveness of deep features as a perceptual metric." *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2018.

Bagdasarian, Milena T., et al. "3dgs. zip: A survey on 3d gaussian splatting compression methods." *Computer Graphics Forum*. Vol. 44. No. 2. 2025.

Chen, Yihang, et al. "Hac: Hash-grid assisted context for 3d gaussian splatting compression." *European Conference on Computer Vision*. Cham: Springer Nature Switzerland, 2024.

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2722/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Saeed Mahmoudpour (Saeed.Mahmoudpour@vub.be)

Accelerating autoregressive integrated moving average models using sparse matrix representations

Program : Electrical engineering - M-IRELE

Description

Context

Statistical time series models (such as autoregressive integrated moving average, ARIMA) are a staple forecasting method for time series. Even with the advent of more modern forecasting methods (e.g., long-short term memory (LSTM) neural networks and Facebook Prophet), they remain an interesting baseline that has the advantage of being interpretable.

Modern ARIMA implementations rely on Kalman filters for fitting and forecasting purposes (notably because Kalman filters and state-space representations are well mastered mathematical tools and support missing observations). This is also the case for seasonal time series models (i.e., seasonal autoregressive integrated moving average, SARIMA) [Brockwell, 2002] [Durbin, 2012].

Interestingly, state-space models of high-order ARIMA models happen to be sparse (which means that the state transition and observation matrices mostly consist of zero coefficients); sparsity levels get even higher in the case of SARIMA models.

However, despite the sparse nature of most of the state-space matrices, it appears that many implementations (e.g., Python statsmodels) do not leverage it and instead rely on standard dense matrix representations for computations.

Objectives and steps

The goal of this master's thesis is to program a custom, high-performance fit-and-forecast program for ARIMA models, relying on sparse matrix representations to reduce computing load. Steps are i) a review of state-space models for ARIMA models and the associated fitting and forecasting methods, ii) implementing a fit-and-forecast program that leverages sparse matrix representations and iii) compare the performance of the developed program to that of Python's statsmodels (in terms of accuracy and computing time), using real and/or synthetic time series. Very motivated students can go further and i) extend the program to SARIMA models, or ii) implement the program in CUDA (for graphical processing unit (GPU) programming) or iii) rely on template meta-programming for implementing compile-time sparse matrices. The BEAMS-EE department possesses various computing platforms (notably a consumer-grade computing tower with a GPU and a rack server with dual Xeon Gold (64 cores in total) and two RTX A6000 GPUs), which are available to Master's thesis students.

Student profile

Ideally, the student has experience in C++ programming and is skilled in mathematics (mostly linear algebra, although basic probability theory and optimization theory are important as well). Knowledge of BLAS, LAPACK and/or the Eigen library is a plus. Having followed the course "Microprocessor architectures" is also a (minor) plus.

References

[Brockwell, 2002] Brockwell, Peter J., and Richard A. Davis, eds. Introduction to time series and forecasting. New York, NY: Springer New York, 2002.

[Durbin, 2012] Durbin, James, and Siem Jan Koopman. Time series analysis by state space methods. Vol. 38. OUP Oxford, 2012.

Contact

Jean-François Determe, jean-francois.determe@ulb.be

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRCBS, M-IRIFS, M- IRPH
Number of topics	1

Supervision

Supervisor : Jean-François Determe (jean-francois.determe@ulb.be)

Digital algorithms on an underwater acoustic modem

Program : *Electrical engineering - M-IRELE*

Description

Context

Underwater communications are peculiar in that traditional electromagnetic communications are often inappropriate due to high attenuation in water. As a result, all medium and long-range underwater communications are acoustic (i.e., they use pressure waves). Bandwidths are also typically orders of magnitude lower than those of over-the-air wireless communications (in underwater acoustic communications, bandwidth generally does not exceed 20 kHz and the carrier frequency is often between 10 and 100 kHz) [Zia, 2021]. These low bandwidths led to the development of many research and commercial modems based on micro-controller units (MCUs) or microprocessor units (MPUs), with some high-end modems relying on field-programmable gate arrays (FPGAs). Given the low carrier frequencies, no analog upconversion and downconversion is needed and signals are generally directly sampled (RX) or converted to analog (TX) in bandpass. Our research group is currently developing such a modem (hardware and software) and possesses simulation tools to facilitate the offline prototyping of such algorithms, prior to hardware implementation.

Objectives and steps

The goal of this master's thesis is to develop basic parts of an underwater communication modem. The steps are to i) validate in simulation a basic transmission chain and ii) implement as many parts of it as possible on hardware. As raw samples can be sent from the client to the TX and received from the RX, the communication chain need not be fully implemented on hardware. The student is expected to leverage microarchitecture enhancements to optimize computational performance. The student may rely on our expertise and analog hardware but should develop their own embedded software. Experimental validation is encouraged for step ii).

Student profile

Ideally, any interested student should have followed the courses "Microprocessor architecture" and "Modulation and coding". This master's thesis is geared toward students that have an interest in building real telecommunication devices and are eager to learn how to carry out practical work on modern, advanced MCU architectures. A basic understanding of linear and non-linear analog electronics as well as transceiver architecture is a plus.

References

[Renner, 2020] Renner, Bernd-Christian et al. "AHOI: Inexpensive, low-power communication and localization for underwater sensor networks and μ AUVs." *ACM Transactions on Sensor Networks (TOSN)* 16, no. 2 (2020): 1-46.

[Zia, 2021] Zia, Muhammad Yousuf Irfan et al. "State-of-the-art underwater acoustic communication

modems: Classifications, analyses and design challenges." Wireless personal communications 116 (2021): 1325-1360.

Contact

Jean-François Determe, jean-francois.determe@ulb.be

Kristopher De Saulnier, Kristopher.De.Saulnier@ulb.be

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Jean-François Determe (jean-francois.determe@ulb.be)

Learn a Robot Arm to Manipulate Objects through Qualitative Modeling.

Program : Computer science and engineering - M-IRIFS

Description

We can program robots perfectly to perform tasks, but only in known environments. Pre-programmed robots struggle to handle new situations. To enable robots to operate in uncontrolled environments, they must be capable of learning. This is where the scientific field of self-learning robots comes into play. In this master's thesis, you will apply this concept to a robotic arm that must learn to manipulate objects: moving, stacking, cleaning up, and more. Our innovative approach, based on qualitative models, will lead to improved manipulation compared to the current state of the art.

The robotic arm (see figure) will be controlled based on camera images. The objects are identified and analyzed within these images, from which the important properties are extracted. During the exploration phase, the robot will try out various actions ("play"), using the observed data to learn a qualitative model that it can then use to perform tasks (the exploitation phase).

Link : <http://parallel.vub.ac.be/learningrobots/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRELE, M-IREMR-M
Number of topics	1

Supervision

Supervisor : Jan Lemeire (jan.lemeire@vub.be)

Learn a Robot to Tackle a Gymnasium Robotic Challenge with Qualitative models.

Program : Computer science and engineering - M-IRIFS

Description

Autonomous robots must be able to solve problems on their own. For this purpose, OpenAI has standardized a set of challenges in a benchmark: <https://gymnasium.farama.org/>. For example, a car must reach the top of the mountain (by “swinging”), a cart must keep a pole upright, and a lunar lander must land between the flags. To solve such a challenge, a learning model is used. This model uses information from the task environment— in the second case, the angle of the pole— to then propose an action: changing the speed. The model must then learn a strategy to move the cart in such a way that it can keep the pole upright for as long as possible. This can be tested in simulation via Gymnasium.

The default approach is reinforcement learning, which trains a neural network by trial-and-error. This, however, has several drawbacks: a lot of training, no explanation is given (a neural network is a black box), and it just works in the environment it was trained in (no generalization or abstraction).

We propose an alternative method based on qualitative models describing relationships in a more abstract and general form:

“Turning the steering wheel clockwise makes the car turn right.”

“Pressing the gas pedal increases the car’s speed.”

“Picking up an object allows it to be moved elsewhere.”

These models can be learned with fewer interactions than traditional reinforcement learning techniques and are typically more transferable across tasks and domains.

Link : <http://parallel.vub.ac.be/learningrobots/>

Language	EN (english)
Open to other master’s programs	Yes
Eligible master’s programs	M-IREMR-M
Number of topics	2

Supervision

Supervisor : Jan Lemeire (jan.lemeire@vub.be)

Security and Privacy in Next-Generation Mobile Networks

Program : Computer science and engineering - M-IRIFS

Description

Modern mobile networks are undergoing a major transformation: from closed, hardware-driven systems to open, software-based, and cloud-native architectures. This shift enables faster innovation, flexibility, and the integration of intelligent applications. Open Radio Access Networks (Open RAN) are at the forefront of this evolution, allowing multiple vendors and software components to interoperate in a highly distributed environment. While this openness creates opportunities for innovation, it also expands the attack surface and raises important questions around trust, data protection, and system integrity.

This thesis investigates security and privacy challenges in Open RAN environments, with flexibility to focus on one or more of the following directions:

- Trust, Authentication, and Access Control
- Runtime Integrity and Attestation
- Privacy Leakage Analysis
- Security for Management and Control Systems
- Post-Quantum Cryptography (PQC) Integration

The thesis will involve:

- Literature review and threat modeling of Open RAN systems
- Design and evaluation of security or privacy-enhancing mechanisms
- Implementation and experimentation

References and further reading

1. O-RAN Work Group 1, "O-RAN Architecture Description," O-RAN ALLIANCE e.V, Tech. Rep. R004-v15.00, October 2025. <https://specifications.o-ran.org/download?id=1013>
2. O-RAN Work Group 11, "Study on Security for Near Real Time RIC and xApps," O-RAN ALLIANCE e.V, Tech. Rep. TR.0-R004-v06.00, October 2025 - <https://specifications.o-ran.org/download?id=1076>
3. M. Polese, L. Bonati, S. D'Oro, S. Basagni and T. Melodia, "Understanding O-RAN: Architecture, Interfaces, Algorithms, Security, and Research Challenges," in IEEE Communications Surveys & Tutorials, vol. 25, no. 2, pp. 1376-1411, Second quarter 2023, doi: 10.1109/COMST.2023.3239220. <https://ieeexplore.ieee.org/document/10024837>
4. M. Liyanage, A. Braeken, S. Shahabuddin, and P. Ranaweera, "Open RAN security: Challenges and opportunities," Journal of Network and Computer Applications, vol. 214, p. 103621, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1084804523000401>.

5. P. Fernando, P. Porambage, M. Liyanage, K. Steenhaut, and A. Braeken, "Securing xApps in Open RAN: A Hierarchical Approach to Authentication and Authorisation," in 2025 IEEE Conference on Communications and Network Security (CNS), 2025, pp. 1-9.
<https://ieeexplore.ieee.org/document/11195058>

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	2

Supervision

Supervisor : An Braeken (an.braeken@vub.be)

Co-supervisor : Pramitha Fernando (pramitha.fernando@vub.be)

Topics offered to students by other
master's programs

TARGET PROGRAM

EM – Computer Engineering

Can machine learning methods approximate the optimal power flow solution for electric transmission systems?

Program : EM - Energy - M-IREMR-E

Description

Context

Optimal Power Flow (OPF) determines the optimal operating point of a power system satisfying its physical and operational constraints. This problem already being non-linear, non-convex and computationally expensive, gets increasingly more complex with the increasing penetration of Renewable Energy Sources (RES). This evergrowing complexity motivates the growing interest in machine learning (ML) as a way to produce fast approximate solutions. However, applying ML to the operation of power systems is not straightforward as the problem is high-dimensional, physics imposes hard constraints, and model relevance depends on the operating regime of each power system case. This thesis takes the Power Grid Library for OPF Benchmarking (PGLib-OPF) as its experimental playground. This open dataset is a collection of AC transmission test cases curated for OPF, ranging from small pedagogical networks to realistic grids with thousands of buses.

Research question

How well do machine learning methods approximate OPF on the cases from the PGLib dataset, and what insights can be extracted on why they succeed or fail across cases and operating conditions?

Approach

The student will (i) familiarise with the provided OPF solvers and the PGLib dataset, (ii) generate labelled train/test data by perturbing case loads and re-solving, (iii) apply standard ML techniques (e.g. regression, random forests, MLPs...) to predict OPF outputs, (iv) evaluate prediction accuracy, optimality gap, constraint violations, and computational speed-up against the solver, and (v) analyse which case characteristics (size, congestion regime, topology...) correlate with model performance. An optional extension, time permitting, would explore graph-aware model architecture.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS, M-IREMR-M
Number of topics	1

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : Chemical & Materials engineering - M-IRMAE

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPs laboratory, ULB.

4. Reporting

- ☐ Weekly meetings with the supervisor(s) to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczyzmalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Number of topics	2

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Plenoptic encoding of holograms with gaussian mixture models

Program : Electrical engineering - M-IRELE

Description

Context:

Holography represents the frontier of visual technology. By encoding the full wavefield of light (capturing both amplitude and phase information), it holds the potential to be the ultimate display system. Unlike traditional stereoscopic screens, holographic displays can perfectly reproduce all natural visual cues, including continuous parallax and physically accurate focus cues.

However, realizing this potential comes with a significant hurdle: computing holograms requires complex wave-optics rendering, making it highly computationally intensive. To make high-end holographic displays practical, particularly for next-generation augmented and virtual reality (AR/VR) systems, the field needs fundamentally novel algorithms and data representations.

Recently, 3D Gaussian mixture models, such as 3D Gaussian splatting, have revolutionized standard scene representation, enabling highly efficient, high-quality rendering. Yet, these existing models are natively designed for ray-based optics and are not directly adapted to the complex, wave-based requirements of holographic rendering.

The primary aim of this thesis is to bridge this gap. The student will develop novel algorithms and data structures using multivariate Gaussian components to create compact, adaptive plenoptic representations specifically tailored for holography. By encoding light fields into these sophisticated mixture models, this research seeks to drastically optimize the computational pipeline, bringing real-time, high-fidelity holographic rendering one step closer to reality.

Research activities and goals:

The first challenge is to bridge the gap between geometric optics and wave optics. The student will develop novel 3D Gaussian mixture representations specifically adapted for holography. This requires moving beyond traditional rendering by accounting for ray-to-wave conversion and incorporating complex-valued amplitudes to accurately model light interference patterns.

Moving from theory to practice, the student will implement an extended rendering framework. This software pipeline will be responsible for translating the newly developed, complex-valued Gaussian mixture representations into holograms.

The developed algorithms will be rigorously evaluated. First, the student will test the framework within a simulated holographic rendering pipeline to benchmark computational efficiency and image quality. Finally, the research culminates in physical validation: the student will deploy their holograms on an in-house holographic display prototype, directly observing the real-world performance and optical characteristics of their plenoptic encoding approach.

Expected Student Profile:

- Strong programming skills (Python, C/C++, GPU programming is a plus)
- Familiarity with 3D graphics is recommended
- Interest in experimental physical research and evaluation (visual and optical testing)

References and further reading:

Zhan, Yicheng, Dong-Ha Shin, Seung-Hwan Baek, and Kaan Aksit. "Complex-Valued Holographic Radiance Fields." ACM Transactions on Graphics (2025). doi: 10.1145/3804450

David Blinder, Tobias Birnbaum, Tomoyoshi Ito, Tomoyoshi Shimobaba. The state-of-the-art in computer generated holography for 3D display[J]. Light: Advanced Manufacturing 3, 35(2022). doi: 10.37188/lam.2022.035

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2725/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Rodolphe Valicon De Soete (Rodolphe.Sasha.Valicon@vub.be)

Perceptual optimization of 3d gaussian splatting for high-fidelity rendering

Program : Electrical engineering - M-IRELE

Description

Context:

3D Gaussian Splatting (3DGS) has recently emerged as an efficient representation for real-time novel view synthesis, offering a compelling alternative to traditional neural rendering techniques. By representing scenes as collections of Gaussian primitives, 3DGS enables high-quality rendering with significantly reduced computational cost. Despite these advantages, most existing approaches rely on pixel-level distortion losses, such as L1 or SSIM, during training. These losses are poorly aligned with human visual perception and often result in overly smooth reconstructions that fail to preserve fine textures and structural details. Recent work has demonstrated that replacing such losses with perceptually motivated alternatives can substantially improve visual quality, with human studies showing strong preference for perceptually optimized models over standard approaches. This highlights the importance of designing training objectives that better reflect perceptual quality, rather than relying solely on traditional image fidelity metrics.

Although perceptual losses have shown promising results in improving 3DGS reconstructions, their design and integration remain relatively unexplored. It is still unclear which perceptual distortions are most suitable for 3D Gaussian representations and how these distortions affect both visual quality and model efficiency. In addition, while improvements are often validated through subjective studies, there is limited understanding of how perceptual gains relate to objective metrics and compression efficiency in 3DGS frameworks.

Research activities and goals:

Objectives: The goal of this thesis is to investigate perceptual optimization strategies for 3D Gaussian Splatting and to analyze their impact on rendering quality. The work will focus on studying different classes of distortion losses, including pixel-based, perceptual, and distribution-based losses, and evaluating their effectiveness in preserving fine details and textures. Particular attention will be given to losses inspired by human perception, such as those based on feature statistics or distribution matching. The thesis will also examine how perceptual optimization affects model characteristics, including the number of Gaussians, rendering efficiency, and compression performance. A secondary objective is to analyze the relationship between perceptual improvements and both objective metrics and human preference, using subjective evaluation as a validation tool.

Methodology and Expected Contributions: The research will involve implementing and integrating different loss functions within a 3DGS training pipeline. Experiments will be conducted on standard datasets to compare reconstruction quality across different optimization strategies. The evaluation will combine objective metrics, such as LPIPS and DISTs, with controlled subjective comparisons to assess perceptual quality. Additional analysis will focus on efficiency-related factors, including model size and rendering performance.

This thesis is expected to provide a systematic analysis of perceptual optimization in 3D Gaussian Splatting and to identify effective loss functions for improving visual quality. It will contribute to a

better understanding of the trade-offs between perceptual fidelity, computational efficiency, and compression, and provide practical insights for designing perceptually optimized 3D rendering systems.

Expected Student Profile:

- Strong programming skills (preferably Python, and familiarity with PyTorch or similar frameworks)
- Basic knowledge of computer vision and/or machine learning
- Familiarity with 3D graphics or rendering is a plus, but not strictly required
- Interest in experimental research and evaluation (including perceptual assessment)

References and further reading:

Kerbl, Bernhard, et al. rd gaussian splatting for real-time radiance field rendering." ACM Trans. Graph. 42.4 (2023): 139-1.

Zhang, Richard, et al. "The unreasonable effectiveness of deep features as a perceptual metric." Proceedings of the IEEE conference on computer vision and pattern recognition. 2018.

Ghildyal, Abhijay, et al. "Non-Aligned Reference Image Quality Assessment for Novel View Synthesis." Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. 2026.

Ozyilkan, Ezgi, et al. "Drop-In Perceptual Optimization for 3D Gaussian Splatting." arXiv preprint arXiv:2603.23297 (2026).

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2721/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Saeed Mahmoudpour (Saeed.Mahmoudpour@vub.be)

Hologram generation via deep learning for 3D holographic display systems

Program : Electrical engineering - M-IRELE

Description

Context

Holographic displays have the potential to become the highest-quality type of 3D display system, as they account for all visual cues by reproducing the full wavefield of light, including both amplitude and phase information. Hologram generation for 3D holographic displays is often done using inverse optimization methods. These methods provide accurate results, but they require many iterations to converge, making the process slow. This thesis investigates the application of deep learning models to reduce the computational time required for hologram generation in a specific type of 3D holographic display.

Research activities and goals:

The student will first study image-to-image deep learning architectures, our hologram generation methods, and our holographic display prototype in our lab. A dataset based on random data will be generated using our forward light propagation model. This dataset will then be used to train different architectures of deep learning models, and their performance will be evaluated using non-random 3D scenes. The work includes programming, working on the optical setup, reviewing literature on computer-generated holography, designing new models for light propagation, and implementing new optimization algorithms.

References and further reading:

Manuel Montoya, Yunfeng Nie, and David Blinder, "Computer-generated holography using the generalized Van Cittert–Zernike Schell propagator," *Opt. Lett.* 51, 2084-2087 (2026)

Huang, L., Chen, H., Liu, T. et al. Self-supervised learning of hologram reconstruction using physics consistency. *Nat Mach Intell* 5, 895–907 (2023)

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2720/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Manuel Montoya (Manuel.Montoya.Zuluaga@vub.be)

Eye-tracking technology for next-generation 3d holographic displays

Program : *Electrical engineering - M-IRELE*

Description

Context:

Next-generation 3D holographic displays are poised to advance fields ranging from entertainment and healthcare to advanced manufacturing. By actively shaping the optical wavefront, these displays can accurately render 3D objects with all natural depth cues. However, achieving this level of precision requires tiny pixels (on the order of the wavelength of light), which inherently necessitate exceptionally high overall pixel counts. Consequently, the immersiveness of these displays, quantified by their space-bandwidth product (SBP) [1], is fundamentally constrained by the immense hardware demands. Because rendering high-resolution holograms requires massive computational resources, SBP remains highly expensive. Optimizing SBP utilization efficiency, specifically by integrating real-time eye-tracking with advanced multiplexing techniques [2], offers a viable pathway to practical digital holography. Developing and evaluating this integration forms the primary objective of this thesis.

Research activities and goals:

This thesis bridges theoretical optical principles with applied systems engineering. Foundationally, you will study the core mechanics of digital holography. Multiplexing expands the effective viewing angle and viewing volume (eyebox) by rapidly adjusting display parameters, leveraging the human eye's persistence of vision.

While current systems rely on static multiplexing, this project aims to implement dynamic multiplexing. By using real-time gaze feedback, the system dynamically allocates computational resources to the user's direct line of sight, thereby maximizing the display's effective SBP. The primary deliverable for this project is a functional proof-of-concept holographic display capable of actively steering light directly to the viewer's pupil in real-time, responsive to continuous eye-tracking data.

From an engineering perspective, we will use a state-of-the-art eye tracker (e.g., a Tobii with 6 Degrees of Freedom) for precise head and gaze tracking. The technical work involves significant software development: interfacing hardware, processing tracking data with minimal latency, and dynamically adjusting the software rendering pipeline to drive the hardware. You will be supported by a team of senior researchers in this highly novel area. Because the integration of active eye-tracking in holographic displays is largely unexplored, this project presents a strong opportunity for scientific publication.

Expected Student Profile:

- Good programming skills (MATLAB or Python, C/C++)
- Enthusiasm for hands-on engineering of next-generation display technologies
- Interest in experimental physical research and evaluation (visual and optical testing)

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2732/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Raees Kizhakkumkara (Raees.Kizhakkumkara.Muhamad@vub.be)

Compressed radiance fields coding for memory-efficient representations and rate-quality trade-offs

Program : Electrical engineering - M-IRELE

Description

Context

Neural radiance field methods, including approaches such as 3D Gaussian Splatting, have significantly advanced the state of the art in novel view synthesis and 3D scene representation. They enable highly realistic rendering from sparse observations, but this quality comes at the cost of substantial memory usage and computational complexity. These limitations become particularly critical in scenarios that require real-time performance or deployment on specialized visualization systems such as light-field displays.

Research activities and goals

Research Objectives: This thesis focuses on developing efficient compression strategies for radiance field representations to reduce memory requirements while preserving visual fidelity. Rather than treating compression as a purely technical problem, the work will explicitly consider the trade-offs between compression rate and perceived quality. Evaluation will play a key role throughout the project. In addition to standard objective metrics such as PSNR, SSIM, and perceptual measures, the thesis will place particular emphasis on perceptual quality assessment in a 3D context. Using a light-field display system available for experiments, the student will investigate how compression artifacts affect depth perception, visual comfort, and overall realism. This aspect is especially important, as artifacts that appear minor in 2D projections can become significantly more noticeable in 3D visualization.

Methodology and Expected Contributions:

The research will involve designing and evaluating compression techniques for radiance field representations, with experiments conducted across different datasets and compression settings. Both objective metrics, such as PSNR and SSIM, and perceptual measures will be used for evaluation. Subjective experiments will be conducted to assess the impact of compression artifacts in realistic viewing conditions.

This thesis is expected to contribute to the development of memory-efficient radiance field representations and to deepen understanding of the relationships among compression, perceptual quality (Rate-Distortion tradeoff), and visualization conditions. The outcomes will support the design of compression methods that are better aligned with human perception, particularly in the context of advanced 3D display systems.

Expected Student Profile:

- Strong programming skills (preferably Python, and familiarity with PyTorch or similar frameworks)
- Basic knowledge of computer vision and/or machine learning
- Familiarity with 3D graphics or rendering is a plus, but not strictly required
- Interest in experimental research and evaluation (including perceptual assessment)

References and further reading

Kerbl, Bernhard, et al. "rd gaussian splatting for real-time radiance field rendering." ACM Trans. Graph. 42.4 (2023): 139-1.

Zhang, Richard, et al. "The unreasonable effectiveness of deep features as a perceptual metric." Proceedings of the IEEE conference on computer vision and pattern recognition. 2018.

Bagdasarian, Milena T., et al. "rds. zip: A survey on 3d gaussian splatting compression methods." Computer Graphics Forum. Vol. 44. No. 2. 2025.

Chen, Yihang, et al. "Hac: Hash-grid assisted context for 3d gaussian splatting compression." European Conference on Computer Vision. Cham: Springer Nature Switzerland, 2024.

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2722/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Saeed Mahmoudpour (Saeed.Mahmoudpour@vub.be)

Accelerating autoregressive integrated moving average models using sparse matrix representations

Program : Electrical engineering - M-IRELE

Description

Context

Statistical time series models (such as autoregressive integrated moving average, ARIMA) are a staple forecasting method for time series. Even with the advent of more modern forecasting methods (e.g., long-short term memory (LSTM) neural networks and Facebook Prophet), they remain an interesting baseline that has the advantage of being interpretable.

Modern ARIMA implementations rely on Kalman filters for fitting and forecasting purposes (notably because Kalman filters and state-space representations are well mastered mathematical tools and support missing observations). This is also the case for seasonal time series models (i.e., seasonal autoregressive integrated moving average, SARIMA) [Brockwell, 2002] [Durbin, 2012].

Interestingly, state-space models of high-order ARIMA models happen to be sparse (which means that the state transition and observation matrices mostly consist of zero coefficients); sparsity levels get even higher in the case of SARIMA models.

However, despite the sparse nature of most of the state-space matrices, it appears that many implementations (e.g., Python statsmodels) do not leverage it and instead rely on standard dense matrix representations for computations.

Objectives and steps

The goal of this master's thesis is to program a custom, high-performance fit-and-forecast program for ARIMA models, relying on sparse matrix representations to reduce computing load. Steps are i) a review of state-space models for ARIMA models and the associated fitting and forecasting methods, ii) implementing a fit-and-forecast program that leverages sparse matrix representations and iii) compare the performance of the developed program to that of Python's statsmodels (in terms of accuracy and computing time), using real and/or synthetic time series. Very motivated students can go further and i) extend the program to SARIMA models, or ii) implement the program in CUDA (for graphical processing unit (GPU) programming) or iii) rely on template meta-programming for implementing compile-time sparse matrices. The BEAMS-EE department possesses various computing platforms (notably a consumer-grade computing tower with a GPU and a rack server with dual Xeon Gold (64 cores in total) and two RTX A6000 GPUs), which are available to Master's thesis students.

Student profile

Ideally, the student has experience in C++ programming and is skilled in mathematics (mostly linear algebra, although basic probability theory and optimization theory are important as well). Knowledge of BLAS, LAPACK and/or the Eigen library is a plus. Having followed the course "Microprocessor architectures" is also a (minor) plus.

References

[Brockwell, 2002] Brockwell, Peter J., and Richard A. Davis, eds. Introduction to time series and forecasting. New York, NY: Springer New York, 2002.

[Durbin, 2012] Durbin, James, and Siem Jan Koopman. Time series analysis by state space methods. Vol. 38. OUP Oxford, 2012.

Contact

Jean-François Determe, jean-francois.determe@ulb.be

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRCBS, M-IRIFS, M- IRPH
Number of topics	1

Supervision

Supervisor : Jean-François Determe (jean-francois.determe@ulb.be)

Digital algorithms on an underwater acoustic modem

Program : *Electrical engineering - M-IRELE*

Description

Context

Underwater communications are peculiar in that traditional electromagnetic communications are often inappropriate due to high attenuation in water. As a result, all medium and long-range underwater communications are acoustic (i.e., they use pressure waves). Bandwidths are also typically orders of magnitude lower than those of over-the-air wireless communications (in underwater acoustic communications, bandwidth generally does not exceed 20 kHz and the carrier frequency is often between 10 and 100 kHz) [Zia, 2021]. These low bandwidths led to the development of many research and commercial modems based on micro-controller units (MCUs) or microprocessor units (MPUs), with some high-end modems relying on field-programmable gate arrays (FPGAs). Given the low carrier frequencies, no analog upconversion and downconversion is needed and signals are generally directly sampled (RX) or converted to analog (TX) in bandpass. Our research group is currently developing such a modem (hardware and software) and possesses simulation tools to facilitate the offline prototyping of such algorithms, prior to hardware implementation.

Objectives and steps

The goal of this master's thesis is to develop basic parts of an underwater communication modem. The steps are to i) validate in simulation a basic transmission chain and ii) implement as many parts of it as possible on hardware. As raw samples can be sent from the client to the TX and received from the RX, the communication chain need not be fully implemented on hardware. The student is expected to leverage microarchitecture enhancements to optimize computational performance. The student may rely on our expertise and analog hardware but should develop their own embedded software. Experimental validation is encouraged for step ii).

Student profile

Ideally, any interested student should have followed the courses "Microprocessor architecture" and "Modulation and coding". This master's thesis is geared toward students that have an interest in building real telecommunication devices and are eager to learn how to carry out practical work on modern, advanced MCU architectures. A basic understanding of linear and non-linear analog electronics as well as transceiver architecture is a plus.

References

[Renner, 2020] Renner, Bernd-Christian et al. "AHOI: Inexpensive, low-power communication and localization for underwater sensor networks and μ AUVs." *ACM Transactions on Sensor Networks (TOSN)* 16, no. 2 (2020): 1-46.

[Zia, 2021] Zia, Muhammad Yousuf Irfan et al. "State-of-the-art underwater acoustic communication

modems: Classifications, analyses and design challenges." Wireless personal communications 116 (2021): 1325-1360.

Contact

Jean-François Determe, jean-francois.determe@ulb.be

Kristopher De Saulnier, Kristopher.De.Saulnier@ulb.be

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Jean-François Determe (jean-francois.determe@ulb.be)

Topics offered to students by other
master's programs

TARGET PROGRAM

EM – Computer Engineering

Stochastic modelling of load profiles for urban energy systems

Program : EM - Energy - M-IREMR-E

Description

The climate disruptions experienced globally over the past decades require a profound transformation of our societies, particularly of our energy systems. In urban environments such as the Brussels-Capital Region, space heating currently accounts for nearly 50% of total final energy consumption. As natural gas remains the dominant energy source to meet this demand, building heating systems must be decarbonised to achieve carbon neutrality targets by 2050.

Most decarbonisation plans rely on relatively rigid and conservative demand modelling. Yet demand estimation forms the basis for optimising decarbonisation pathways. Traditionally, the assessment of thermal demand (heating and cooling) is based on modelling the physical envelope of buildings and the technological systems installed within them. When the spatial and temporal scale of analysis increases – as in long-term urban or regional studies – numerous simplifying and often rigid assumptions are introduced to represent the entire building stock.

However, this aggregated approach tends to overlook the individuality of each building, both from a technical perspective (architectural characteristics, energy systems, and sector of activity) and from a social perspective (comfort preferences and user behaviours). Failing to account for these individual factors also leads to the neglect of other, more systemic dimensions, whether technical (e.g. network peak loads), social (e.g. usage inequalities), or legal (e.g. regulation and heritage protection). Consequently, urban transition strategies could be biased or even hindered.

The objective of this thesis is twofold: first, to highlight the unique characteristics of buildings; and second, to assess the systemic flexibility potential of energy demand through a disaggregated modelling approach.

The project is divided into two parts. First, the student will develop synthetic and stochastic demand-profile generators for gas and electricity consumption. Second, the model will be applied at the scale of the Brussels-Capital Region to evaluate the impact of different socio-technical demand-evolution scenarios.

The stochastic framework will make the underlying assumptions explicit and enable the quantification of uncertainty. The quality of the generated profiles will be assessed using currently available real-world consumption data. In particular, the student will analyse the impact of societal changes such as energy sharing practices or slow heating strategies on future demand scenarios.

A basic knowledge of Python and an interest in urban energy systems are essential prerequisites.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : Procacci Alberto (alberto.procacci@ulb.be)

Co-supervisor : Coussement Axel (axel.coussement@ulb.be)

Can machine learning methods approximate the optimal power flow solution for electric transmission systems?

Program : EM - Energy - M-IREMR-E

Description

Context

Optimal Power Flow (OPF) determines the optimal operating point of a power system satisfying its physical and operational constraints. This problem already being non-linear, non-convex and computationally expensive, gets increasingly more complex with the increasing penetration of Renewable Energy Sources (RES). This evergrowing complexity motivates the growing interest in machine learning (ML) as a way to produce fast approximate solutions. However, applying ML to the operation of power systems is not straightforward as the problem is high-dimensional, physics imposes hard constraints, and model relevance depends on the operating regime of each power system case. This thesis takes the Power Grid Library for OPF Benchmarking (PGLib-OPF) as its experimental playground. This open dataset is a collection of AC transmission test cases curated for OPF, ranging from small pedagogical networks to realistic grids with thousands of buses.

Research question

How well do machine learning methods approximate OPF on the cases from the PGLib dataset, and what insights can be extracted on why they succeed or fail across cases and operating conditions?

Approach

The student will (i) familiarise with the provided OPF solvers and the PGLib dataset, (ii) generate labelled train/test data by perturbing case loads and re-solving, (iii) apply standard ML techniques (e.g. regression, random forests, MLPs...) to predict OPF outputs, (iv) evaluate prediction accuracy, optimality gap, constraint violations, and computational speed-up against the solver, and (v) analyse which case characteristics (size, congestion regime, topology...) correlate with model performance. An optional extension, time permitting, would explore graph-aware model architecture.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS, M-IREMR-M
Number of topics	1

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : Chemical & Materials engineering - M-IRMAE

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPS laboratory, ULB.

4. Reporting

- ☐ Weekly meetings with the supervisor(s) to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczyzmalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Number of topics	2

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Plenoptic encoding of holograms with gaussian mixture models

Program : Electrical engineering - M-IRELE

Description

Context:

Holography represents the frontier of visual technology. By encoding the full wavefield of light (capturing both amplitude and phase information), it holds the potential to be the ultimate display system. Unlike traditional stereoscopic screens, holographic displays can perfectly reproduce all natural visual cues, including continuous parallax and physically accurate focus cues.

However, realizing this potential comes with a significant hurdle: computing holograms requires complex wave-optics rendering, making it highly computationally intensive. To make high-end holographic displays practical, particularly for next-generation augmented and virtual reality (AR/VR) systems, the field needs fundamentally novel algorithms and data representations.

Recently, 3D Gaussian mixture models, such as 3D Gaussian splatting, have revolutionized standard scene representation, enabling highly efficient, high-quality rendering. Yet, these existing models are natively designed for ray-based optics and are not directly adapted to the complex, wave-based requirements of holographic rendering.

The primary aim of this thesis is to bridge this gap. The student will develop novel algorithms and data structures using multivariate Gaussian components to create compact, adaptive plenoptic representations specifically tailored for holography. By encoding light fields into these sophisticated mixture models, this research seeks to drastically optimize the computational pipeline, bringing real-time, high-fidelity holographic rendering one step closer to reality.

Research activities and goals:

The first challenge is to bridge the gap between geometric optics and wave optics. The student will develop novel 3D Gaussian mixture representations specifically adapted for holography. This requires moving beyond traditional rendering by accounting for ray-to-wave conversion and incorporating complex-valued amplitudes to accurately model light interference patterns.

Moving from theory to practice, the student will implement an extended rendering framework. This software pipeline will be responsible for translating the newly developed, complex-valued Gaussian mixture representations into holograms.

The developed algorithms will be rigorously evaluated. First, the student will test the framework within a simulated holographic rendering pipeline to benchmark computational efficiency and image quality. Finally, the research culminates in physical validation: the student will deploy their holograms on an in-house holographic display prototype, directly observing the real-world performance and optical characteristics of their plenoptic encoding approach.

Expected Student Profile:

- Strong programming skills (Python, C/C++, GPU programming is a plus)
- Familiarity with 3D graphics is recommended
- Interest in experimental physical research and evaluation (visual and optical testing)

References and further reading:

Zhan, Yicheng, Dong-Ha Shin, Seung-Hwan Baek, and Kaan Aksit. "Complex-Valued Holographic Radiance Fields." ACM Transactions on Graphics (2025). doi: 10.1145/3804450

David Blinder, Tobias Birnbaum, Tomoyoshi Ito, Tomoyoshi Shimobaba. The state-of-the-art in computer generated holography for 3D display[J]. Light: Advanced Manufacturing 3, 35(2022). doi: 10.37188/lam.2022.035

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2725/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Rodolphe Valicon De Soete (Rodolphe.Sasha.Valicon@vub.be)

Perceptual optimization of 3d gaussian splatting for high-fidelity rendering

Program : Electrical engineering - M-IRELE

Description

Context:

3D Gaussian Splatting (3DGS) has recently emerged as an efficient representation for real-time novel view synthesis, offering a compelling alternative to traditional neural rendering techniques. By representing scenes as collections of Gaussian primitives, 3DGS enables high-quality rendering with significantly reduced computational cost. Despite these advantages, most existing approaches rely on pixel-level distortion losses, such as L1 or SSIM, during training. These losses are poorly aligned with human visual perception and often result in overly smooth reconstructions that fail to preserve fine textures and structural details. Recent work has demonstrated that replacing such losses with perceptually motivated alternatives can substantially improve visual quality, with human studies showing strong preference for perceptually optimized models over standard approaches. This highlights the importance of designing training objectives that better reflect perceptual quality, rather than relying solely on traditional image fidelity metrics.

Although perceptual losses have shown promising results in improving 3DGS reconstructions, their design and integration remain relatively unexplored. It is still unclear which perceptual distortions are most suitable for 3D Gaussian representations and how these distortions affect both visual quality and model efficiency. In addition, while improvements are often validated through subjective studies, there is limited understanding of how perceptual gains relate to objective metrics and compression efficiency in 3DGS frameworks.

Research activities and goals:

Objectives: The goal of this thesis is to investigate perceptual optimization strategies for 3D Gaussian Splatting and to analyze their impact on rendering quality. The work will focus on studying different classes of distortion losses, including pixel-based, perceptual, and distribution-based losses, and evaluating their effectiveness in preserving fine details and textures. Particular attention will be given to losses inspired by human perception, such as those based on feature statistics or distribution matching. The thesis will also examine how perceptual optimization affects model characteristics, including the number of Gaussians, rendering efficiency, and compression performance. A secondary objective is to analyze the relationship between perceptual improvements and both objective metrics and human preference, using subjective evaluation as a validation tool.

Methodology and Expected Contributions: The research will involve implementing and integrating different loss functions within a 3DGS training pipeline. Experiments will be conducted on standard datasets to compare reconstruction quality across different optimization strategies. The evaluation will combine objective metrics, such as LPIPS and DISTs, with controlled subjective comparisons to assess perceptual quality. Additional analysis will focus on efficiency-related factors, including model size and rendering performance.

This thesis is expected to provide a systematic analysis of perceptual optimization in 3D Gaussian Splatting and to identify effective loss functions for improving visual quality. It will contribute to a

better understanding of the trade-offs between perceptual fidelity, computational efficiency, and compression, and provide practical insights for designing perceptually optimized 3D rendering systems.

Expected Student Profile:

- Strong programming skills (preferably Python, and familiarity with PyTorch or similar frameworks)
- Basic knowledge of computer vision and/or machine learning
- Familiarity with 3D graphics or rendering is a plus, but not strictly required
- Interest in experimental research and evaluation (including perceptual assessment)

References and further reading:

Kerbl, Bernhard, et al. rd gaussian splatting for real-time radiance field rendering." ACM Trans. Graph. 42.4 (2023): 139-1.

Zhang, Richard, et al. "The unreasonable effectiveness of deep features as a perceptual metric." Proceedings of the IEEE conference on computer vision and pattern recognition. 2018.

Ghildyal, Abhijay, et al. "Non-Aligned Reference Image Quality Assessment for Novel View Synthesis." Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. 2026.

Ozyilkan, Ezgi, et al. "Drop-In Perceptual Optimization for 3D Gaussian Splatting." arXiv preprint arXiv:2603.23297 (2026).

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2721/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Saeed Mahmoudpour (Saeed.Mahmoudpour@vub.be)

Hologram generation via deep learning for 3D holographic display systems

Program : Electrical engineering - M-IRELE

Description

Context

Holographic displays have the potential to become the highest-quality type of 3D display system, as they account for all visual cues by reproducing the full wavefield of light, including both amplitude and phase information. Hologram generation for 3D holographic displays is often done using inverse optimization methods. These methods provide accurate results, but they require many iterations to converge, making the process slow. This thesis investigates the application of deep learning models to reduce the computational time required for hologram generation in a specific type of 3D holographic display.

Research activities and goals:

The student will first study image-to-image deep learning architectures, our hologram generation methods, and our holographic display prototype in our lab. A dataset based on random data will be generated using our forward light propagation model. This dataset will then be used to train different architectures of deep learning models, and their performance will be evaluated using non-random 3D scenes. The work includes programming, working on the optical setup, reviewing literature on computer-generated holography, designing new models for light propagation, and implementing new optimization algorithms.

References and further reading:

Manuel Montoya, Yunfeng Nie, and David Blinder, "Computer-generated holography using the generalized Van Cittert–Zernike Schell propagator," *Opt. Lett.* 51, 2084-2087 (2026)

Huang, L., Chen, H., Liu, T. et al. Self-supervised learning of hologram reconstruction using physics consistency. *Nat Mach Intell* 5, 895–907 (2023)

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2720/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Manuel Montoya (Manuel.Montoya.Zuluaga@vub.be)

Eye-tracking technology for next-generation 3d holographic displays

Program : *Electrical engineering - M-IRELE*

Description

Context:

Next-generation 3D holographic displays are poised to advance fields ranging from entertainment and healthcare to advanced manufacturing. By actively shaping the optical wavefront, these displays can accurately render 3D objects with all natural depth cues. However, achieving this level of precision requires tiny pixels (on the order of the wavelength of light), which inherently necessitate exceptionally high overall pixel counts. Consequently, the immersiveness of these displays, quantified by their space-bandwidth product (SBP) [1], is fundamentally constrained by the immense hardware demands. Because rendering high-resolution holograms requires massive computational resources, SBP remains highly expensive. Optimizing SBP utilization efficiency, specifically by integrating real-time eye-tracking with advanced multiplexing techniques [2], offers a viable pathway to practical digital holography. Developing and evaluating this integration forms the primary objective of this thesis.

Research activities and goals:

This thesis bridges theoretical optical principles with applied systems engineering. Foundationally, you will study the core mechanics of digital holography. Multiplexing expands the effective viewing angle and viewing volume (eyebox) by rapidly adjusting display parameters, leveraging the human eye's persistence of vision.

While current systems rely on static multiplexing, this project aims to implement dynamic multiplexing. By using real-time gaze feedback, the system dynamically allocates computational resources to the user's direct line of sight, thereby maximizing the display's effective SBP. The primary deliverable for this project is a functional proof-of-concept holographic display capable of actively steering light directly to the viewer's pupil in real-time, responsive to continuous eye-tracking data.

From an engineering perspective, we will use a state-of-the-art eye tracker (e.g., a Tobii with 6 Degrees of Freedom) for precise head and gaze tracking. The technical work involves significant software development: interfacing hardware, processing tracking data with minimal latency, and dynamically adjusting the software rendering pipeline to drive the hardware. You will be supported by a team of senior researchers in this highly novel area. Because the integration of active eye-tracking in holographic displays is largely unexplored, this project presents a strong opportunity for scientific publication.

Expected Student Profile:

- Good programming skills (MATLAB or Python, C/C++)
- Enthusiasm for hands-on engineering of next-generation display technologies
- Interest in experimental physical research and evaluation (visual and optical testing)

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2732/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Raees Kizhakkumkara (Raees.Kizhakkumkara.Muhamad@vub.be)

Compressed radiance fields coding for memory-efficient representations and rate-quality trade-offs

Program : Electrical engineering - M-IRELE

Description

Context

Neural radiance field methods, including approaches such as 3D Gaussian Splatting, have significantly advanced the state of the art in novel view synthesis and 3D scene representation. They enable highly realistic rendering from sparse observations, but this quality comes at the cost of substantial memory usage and computational complexity. These limitations become particularly critical in scenarios that require real-time performance or deployment on specialized visualization systems such as light-field displays.

Research activities and goals

Research Objectives: This thesis focuses on developing efficient compression strategies for radiance field representations to reduce memory requirements while preserving visual fidelity. Rather than treating compression as a purely technical problem, the work will explicitly consider the trade-offs between compression rate and perceived quality. Evaluation will play a key role throughout the project. In addition to standard objective metrics such as PSNR, SSIM, and perceptual measures, the thesis will place particular emphasis on perceptual quality assessment in a 3D context. Using a light-field display system available for experiments, the student will investigate how compression artifacts affect depth perception, visual comfort, and overall realism. This aspect is especially important, as artifacts that appear minor in 2D projections can become significantly more noticeable in 3D visualization.

Methodology and Expected Contributions:

The research will involve designing and evaluating compression techniques for radiance field representations, with experiments conducted across different datasets and compression settings. Both objective metrics, such as PSNR and SSIM, and perceptual measures will be used for evaluation. Subjective experiments will be conducted to assess the impact of compression artifacts in realistic viewing conditions.

This thesis is expected to contribute to the development of memory-efficient radiance field representations and to deepen understanding of the relationships among compression, perceptual quality (Rate-Distortion tradeoff), and visualization conditions. The outcomes will support the design of compression methods that are better aligned with human perception, particularly in the context of advanced 3D display systems.

Expected Student Profile:

- Strong programming skills (preferably Python, and familiarity with PyTorch or similar frameworks)
- Basic knowledge of computer vision and/or machine learning
- Familiarity with 3D graphics or rendering is a plus, but not strictly required
- Interest in experimental research and evaluation (including perceptual assessment)

References and further reading

Kerbl, Bernhard, et al. "3d gaussian splatting for real-time radiance field rendering." *ACM Trans. Graph.* 42.4 (2023): 139-1.

Zhang, Richard, et al. "The unreasonable effectiveness of deep features as a perceptual metric." *Proceedings of the IEEE conference on computer vision and pattern recognition*. 2018.

Bagdasarian, Milena T., et al. "3dgs. zip: A survey on 3d gaussian splatting compression methods." *Computer Graphics Forum*. Vol. 44. No. 2. 2025.

Chen, Yihang, et al. "Hac: Hash-grid assisted context for 3d gaussian splatting compression." *European Conference on Computer Vision*. Cham: Springer Nature Switzerland, 2024.

Link : <https://www.etrovub.be/education/master/master-thesis-topics-guidelines/thesis-details/overview/2722/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	1

Supervision

Supervisor : David Blinder (david.blinder@vub.be)

Co-supervisor : Saeed Mahmoudpour (Saeed.Mahmoudpour@vub.be)

Accelerating autoregressive integrated moving average models using sparse matrix representations

Program : Electrical engineering - M-IRELE

Description

Context

Statistical time series models (such as autoregressive integrated moving average, ARIMA) are a staple forecasting method for time series. Even with the advent of more modern forecasting methods (e.g., long-short term memory (LSTM) neural networks and Facebook Prophet), they remain an interesting baseline that has the advantage of being interpretable.

Modern ARIMA implementations rely on Kalman filters for fitting and forecasting purposes (notably because Kalman filters and state-space representations are well mastered mathematical tools and support missing observations). This is also the case for seasonal time series models (i.e., seasonal autoregressive integrated moving average, SARIMA) [Brockwell, 2002] [Durbin, 2012].

Interestingly, state-space models of high-order ARIMA models happen to be sparse (which means that the state transition and observation matrices mostly consist of zero coefficients); sparsity levels get even higher in the case of SARIMA models.

However, despite the sparse nature of most of the state-space matrices, it appears that many implementations (e.g., Python statsmodels) do not leverage it and instead rely on standard dense matrix representations for computations.

Objectives and steps

The goal of this master's thesis is to program a custom, high-performance fit-and-forecast program for ARIMA models, relying on sparse matrix representations to reduce computing load. Steps are i) a review of state-space models for ARIMA models and the associated fitting and forecasting methods, ii) implementing a fit-and-forecast program that leverages sparse matrix representations and iii) compare the performance of the developed program to that of Python's statsmodels (in terms of accuracy and computing time), using real and/or synthetic time series. Very motivated students can go further and i) extend the program to SARIMA models, or ii) implement the program in CUDA (for graphical processing unit (GPU) programming) or iii) rely on template meta-programming for implementing compile-time sparse matrices. The BEAMS-EE department possesses various computing platforms (notably a consumer-grade computing tower with a GPU and a rack server with dual Xeon Gold (64 cores in total) and two RTX A6000 GPUs), which are available to Master's thesis students.

Student profile

Ideally, the student has experience in C++ programming and is skilled in mathematics (mostly linear algebra, although basic probability theory and optimization theory are important as well). Knowledge of BLAS, LAPACK and/or the Eigen library is a plus. Having followed the course "Microprocessor architectures" is also a (minor) plus.

References

[Brockwell, 2002] Brockwell, Peter J., and Richard A. Davis, eds. Introduction to time series and forecasting. New York, NY: Springer New York, 2002.

[Durbin, 2012] Durbin, James, and Siem Jan Koopman. Time series analysis by state space methods. Vol. 38. OUP Oxford, 2012.

Contact

Jean-François Determe, jean-francois.determe@ulb.be

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRCBS, M-IRIFS, M- IRPH
Number of topics	1

Supervision

Supervisor : Jean-François Determe (jean-francois.determe@ulb.be)

Digital algorithms on an underwater acoustic modem

Program : *Electrical engineering - M-IRELE*

Description

Context

Underwater communications are peculiar in that traditional electromagnetic communications are often inappropriate due to high attenuation in water. As a result, all medium and long-range underwater communications are acoustic (i.e., they use pressure waves). Bandwidths are also typically orders of magnitude lower than those of over-the-air wireless communications (in underwater acoustic communications, bandwidth generally does not exceed 20 kHz and the carrier frequency is often between 10 and 100 kHz) [Zia, 2021]. These low bandwidths led to the development of many research and commercial modems based on micro-controller units (MCUs) or microprocessor units (MPUs), with some high-end modems relying on field-programmable gate arrays (FPGAs). Given the low carrier frequencies, no analog upconversion and downconversion is needed and signals are generally directly sampled (RX) or converted to analog (TX) in bandpass. Our research group is currently developing such a modem (hardware and software) and possesses simulation tools to facilitate the offline prototyping of such algorithms, prior to hardware implementation.

Objectives and steps

The goal of this master's thesis is to develop basic parts of an underwater communication modem. The steps are to i) validate in simulation a basic transmission chain and ii) implement as many parts of it as possible on hardware. As raw samples can be sent from the client to the TX and received from the RX, the communication chain need not be fully implemented on hardware. The student is expected to leverage microarchitecture enhancements to optimize computational performance. The student may rely on our expertise and analog hardware but should develop their own embedded software. Experimental validation is encouraged for step ii).

Student profile

Ideally, any interested student should have followed the courses "Microprocessor architecture" and "Modulation and coding". This master's thesis is geared toward students that have an interest in building real telecommunication devices and are eager to learn how to carry out practical work on modern, advanced MCU architectures. A basic understanding of linear and non-linear analog electronics as well as transceiver architecture is a plus.

References

[Renner, 2020] Renner, Bernd-Christian et al. "AHOI: Inexpensive, low-power communication and localization for underwater sensor networks and μ AUVs." *ACM Transactions on Sensor Networks (TOSN)* 16, no. 2 (2020): 1-46.

[Zia, 2021] Zia, Muhammad Yousuf Irfan et al. "State-of-the-art underwater acoustic communication

modems: Classifications, analyses and design challenges." Wireless personal communications 116 (2021): 1325-1360.

Contact

Jean-François Determe, jean-francois.determe@ulb.be

Kristopher De Saulnier, Kristopher.De.Saulnier@ulb.be

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Jean-François Determe (jean-francois.determe@ulb.be)

Computer Science & Engineering – Master Thesis Topics (M-IRIFS)

Academic year 2026–2027

Recognition of construction work activities using wearable sensors

Programme : Computer science and engineering - M-IRIFS

Description

Wearable sensing technologies such as inertial measurement units (IMUs) enable continuous monitoring of human motion and are increasingly used to analyse work activities in industrial environments.

Automatically recognising which task a worker is performing could support future intelligent assistance systems, such as exoskeletons that adapt their behaviour depending on the task.

In this thesis, the student will investigate how motion data from wearable sensors can be used to recognise different construction-related activities.

The work includes:

- Literature study on activity recognition using wearable sensors
- Collection or use of an experimental dataset of simple construction tasks
- Extraction of relevant motion features from sensor data
- Implementation of simple classification methods
- Evaluation of recognition performance across different activities

Example activities include walking, panel handling, static holding and fastening operations.

The thesis combines data analysis and experimentation, and will be carried out in the AugmentX research infrastructure at VUB. The student will work on a practical problem with applications in intelligent assistance systems and human-robot collaboration.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IREMR-M
Nombre de sujets	1

Encadrement

Promoteur : Ilias El Makrini

Contact : ilias.el.makrini@vub.be

Transducer-based quantum algorithms

Programme : Computer science and engineering - M-IRIFS

Description

Transducers are a new framework to design quantum algorithms that has several advantages: it is relatively simple, leads to optimal algorithms in the quantum query complexity model, while also allowing to control quantum time complexity [1], and is inherently error-free which makes it possible to compose subroutines with incurring additional log factors [2].

The goal of this Master Thesis would be to develop new quantum algorithms based on transducers, starting by translating known quantum algorithms in this framework, and potentially leading to new applications.

[1] Aleksandrs Belovs, Stacey Jeffery, and Duyal Yolcu. Taming Quantum Time Complexity. Quantum 8, 1444 (2024). [<https://quantum-journal.org/papers/q-2024-08-23-1444/>]

[2] Aleksandrs Belovs, Stacey Jeffery. Space-Efficient Quantum Error Reduction without log Factors. arXiv:2502.09249. [<https://arxiv.org/abs/2502.09249>]

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M- IRPH
Nombre de sujets	1

Encadrement

Promoteur : Jérémie Roland

Contact : Jeremie.Roland@ulb.be

Automating 3D Geometric Measurement of Mechanical Test Benches Using Structured Scanning and Point Cloud Analysis

Programme : Computer science and engineering - M-IRIFS

Description

Mechanical test benches must meet strict geometric tolerances to ensure that experimental measurements accurately reflect material and structural behavior rather than setup artifacts. Verifying these tolerances manually is a slow and error-prone process that becomes particularly burdensome when benches are frequently reconfigured or when high-precision applications demand exhaustive dimensional audits. This thesis designs and validates an automated system that acquires the complete 3D geometry of a mechanical test bench using a scanning sensor mounted on a motorized positioning stage, and processes the resulting point cloud data to extract quantitative geometric parameters without manual intervention. The system plans acquisition trajectories to ensure full coverage, registers multi-view scans into a unified coordinate frame, and computes deviations from CAD reference geometry to identify misalignments, deformations, and tolerance violations. Output is presented as an interactive 3D deviation map and a structured dimensional report, giving mechanical engineers a rapid, reproducible qualification tool that replaces manual measurement campaigns and supports traceability in accredited testing environments.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Encadrement

Promoteur : Olivier Debeir

Contact : olivier.debeir@ulb.be

Privacy-by-Design People Counting in Lecture Halls Using an Embedded Depth Camera System

Programme : Computer science and engineering - M-IRIFS

Description

This master's thesis addresses the challenge of occupancy monitoring in academic environments through the design of a GDPR-compliant, privacy-by-design vision system capable of counting individuals in a lecture hall without capturing or processing any identifying information. Built around a low-power embedded platform, it requires a lightweight inference pipeline, optimised for constrained hardware, performs robust people detection and counting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Encadrement

Promoteur : Olivier Debeir

Contact : olivier.debeir@ulb.be

Improving protein language models for predicting protein thermal and thermodynamic stability

Programme : Computer science and engineering - M-IRIFS

Description

This project investigates recent advances in protein language models, including co-distillation and mixture-of-experts architectures, and explores their integration with structural information and other biological data. By leveraging these approaches, we aim to advance the current state of the art in protein language modeling and improve performance on key predictive tasks, such as protein thermal and thermodynamic stability.

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	
Nombre de sujets	1

Encadrement

Promoteur : Pucci Fabrizio

Contact : Fabrizio.Pucci@ulb.be

Co-encadrant : Rooman Marianne

Contact : Marianne.Rooman@ulb.be

Construction of a multiple-criteria evaluation process for student engineering projects

Programme : Computer science and engineering - M-IRIFS

Description

Every bachelor student at Ecole Polytechnique de Bruxelles (EPB) must realize at least two projects during their first two years of study. These projects involve multiple different aspects, namely the construction of some model, the realization of a prototype implementing the model, the writing of a technical report, an oral presentation of the work, and in the case of the second project, an overview of the project management.

Currently, the evaluations of these points are performed separately by different parties using predefined evaluation grids. Such grids are great to objectivize the expectations of the teaching staff and tend to uniformize the grading if performed by different people. They are however based on natural language values (e.g.: "The slides are overall clear and allow the transfer of information") and translating these to a numerical grade is not trivial. Moreover, combining the different grids also involve subjective choice that is not clear to pre-define, such as a weight associated to each grid.

In this master thesis, the student is expected to apply concepts from multiple criteria decision aid and natural language preference learning to develop a realistic and applicable evaluation process for bachelor projects. Ideally, the method(s) developed by the student could be compared with existing approaches and eventually applied in the following years. Concerning the supervision, I would be available for weekly meetings (at the student's demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentations skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be interested in didactics and will be confronted to an open applied problem with many possible leads to try. Moreover, this subject lies between multiple fields, some of which I do not master (at all). The student should thus be able to take initiatives, remain curious and be independent in its research.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	1

Encadrement

Promoteur : Dimitris Sacharidis

Contact : dimitris.sacharidis@ulb.be

GPS and IMU-Aided Time-Lapse Imaging Platform for Automated Condition Monitoring of Linear Infrastructure

Programme : Computer science and engineering - M-IRIFS

Description

Roads, canals, and other linear infrastructure assets degrade gradually over time, yet systematic visual monitoring of these structures at scale remains logistically complex and costly. This thesis designs and validates a mobile time-lapse camera system that acquires continuous image sequences along linear infrastructure corridors, enriched with GPS position and IMU orientation data at each capture event. By anchoring every frame to a precise spatial reference, the system enables the construction of georeferenced image timelines that can be compared across acquisition campaigns to detect and localize structural changes. Automated analysis modules identify surface deterioration, deformation patterns, and anomalies by applying computer vision techniques to temporally aligned image pairs. The result is a practical, low-cost survey tool that provides infrastructure managers and engineers with a structured, queryable visual record of asset condition, supporting proactive maintenance decisions and regulatory reporting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Encadrement

Promoteur : Olivier Debeir

Contact : olivier.debeir@ulb.be

Machine Learning-Based Digitization of Seismic Traces from Scanned Historical Seismograms for Archival Data Recovery

Programme : Computer science and engineering - M-IRIFS

Description

Seismological observatories worldwide hold vast collections of paper seismograms recording earthquakes and ground motion events going back to the late nineteenth century. This historical data is of exceptional scientific value for long-term seismic hazard assessment, source characterization of pre-instrumental earthquakes, and the calibration of modern seismic models, yet it remains largely inaccessible because converting analog traces into digital waveforms requires expert manual tracing on a record-by-record basis. This thesis builds a machine learning system that automates the recovery of seismic waveform data from scanned seismogram images. Starting from raw scan inputs, the pipeline handles document restoration, trace isolation, and waveform vectorization, translating the visual trace geometry into calibrated time series data that can be ingested by standard seismological software. The system is designed to process large archival collections with minimal human intervention, enabling seismologists to unlock decades of previously inaccessible observational data for modern reanalysis.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Encadrement

Promoteur : Olivier Debeir

Contact : olivier.debeir@ulb.be

On intransitive indifference relations and PROMETHEE methods

Programme : Computer science and engineering - M-IRIFS

Description

When a problem involves multiple (conflicting) criteria, the notion of an “optimal” solution is ill-defined. Consider for example the problem of choosing the best place to host a conference, i.e. the least expensive, fanciest, and most accessible. It seems very unlikely that one place is the best on all these criteria.

The field of Multiple Criteria Decision Aid (MCDA) emerged in the 1960s to help decision makers who face such problems. In this context, the PROMETHEE I and PROMETHEE II methods rely on pairwise comparisons and preference functions to construct rankings of the available alternatives. In PROMETHEE, decision makers begin by describing their preferences regarding each criterion. When these preferences are crisp (strict), the procedure yields, for each criterion, a binary relation between alternatives that generally satisfies transitivity of strict preference (if $a > b$ and $b > c$ then $a > c$) but not transitivity of indifference ($a \sim b$ and $b \sim c$ but $a > c$).

However, the PROMETHEE I and II aggregation procedure produce rankings, and hence a form of global indifference that is transitive, since alternatives with identical net flows are considered indifferent. This raises several theoretical and practical questions: how does the aggregation process “repair” the non-transitive local indifference into a globally transitive indifference? To what extent is the global indifference meaningful when the underlying unidimensional relations exhibit cycles of indifference? Can alternative aggregation procedures or variants of PROMETHEE preserve or reflect the structure of local indifference more faithfully?

In this master thesis, the student is expected to investigate the contrast between non-transitive indifference at the criterion level and transitive indifference in the final ranking, both from a theoretical and methodological perspective. This could include revisiting the formal properties of PROMETHEE preference functions and the binary relations they generate; studying the structure of local indifference cycles and their propagation during aggregation; exploring alternative formulations or extensions that preserve local structures (e.g., partial orders, forest orders, interval-based flows, robust PROMETHEE approaches); or evaluating whether modified procedures could yield rankings that better reflect decision makers’ intent.

Concerning the supervision, I would be available for weekly meetings (at the student’s demand), and the student would be expected to give a ten-minute presentation of their work every six to eight weeks in order to receive regular feedback on their presentation skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be ready to work on theoretical mathematics, in particular on binary relations on sets and orders representations.

Langue	EN (english)
Ouvert à d’autres masters	Yes

Masters concernés	M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	1

Encadrement

Promoteur : Dimitris Sacharidis

Contact : dimitris.sacharidis@ulb.be

Non-compensatory grading methods for university exams

Programme : Computer science and engineering - M-IRIFS

Description

At Ecole polytechnique de Bruxelles (EPB), most exams are composed of multiple questions supposed to evaluate the students' understanding or mastery of various concepts. Each question is graded independently and all grades are then aggregated, often using a weighted sum approach. In the fields of multiple-criteria decision aid (MCDA) and multi-objective optimization, the weighted sum approaches are often criticized for various reasons, one of which is that they are subject to compensations. In short, this means that a defect on one criterion can always be compensated by an improvement on another. In the context of grading mentioned above, if a student scores perfectly on one questions (20/20) and completely fails another (0/20) their final score is 10/20 and they succeed the exam. This would be the same if the student scored 10/20 at both questions, though from the perspective of the teacher the second case might be considered better or worse than the first. Some MCDA methods are non-compensatory by construction, for example ELECTRE methods, the lexicographic methods or treshold-based methods.

In this master thesis, the student is expected to navigate between theoretical aspects of MCDA and practical constraints of teaching activities to explore and propose realistic grading methods with good mathematical properties (non-compensations, monotony, robustness, etc.).

Concerning the supervision, I would be available for weekly meetings (at the student's demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentations skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC. Expected profile: the student should be interested in didactics and will be confronted to an open problem with many possible leads to try.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M- IRPH
Nombre de sujets	1

Encadrement

Promoteur : Dimitris Sacharidis

Contact : dimitris.sacharidis@ulb.be

Explainability of decisions from PROMETHEE based models

Programme : Computer science and engineering - M-IRIFS

Description

In many real-world decision problems — selecting candidates for a position, ranking infrastructure projects, or allocating research funding — stakeholders are not only interested in the outcome of a decision process, but also in understanding why a particular alternative was preferred over another. This need for transparency is both ethical, as decisions may significantly affect individuals or organizations, and practical, as trust in a decision support tool should be constructed.

The PROMETHEE I and PROMETHEE II methods, developed in the 1980s, are widely used outranking methods in multiple-criteria decision aid (MCDA). They rely on pairwise comparisons across criteria, weighted preference functions, and the aggregation of these into net flow scores that induce a ranking of alternatives. While the mathematical structure of PROMETHEE is relatively transparent compared to black-box approaches such as neural networks, translating its outputs into natural language justifications that are meaningful to a non-expert decision maker remains an open challenge. For instance, stating that alternative a outranks alternative b because its net flow is higher offers little intuitive value without further context about which criteria drove that difference, how decisive those differences were, and whether the conclusion is robust to small changes in the model parameters.

In this master thesis, the student is expected to investigate explainability in the context of PROMETHEE-based decision models, drawing on concepts from both MCDA and the broader literature on explainable artificial intelligence (XAI). This could include formalizing notions of explanation suited to outranking methods (e.g., criterion-level contribution decompositions, contrastive or counterfactual explanations of the form “alternative a would have been preferred if criterion k had been weighted differently”); studying the relationship between robustness analysis tools already available in PROMETHEE and the production of explanations; or developing a prototype explanation module that generates human-readable justifications for a given ranking. The practical applicability of the proposed approach should be evaluated, ideally on a real or realistic decision problem.

Concerning the supervision, I would be available for weekly meetings (at the student’s demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentation skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be interested in didactics and will be confronted to an open problem with many possible leads to try. The student should be comfortable with discrete mathematics and logic. Familiarity with probability and statistics is a plus.

Langue	EN (english)
Ouvert à d'autres masters	Yes

Masters concernés	M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	2

Encadrement

Promoteur : Dimitris Sacharidis

Contact : dimitris.sacharidis@ulb.be

Learning preferences of students towards course practices

Programme : Computer science and engineering - M-IRIFS

Description

University courses are composed of a wide variety of teaching and assessment practices: lectures, exercise sessions, project work, oral examinations, written tests, flipped classroom approaches, peer feedback, and many others. While instructors often choose these practices based on experience or tradition, little is typically known about how students themselves perceive and value different combinations of course activities.

Understanding student preferences is non-trivial. A student may prefer oral exams over written ones in general, yet that preference may weaken or reverse when the course involves heavy mathematical content. Such context-dependent and potentially inconsistent preferences are difficult to capture with simple questionnaires or Likert scales. The field of preference learning, at the intersection of machine learning and multiple-criteria decision aid (MCDA), offers structured methods to elicit, represent, and reason about such preferences from observed data or pairwise comparisons.

In this master thesis, the student is expected to design and apply a preference learning methodology to model how students rank or evaluate different course practice profiles. This includes identifying relevant course attributes (e.g., type of assessment, frequency of feedback, degree of autonomy), collecting preference data through an appropriate elicitation protocol, and fitting a preference model - such as a utility function, a sorting rule, or an outranking relation - to the collected data. The work should also address the robustness of the inferred preferences and discuss the practical implications for course design. Ideally, the methodology could be piloted within one or more courses at Ecole polytechnique de Bruxelles and the results compared across student profiles (year of study, discipline, prior academic performance).

Concerning the supervision, I would be available for weekly meetings (at the student's demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentation skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be interested in didactics and will be confronted to an open problem with many possible leads to try. The student should be ready for data-driven approaches. Ideally, the student would propose an end-to-end pipeline to apply on courses or cohorts.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	2

Encadrement

Promoteur : Dimitris Sacharidis

Contact : dimitris.sacharidis@ulb.be

Topics offered to students by other
master's programs

TARGET PROGRAM

COMPUTER engineering

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Automated Muscle and Tendon Fiber Orientation Tracking in Calf Ultrasound Images Using Computer Vision

Description

Understanding how muscle and tendon fibers are oriented in the calf is essential for assessing athletic performance, diagnosing musculoskeletal conditions, and guiding rehabilitation. Ultrasound imaging offers a non-invasive, real-time window into this fiber architecture, but extracting quantitative orientation data currently requires manual tracing by trained specialists. This thesis designs and validates a computer vision pipeline that automatically detects and tracks fiber orientation in ultrasound images of the calf region. By combining classical image processing techniques with deep learning-based segmentation, the system estimates pennation angles, fiber bundle trajectories, and tendon alignment across static and dynamic acquisition sequences. The tool is evaluated in both laboratory and clinical contexts, with the goal of providing a reproducible, accessible measurement instrument for clinicians, physiotherapists, and sports scientists.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Development of a dedicated, affordable ultrasound system for Automated Detection of Inflammatory Activity in Inflammatory Bowel Disease

Description

This project focuses on designing a low-cost ultrasound device tailored for intestinal imaging in inflammatory bowel disease (IBD). IBD monitoring currently relies on invasive procedures like colonoscopy, while ultrasound offers a non-invasive and patient-friendly alternative. However, interpretation remains operator-dependent, limiting its broader adoption. The goal is to develop a simple, portable, and possibly open-source system capable of acquiring clinically relevant images. The project also integrates AI-based feedback to assist users in assessing image quality and detecting inflammation. Ultimately, it aims to democratize access to reliable IBD monitoring tools.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Implementation of an electrode to stimulate Vagus Nerve

Description

This project aims to design and implement a stimulation electrode for the vagus nerve to enable closed-loop neuromodulation. Vagus nerve stimulation (VNS) is used in epilepsy treatment, but current approaches are largely empirical and not fully optimized. The work involves understanding electrode design constraints, including materials, geometry, and implantation techniques. A prototype electrode will be developed and tested both in vitro and in vivo. This will complete an existing recording setup and enable responsive stimulation based on detected physiological signals. The project contributes to improving personalized neuromodulation therapies.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Simulation of a biocompatible and implantable optical fiber-based flexure sensor

Description

This project focuses on developing an implantable sensor to monitor bladder volume in patients with neurogenic bladder dysfunction. Current management techniques are often invasive and uncomfortable, underscoring the need for continuous, reliable monitoring solutions. The proposed approach relies on optical fiber sensors, which are small, biocompatible, and immune to electromagnetic interference, making them well-suited for in vivo applications. The sensing principle is based on bending-induced light loss, where changes in bladder curvature affect the transmitted optical signal. The work involves modeling and simulating the sensor's coupled mechanical and optical behavior under different design configurations. Ultimately, the goal is to identify an optimal, compact, and implantable solution that could enable closed-loop bladder management and improve patients' quality of life.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Estimating physical workload during manual tasks using wearable sensing

Description

Many industrial tasks involve lifting, holding components or working in constrained postures, which can lead to physical fatigue and musculoskeletal disorders.

Recent wearable sensing technologies (e.g. inertial sensors) enable monitoring human motion during such tasks. However, translating these measurements into meaningful indicators of physical workload remains an open challenge.

In this thesis, the student will investigate how wearable motion data can be used to estimate simple indicators of physical workload.

The work includes:

- Literature study on ergonomic workload assessment and wearable sensing
- Experimental measurements using wearable sensors during manual tasks
- Extraction of motion features from recorded data
- Development of simple workload indicators
- Analysis of these indicators across different tasks

The thesis combines experimental work and data analysis, and will be carried out in the AugmentX research infrastructure at VUB (Brussels). The student will gain hands-on experience with wearable sensors and real experimental data in an industrially relevant context.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : El Makrini Ilias (ilias.el.makrini@vub.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Prediction of pathological complete response after neo-adjuvant treatment in triple negative breast cancer using multimodal and longitudinal data

Description

Background

Triple-negative breast cancer (TNBC) is an aggressive and heterogeneous subtype of breast cancer that primarily affects young women and lacks targeted therapeutic options. Therefore, chemotherapy—and more recently chemo-immunotherapy—constitutes the standard treatment. The pivotal KEYNOTE-522 (KN522) study established the addition of the immune checkpoint inhibitor (ICI) pembrolizumab to neoadjuvant chemotherapy (NACT) as a new standard for high-risk early-stage TNBC, significantly improving pathological complete response (pCR), event-free survival, and overall survival. However, adding an ICI to NACT also leads to increased toxicity and cost, and not all patients derive the same benefit.

To date, no biomarker analysis has identified a subgroup of patients that clearly derives different levels of benefit from adding an immune checkpoint inhibitor. As a result, pembrolizumab combined with neoadjuvant chemotherapy remains the standard of care for high-risk early-stage (stage II–III) TNBC. Identifying patients who could safely avoid immunotherapy is an important ongoing research goal.

Primary objective: to develop a multimodal predictive tool (integrating longitudinal radiological, pathological, and clinical data and deep learning) capable of predicting pathological complete response (pCR) in patients with stage II/III triple-negative breast cancer treated with neoadjuvant chemotherapy combined with an immune checkpoint inhibitor (ICI) according to the KN-522 regimen.

Contact

Prof. Ir. Jennifer Dhont (jennifer.dhont@ulb.be), Head of Data Science & AI Research Unit at Hopital Universitaire de Bruxelles (Erasme campus)

Note: this master thesis topic requires occasional presence on the Erasme campus (Institut Jules Bordet)

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Dhont Jennifer (jennifer.dhont@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

An AI-based automated analysis of electroencephalographic (EEG) recording to aid in the diagnosis of epilepsy

Description

This project aims to develop AI algorithms to automatically detect epileptic patterns in EEG recordings. Manual analysis is time-consuming and prone to variability, especially with large datasets. The work will explore different machine learning approaches, including CNNs and recurrent neural networks. The developed models will be trained and validated on clinical EEG databases. Their performance will be compared with expert annotations and existing methods. The final goal is to support clinicians with reliable, automated tools for epilepsy diagnosis.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Acoustic cough analysis

Description

This project focuses on improving the clinical usability of an acoustic cough analysis tool for patients with swallowing disorders. Current clinical assessments are subjective, while the existing software uses complex features that are difficult to interpret. The goal is to simplify these features into a small number of meaningful indicators. A user-friendly interface will be developed for clinicians to visualize and interpret results. Clinical validation will ensure the tool's relevance and usability in real-world settings. Ultimately, the system aims to help identify patients at risk of lung infections.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Exploitation de signaux hémodynamiques continus pour la détection précoce de profils à risque ischémique après hémorragie méningée

Description

Contexte :

Chez les patients présentant une hémorragie méningée, l'un des enjeux majeurs en réanimation est d'identifier précocement ceux qui risquent de développer un phénomène ischémique secondaire. Ce problème est particulièrement important, car il conditionne la prévention, la surveillance et la prise en charge ultérieure. D'après les échanges avec le service concerné, ce besoin est aujourd'hui peu couvert, alors même que de nombreuses données sont déjà disponibles en pratique : ECG, onde de pouls invasive ou non invasive, pression veineuse centrale, et autres paramètres monitorés en continu. Le contexte est donc particulièrement intéressant, car il combine un besoin clinique réel, un manque de solution satisfaisante, et un accès à des données riches déjà présentes.

Objectif :

L'objectif de ce mémoire est d'étudier si les signaux hémodynamiques disponibles en routine peuvent aider à mieux caractériser les patients à risque d'évolution ischémique après une hémorragie méningée. Le travail pourra porter sur l'exploration de jeux de données existants, l'analyse de tendances ou de profils de signaux, et l'identification d'indices potentiellement utiles pour une détection plus précoce. Ce mémoire vise avant tout à évaluer la faisabilité et la pertinence d'une telle approche, dans un contexte où les données sont abondantes mais encore peu exploitées à cette fin.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Haut Benoit (Benoit.Haut@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Food and house dust mite allergens

Description

Allergy represents an important public health problem. On the one hand, we are developing bioinformatics tools to predict whether a protein corresponds to a food allergen. Such tools are very important for the development of new food products. On the other hand, we are studying certain structural and dynamic properties of house dust mite allergens.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRMAE, M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Gilis Dimitri (dimitri.gilis@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Génération de signaux physiologiques synthétiques plausibles pour la validation de pipelines d'analyse

Description

Contexte : Le développement de nouvelles méthodes d'analyse de signaux physiologiques est souvent limité par l'absence de données parfaitement annotées et par la difficulté d'explorer systématiquement l'impact de certaines variations physiologiques ou de certains artefacts. La génération de signaux synthétiques plausibles constitue alors un outil méthodologique précieux : elle permet de contrôler explicitement les paramètres du système simulé, de reproduire certaines dynamiques physiologiques, et de tester la robustesse de méthodes d'analyse dans un cadre maîtrisé. Objectif : L'objectif de ce mémoire est de développer un cadre simple de simulation de signaux physiologiques plausibles, avec la possibilité d'introduire des variations contrôlées et des perturbations réalistes. L'étudiant travaillera sur la définition des caractéristiques essentielles du signal, la génération de formes d'onde synthétiques et l'utilisation de ces signaux pour tester la robustesse de pipelines d'analyse. Le sujet convient particulièrement à un étudiant intéressé par la modélisation et la validation méthodologique.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Haut Benoit (Benoit.Haut@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Utilisation de Physics-Informed Neural Networks pour l'estimation d'états physiologiques à partir de signaux continus

Description

Contexte : Les approches d'apprentissage automatique classiques offrent une grande flexibilité, mais elles sont souvent peu interprétables et fortement dépendantes de la quantité et de la qualité des données disponibles. À l'inverse, les modèles physiologiques offrent un cadre interprétable, mais leur identification peut être difficile lorsqu'ils sont confrontés à des données bruitées ou incomplètes. Les Physics-Informed Neural Networks (PINNs) proposent une voie intermédiaire, en intégrant des contraintes physiques ou physiologiques dans l'apprentissage. Ils constituent ainsi une approche prometteuse pour relier des signaux continus à des états latents ou paramètres non directement observables. Objectif : L'objectif de ce mémoire est d'explorer l'intérêt des PINNs pour l'estimation de variables physiologiques à partir de signaux continus, dans un cadre simple mais rigoureusement défini. Le travail pourra inclure une revue méthodologique des PINNs, la mise en place d'un cas d'étude pilote, puis une comparaison avec des approches plus classiques de modélisation ou d'apprentissage supervisé. Le mémoire visera à évaluer ce que ces approches hybrides apportent réellement en termes d'identifiabilité, de robustesse et d'interprétabilité dans un contexte biomédical.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Haut Benoit (Benoit.Haut@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Évaluation du potentiel des signaux PPG dans une approche de modélisation physiologique simplifiée

Description

Contexte : Les signaux de photopléthysmographie (PPG) sont particulièrement attractifs en raison de leur caractère non invasif et de leur facilité d'acquisition. En pratique, ils sont toutefois principalement utilisés pour des usages simples, comme l'estimation de la fréquence cardiaque ou de la saturation en oxygène. La question scientifique sous-jacente est de savoir dans quelle mesure ces signaux peuvent être interprétés comme des observations indirectes du système cardiovasculaire, et s'ils peuvent être intégrés à une approche fondée sur la modélisation afin d'en extraire des informations hémodynamiques plus riches. Objectif : L'objectif de ce mémoire est d'évaluer, de manière critique, le potentiel des signaux PPG pour une exploitation modèle-guidée. Il s'agira d'identifier quelles composantes du signal semblent plausiblement reliées à des variables physiologiques d'intérêt, quelles hypothèses de modélisation peuvent être formulées, et dans quelles limites ces approches restent scientifiquement crédibles. Le travail pourra combiner revue de la littérature, analyse exploratoire de données et discussion structurée sur les perspectives et verrous de cette modalité.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Haut Benoit (Benoit.Haut@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Experimental platform for human–exoskeleton collaboration in construction tasks

Description

Many construction and industrial tasks involve handling components, maintaining constrained postures, and performing repetitive operations such as fastening or drilling. These activities can lead to significant physical workload and fatigue.

Industrial exoskeletons aim to support workers during such tasks, but understanding how they interact with human movement in realistic situations remains an open challenge.

In this thesis, the student will develop a laboratory platform to study human–exoskeleton collaboration during simplified construction-like tasks.

The work includes:

- Literature study on exoskeleton use in industrial and construction environments
- Design of a laboratory mock-up (e.g. panel handling, alignment, fastening)
- Development of repeatable task scenarios for experiments
- Integration of wearable sensing technologies to capture human motion
- Pilot experiments with participants
- Analysis of human motion and human–exoskeleton interaction

The thesis combines experimental design, hands-on setup development and data analysis, and will be carried out in the AugmentX research infrastructure at VUB. The student will work on a realistic setup linked to ongoing research in human–robot collaboration.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : El Makrini Ilias (ilias.el.makrini@vub.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

NeuroBridge: From Scanned PDFs to Unified Diagnosis, an AI Pipeline Bridging Radiology and Anatomopathology Reports

Description

Neurological diagnosis draws on two complementary medical specialties, radiology and anatomopathology, yet their reports are produced independently, in inconsistent formats, and often only available as scanned PDF documents. This thesis develops NeuroBridge, an AI-driven pipeline that transforms raw PDF inputs including low-quality scans into structured, machine-readable clinical data. Combining OCR, layout analysis, and domain-specific NLP, the system extracts key diagnostic findings from both report types and maps them onto a shared semantic framework. The outcome is an integrated diagnostic view designed to support clinicians in identifying concordances and discrepancies across the two protocols, reducing the cognitive load of cross-specialty interpretation.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

AI-Driven Assessment of Intestinal Ultrasound for Automated Detection of Inflammatory Activity in Inflammatory Bowel Disease

Description

This project develops an AI-based system to automatically analyze intestinal ultrasound images in Inflammatory Bowel Disease (IBD). The goal is to reduce operator dependency and improve diagnostic consistency. The approach involves a two-step pipeline: first assessing image quality, then detecting inflammatory activity. Deep learning models (e.g., CNNs or transformers) will be trained on annotated datasets. Performance will be evaluated against expert clinicians and standard metrics. This work aims to facilitate wider adoption of ultrasound in IBD monitoring.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

A Web-Based Air Quality Platform for Patient-Centric Environmental Exposure Assessment in Clinical Research

Description

Environmental air quality has a measurable impact on patient health, yet clinicians and clinical researchers currently lack practical tools to assess individual exposure at their home work etc. This thesis builds a web-based platform that takes a patient address as input and automatically queries all available air quality databases to reconstruct a comprehensive environmental exposure profile. The tool is designed to assist clinicians during clinical studies by surfacing relevant environmental context alongside patient records, enabling more informed interpretation of health outcomes and facilitating the inclusion of air quality as a structured variable in clinical research protocols.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Machine Learning-Driven Trace Extraction from Kymographs for Quantitative Analysis of Intracellular Dynamics in Wild-Type and Mutant Models

Description

Kymographs provide a compact visual representation of how particles, vesicles, or molecular motors move along a biological structure over time, making them widely used in studies of axonal transport, ciliary beating, and cytoskeletal dynamics. Despite their utility, extracting meaningful quantitative data from kymographs currently requires laborious manual tracing, a process that is slow, subjective, and poorly scalable when comparing wild-type organisms to genetic mutants across large experimental datasets. This thesis presents a machine learning pipeline that automates the detection and extraction of individual traces from fluorescence kymograph images and derives physiological parameters directly from their geometry and intensity profiles. The system classifies trace populations by directionality and motility state, computes transport metrics such as velocity and run length distributions, and generates structured comparative outputs enabling statistically robust phenotype quantification between experimental groups.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Signal quality in intraneural and extraneural electrodes

Description

This project compares signal acquisition quality between intraneural and extraneural electrodes used for nerve recordings. These electrodes are critical for monitoring vagus nerve activity in neuromodulation applications. A phantom nerve model will be developed to simulate realistic conditions, including noise sources such as electromyographic interference. Both electrode types will be tested to assess signal amplitude, noise, and reliability. The study aims to better understand trade-offs between invasiveness and signal quality. Results could guide the design of more effective neural interfaces.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

AI-Driven Assessment of Rehabilitation Quality Through Joint Angle Trajectory Analysis

Description

Assessing whether a patient is performing rehabilitation exercises correctly and progressing over time is a task that currently depends heavily on the availability and judgment of a trained therapist. This thesis proposes a data-driven platform that uses recorded joint angle measurements to automatically evaluate the quality of rehabilitation sessions. By analyzing angular trajectories captured through wearable sensors or video-based pose estimation, the system computes objective quality indicators such as range of motion compliance, movement symmetry, inter-repetition variability, and adherence to prescribed motion patterns. Machine learning models trained on expert-annotated exercise recordings learn to map these features onto quality scores aligned with clinical standards. The resulting tool provides physiotherapists with structured, session-by-session feedback and longitudinal progress tracking, supporting more informed and personalized rehabilitation management without requiring continuous in-person supervision.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Évaluation de la qualité de signaux physiologiques pulsés en vue d'analyses hémodynamiques avancées

Description

Contexte : L'exploitation quantitative de signaux physiologiques pulsés suppose que ceux-ci soient suffisamment fiables pour refléter la dynamique du système cardiovasculaire. En pratique, ces signaux peuvent être altérés par de nombreux facteurs : artefacts de mouvement, bruit instrumental, saturation du capteur, mauvais couplage capteur-sujet, amortissement, dérive ou pertes de contact. La question de la qualité du signal constitue donc un verrou méthodologique fondamental, car toute inférence physiologique ultérieure dépend de la validité du signal analysé. Objectif : L'objectif de ce mémoire est de développer une méthodologie d'évaluation de la qualité de signaux physiologiques pulsés, afin de distinguer automatiquement les segments exploitables de ceux qui ne le sont pas. Le travail pourra comprendre une revue critique des approches existantes, l'identification de critères objectifs de qualité, l'analyse de signaux réels, puis la mise en place d'un outil de scoring ou de classification. L'enjeu est de produire un cadre méthodologique réutilisable pour des analyses ultérieures de signaux hémodynamiques.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Haut Benoit (Benoit.Haut@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Biophysics of Red Blood Cells and Platelets

Description

This project explores the physical behavior of blood, focusing on red blood cells (RBCs) and platelets (PLTs), which play a key role in processes such as thrombosis and hemorrhage. Blood is a complex fluid composed of deformable and electrically charged cells, making its dynamics difficult to model and understand. The project combines experimental and numerical approaches to investigate how cell shape variability and interactions influence blood flow behavior. A particular focus is placed on platelet transport mechanisms, including unconventional dynamics such as Lévy-flight-like motion observed under certain conditions. Additionally, the role of electrical charges on RBC interactions will be studied by applying electric fields in flow experiments. Overall, the work aims to deepen fundamental understanding of blood biophysics with potential implications for medical research and diagnostics.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Artificial intelligence methods to design ligands for olfactory receptors

Description

The olfactory system relies on protein receptors expressed by olfactory neurons. These olfactory

receptors belong to the family of G protein-coupled membrane receptors (GPCR). The relationships between odorant molecules, targeted olfactory receptors and odour perception are

complex and not yet well understood. In addition, it has been shown that some olfactory receptors are expressed in tissues other than the olfactory epithelium and may have a physiological or potentially therapeutic role.

This project consists in developing artificial intelligence approaches, allowing (1) to predict the

olfactory receptor(s) targeted by an odorant molecule, and (2) to design de novo a molecule able

to activate a given olfactory receptor. It is carried out in collaboration with the group of Prof. I.

Langer (Faculty of Medicine), which experimentally characterises these systems.

The master thesis topics related to this project can be entirely bioinformatics or include an experimental part.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRMAE, M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Gilis Dimitri (dimitri.gilis@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Analyse de signaux cardiovasculaires continus pour aider à l'identification étiologique des AVC ischémiques

Description

Contexte :

Après un AVC ischémique, l'une des questions majeures est de mieux comprendre l'origine de l'événement, en particulier lorsqu'un trouble du rythme ou un mécanisme cardiovasculaire sous-jacent est suspecté. En pratique, cette démarche repose souvent sur des enregistrements prolongés, comme le Holter, et sur des analyses qui peuvent être longues et consommatrices de ressources. La discussion menée avec le service de neurologie suggère qu'il pourrait exister, dans des signaux déjà disponibles comme l'ECG ou certaines ondes de pouls, des informations utiles pour accélérer ou faciliter cette identification, avec un intérêt à la fois clinique et organisationnel .

Objectif :

L'objectif de ce mémoire est d'explorer si des signaux cardiovasculaires déjà acquis en routine chez des patients en stroke unit peuvent apporter une aide supplémentaire pour orienter l'identification étiologique d'un AVC ischémique. Le travail pourra inclure une revue de la littérature, l'analyse exploratoire de signaux disponibles, l'étude de marqueurs ou de patterns potentiellement pertinents, ainsi qu'une réflexion critique sur leur utilité réelle dans ce contexte. Le but n'est pas de remplacer la démarche diagnostique actuelle, mais d'évaluer si une exploitation plus fine de signaux déjà mesurés pourrait contribuer à rendre cette démarche plus rapide, plus objective ou plus efficace.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Haut Benoit (Benoit.Haut@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Depth Camera-Based Person Tracking for Quantitative Balance Assessment

Description

This master's thesis presents a computer vision system for the automatic assessment of postural balance using a depth camera. By leveraging 3D skeletal tracking and point cloud analysis, the system continuously estimates key biomechanical parameters, such as center of mass projection, sway path, and postural stability indices, without requiring wearable sensors or clinical-grade force platforms. The proposed pipeline integrates real-time person detection, joint localization, and temporal motion analysis to produce quantitative balance metrics comparable to standard neuropsychological assessment protocols. The system is evaluated on a cohort of participants under various stance conditions, demonstrating its potential as a low-cost, non-intrusive tool for clinical screening and rehabilitation monitoring in collaboration with neuropsychological practice.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Evaluation and Benchmarking of Feature-Based Registration Pipelines Under Challenging Initial Conditions for Whole-Slide Images

Description

This project focuses on the evaluation of various configurations of a feature-based registration pipeline, with particular attention to their robustness under varying initial conditions in the domain of *Whole-Slide Image* (WSI) registration.

Context

In digital pathology, the integration of information from multiple WSIs is often required to obtain a comprehensive understanding of complex biological processes, such as cancer development and progression. This integration requires accurate spatial alignment of corresponding tissue regions across WSIs, a process referred to as WSI registration. Due to challenges such as image artefacts, varying staining, and large tissue deformations, WSI registration remains a difficult problem in computer vision.

Recent challenges, such as ANHIR

[[Borovec2020](<https://doi.org/10.1109/TMI.2020.2986331>)] and ACROBAT [[Weitz2024](<https://doi.org/10.1016/j.media.2024.103257>)], have brought attention to the state-of-the-art in WSI registration. These challenges evaluate the performance of registration algorithms on real-world datasets comprising multi-stained slides, such as Hematoxylin & Eosin and Immunohistochemistry. Successful approaches generally follow a two-stage process: an initial low-resolution rigid or affine alignment, followed by a high-resolution non-rigid (deformable) registration. This two-step approach effectively constrains the parameter space within which the non-linear elastic transformation is subsequently estimated, thereby significantly improving the quality of the final alignment.

Among the strategies for estimating initial alignment, feature-based methods have emerged as the most widely used, with six out of eight top-performing teams in the ACROBAT challenge employing such techniques

[[Weitz2024](<https://doi.org/10.1016/j.media.2024.103257>)]. Feature-based registration

typically involves three key stages: (i) pre-processing, (ii) local feature extraction, and (iii) robust matching. Each of these stages can be performed using a variety of algorithms, ranging from traditional approaches to deep learning-based methods [[Marzahl2021](<https://proceedings.mlr.press/v156/marzahl21a.html>), [Gatenbee2023](<https://doi.org/10.1038/s41467-023-40218-9>), [Elskens2023](<https://doi.org/10.1109/SIPAIM56729.2023.10373514>), [Wodzinski2024](<https://doi.org/10.1016/j.cmpb.2024.108187>), [Elskens2025](<http://dx.doi.org/10.13140/RG.2.2.29399.79521>)].

Objectives

The main objective of this project is to systematically evaluate and benchmark feature-based registration pipelines with respect to their robustness to challenging initial conditions.

More specifically, the project aims to:

- Quantify the limits of different pipelines in handling:
 - Large translations and rotations
 - Scale variations and geometric distortions
 - Imaging artefacts and staining differences
- Determine failure thresholds, i.e., the maximum level of perturbation beyond which registration performance significantly degrades.
- Propose a novel method to better handle the initial conditions (as a pre-registration step)

Methods

The project will involve a comparative study of several state-of-the-art feature detection and matching algorithms found in recent literature. These may include: SuperPoint [[DeTone2018](<https://doi.org/10.1109/CVPRW.2018.00060>)], LightGlue [[Lindenberger2023](<https://doi.org/10.1109/ICCV51070.2023.01616>)], LoFTR [[Sun2021](<https://doi.org/10.48550/arXiv.2104.00680>)] and OmniGlue [[Jiang2024](<https://doi.org/10.1109/CVPR52733.2024.01878>)]. Each algorithm will be implemented and evaluated under controlled experimental settings.

A novel evaluation protocol will be developed, grounded in existing metrics from the literature while integrating innovative criteria specifically tailored to the tasks explored in this project. The evaluation will include, but not be limited to, assessments of robustness

to large displacements (e.g., rotation, translation, and shear) as well as the ability of each pipeline configuration to effectively filter outliers during robust matching. The goal is to design a comprehensive and reproducible benchmarking approach focused on critical aspects of feature-based registration pipelines within the context of digital pathology.

Prerequisites

Candidates should have:

- A solid foundation in Python programming
- A willingness to work with containerization tools such as Docker (prior experience is a plus but not mandatory)
- Successfully completed INFO-H500 or an equivalent course in image processing, computer vision, or machine learning

Contact person

For further information or to express interest in this project, please contact:

****arthur.elskens@ulb.be**** and ****olivier.debeir@ulb.be****.

References

[Borovec2020] Borovec, J., Kybic, J., Arganda-Carreras, I., Sorokin, D.V., Bueno, G., Khvostikov, A.V., . . . Munoz-Barrutia, A. (2020, October). ANHIR: Automatic Non-Rigid Histological Image Registration Challenge IEEE Transactions on Medical Imaging, 39 (10), 3042-3052, <https://doi.org/10.1109/TMI.2020.2986331>

[Weitz2024] Weitz, P., Valkonen, M., Solorzano, L., Carr, C., Kartasalo, K., Boissin, C., . . . Rantalainen, M. (2024, October). The ACROBAT 2022 challenge: Automatic registration of breast cancer tissue. Medical Image Analysis, 97, 103257, <https://doi.org/10.1016/j.media.2024.103257>

[Marzahl2021] Marzahl, C., Wilm, F., Dressler, F., Tharun, L., Perner, S., Bertram, C., . . . Breininger, K. (2021). Robust Quad-Tree based Registration on Whole Slide Images. Proceedings of Machine Learning Research (Vol. 156, pp. 181-190).

[Gatenbee2023] Gatenbee, C.D., Baker, A.-M., Prabhakaran, S., Swinyard, O., Slebos, R.J.C., Mandal, G., . . . Anderson, A.R.A. (2023, July). Virtual alignment of pathology image series for multi-gigapixel whole slide images. *Nature Communications*, 14 (1), 4502, <https://doi.org/10.1038/s41467-023-40218-9>

[Elskens2023] Elskens, A., Foucart, A., Zindy, E., Debeir, O., Decaestecker, C. (2023, November). Assessing Local Descriptors for Feature-Based Registration of Whole-Slide Images. 2023 19th International Symposium on Medical Information Processing and Analysis (SIPAIM) (pp. 1-4). Mexico City, Mexico: IEEE. <https://doi.org/10.1109/SIPAIM56729.2023.10373514>

[Wodzinski2024] Wodzinski, M., Marini, N., Atzori, M., Müller, H. (2024, June). RegWSI: Whole slide image registration using combined deep feature- and intensity-based methods: Winner of the ACROBAT 2023 challenge. *Computer Methods and Programs in Biomedicine*, 250, 108187, <https://doi.org/10.1016/j.cmpb.2024.108187>

[Elskens2025] Elskens, A., Foucart, A., Debeir, O., Decaestecker, C. (2025, May). Impact of Pre processing and Local Feature Extraction on Feature Based Registration of Whole Slide Images. Preprint at <http://dx.doi.org/10.13140/RG.2.2.29399.79521>

[DeTone2018] DeTone, D., Malisiewicz, T., Rabinovich, A. (2018, June). SuperPoint: Self-Supervised Interest Point Detection and Description. 2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW) (pp. 337-33712). Salt Lake City, UT, USA: IEEE. <https://doi.org/10.1109/CVPRW.2018.00060>

[Lindenberger2023] Lindenberger, P., Sarlin, P.-E., Pollefeys, M. (2023, October). LightGlue: Local Feature Matching at Light Speed. 2023 IEEE/CVF International Conference on Computer Vision (ICCV) (pp. 17581-17592). <https://doi.org/10.1109/ICCV51070.2023.01616>

[Sun2021] Sun, J., Shen, Z., Wang, Y., Bao, H., Zhou, X. (2021, June). LoFTR: Detector-Free Local Feature Matching with Transformers. 2021 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) (pp. 8918-8927). Nashville, TN, USA: IEEE. <https://doi.org/10.1109/CVPR46437.2021.00881>

[Jiang2024] Jiang, H., Karpur, A., Cao, B., Huang, Q., Araujo, A. (2024, June). OmniGlue: Generalizable Feature Matching with Foundation Model Guidance. 2024 IEEE/CVF

Conference on Computer Vision and Pattern Recognition (CVPR) (pp. 19865-19875).
Seattle, WA, USA: IEEE. <https://doi.org/10.1109/CVPR52733.2024.01878>

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Optimized GNNs for Interpretable Brain Connectivity

Description

This project explores the use of Graph Neural Networks (GNNs) to analyze brain connectivity for epilepsy diagnosis. Brain connectivity captures interactions between brain regions and provides richer information than traditional EEG analysis. While previous machine learning approaches showed promising results, more complex GNNs have not yet achieved optimal performance. The objective is to design improved GNN architectures that enhance predictive accuracy. A second key goal is to incorporate explainable AI methods to identify clinically meaningful brain subnetworks. This work bridges advanced machine learning with interpretable neuroscience.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Electrical modeling and control of cold atmospheric plasma for endoscopes

Description

This project investigates the use of cold atmospheric plasma (CAP) for disinfecting endoscope channels. CAP shows strong antimicrobial potential but introduces thermal risks that could damage sensitive medical devices. The work aims to build an electrical and electro-thermal model linking plasma operation to temperature effects. Based on this model, control strategies will be developed to regulate temperature while maintaining disinfection efficiency. Experimental validation will compare open-loop and closed-loop performance. The final objective is a safe, optimized plasma-based sterilization approach for medical applications.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Analyse comparative des signaux ICG et SCG dans une logique d'inférence de variables cardiovasculaires latentes

Description

Contexte : L'impédancemétrie thoracique (ICG) et la seismocardiographie (SCG) représentent deux modalités non invasives permettant d'observer indirectement des phénomènes liés à l'activité cardiovasculaire. Bien que ces signaux soient régulièrement proposés pour l'estimation de variables telles que le débit cardiaque ou certains temps caractéristiques du cycle cardiaque, leur interprétation reste délicate et fortement dépendante du contexte expérimental et de la qualité des mesures. Une question importante est donc de déterminer si ces signaux peuvent raisonnablement être reliés à un modèle cardiovasculaire simplifié permettant l'inférence d'états ou paramètres latents.

Objectif : L'objectif de ce mémoire est de comparer l'ICG et la SCG dans une perspective de modélisation physiologique, afin d'évaluer leur capacité potentielle à informer sur des états internes du système cardiovasculaire. Le travail pourra inclure une analyse comparative de la littérature, une exploration de signaux disponibles, ainsi qu'une réflexion structurée sur les relations possibles entre ces mesures et un modèle simplifié du système. L'enjeu est moins de produire une méthode finale que d'identifier, de manière rigoureuse, les hypothèses les plus plausibles et les limites structurelles de ces modalités.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Haut Benoit (Benoit.Haut@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Depth Camera-Based Person Tracking for Quantitative Balance Assessment

Description

This master's thesis presents a computer vision system for the automatic assessment of postural balance using a depth camera. By leveraging 3D skeletal tracking and point cloud analysis, the system continuously estimates key biomechanical parameters, such as center of mass projection, sway path, and postural stability indices, without requiring wearable sensors or clinical-grade force platforms. The proposed pipeline integrates real-time(opt.) person detection, joint localization, and temporal motion analysis to produce quantitative balance metrics comparable to standard neuropsychological assessment protocols. The system is evaluated on a cohort of participants under various stance conditions, demonstrating its potential as a low-cost, non-intrusive tool for clinical screening and rehabilitation monitoring in collaboration with neuropsychological practice.

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Chemical & Materials
engineering - M-IRMAE

Representation Learning for Polymer Cure: Building a Low Dimensional Embedding of Network Evolution

Description

Context

The behaviour of a curing polymer network is governed by a combination of monomer chemistry, reaction progression, and the evolving topology of the macromolecular structure. Today, no compact set of descriptors exists that can capture this evolution across different chemistries and curing paths, which limits both prediction and design of thermoset materials. Recent advances in data driven modelling provide a new opportunity: instead of imposing predefined descriptors, one can learn a reduced “state” directly from physically consistent simulations of network formation.

Objective

This master thesis aims to develop and analyse a low dimensional embedding (feature vector) that captures the essential features of curing polymer networks. The embedding will be learned from large, synthetic datasets generated by simplified, physically consistent polymerization models. The emphasis is on discovering interpretable patterns and identifying the conditions under which different curing histories converge to similar states.

Expected work

- Generate a synthetic dataset of curing trajectories using provided tools (conversion histories + evolving structural descriptors).
- Construct descriptors of monomer chemistry using group contribution theory and cohesive interaction parameters.
- Train a self supervised model to learn a compact embedding that jointly represents chemistry, conversion and network topology.
- Analyse the embedding for physical meaning, robustness and invariance across stoichiometry, functionality and cure paths.
- Identify when different curing trajectories collapse onto similar states, and where the limits of state reduction appear.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS

Nombre de sujets	1
-------------------------	---

Supervision

Supervisor : Van Assche Guy (Guy.van.assche@vub.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Adaptable Tensor Display

Description

Develop a fully functional prototype of a **configurable tensor display** with a professional finish.

Context

Tensor Display, also called compressive light display, or multi-layer light filed display, are a class of glasses-free 3D displays. They typically consist of stacked LCD layers placed in front of a backlight. While three-layer systems are common, configurations with 2, 3, or 4 layers are also used, and the spacing between layers is an important design parameter.

Objective

Design and build a hardware and software platform for a tensor display that can be easily reconfigured.

The prototype should support:

- Switching between 2, 3, or 4 layers
- Adjusting the spacing between layers
- Software control capable of operating the display under different configurations

The key goals are:

- * Building a modular tensor display prototype with interchangeable mechanical components
- * Developing the software to operate the display in multiple configurations
- * Integrating all elements into a robust, polished prototype

Prerequisite

* Programming skills in C++ and Python

* Basic knowledge of CAD and 3D printing is recommended but not mandatory

Supervision

Supervisors : Daniele Bonatto, Eline Soetens

Contact person : Eline Soetens (eline.soetens@ulb.be)

####

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Bonatto Daniele (daniele.bonatto@ulb.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Adaptable Tensor Display

Description

Develop a fully functional prototype of a **configurable tensor display** with a professional finish.

Context

Tensor Display, also called compressive light display, or multi-layer light filed display, are a class of glasses-free 3D displays. They typically consist of stacked LCD layers placed in front of a backlight. While three-layer systems are common, configurations with 2, 3, or 4 layers are also used, and the spacing between layers is an important design parameter.

Objective

Design and build a hardware and software platform for a tensor display that can be easily reconfigured.

The prototype should support:

- Switching between 2, 3, or 4 layers
- Adjusting the spacing between layers
- Software control capable of operating the display under different configurations

The key goals are:

- * Building a modular tensor display prototype with interchangeable mechanical components
- * Developing the software to operate the display in multiple configurations
- * Integrating all elements into a robust, polished prototype

Prerequisite

* Programming skills in C++ and Python

* Basic knowledge of CAD and 3D printing is recommended but not mandatory

Supervision

Supervisors : Daniele Bonatto, Eline Soetens

Contact person : Eline Soetens (eline.soetens@ulb.be)

####

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Bonatto Daniele (daniele.bonatto@ulb.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Hexagonal Fourier transform for Compression of Plenoptic images

Description

Description

Plenoptic cameras (such as Raytrix) possess a main lens, a sheet of micro-lens, and a CMOS sensor. This special design offers the possibility to capture directional light rays and thus, 3D information about the scene. These cameras are called Light field cameras and are theoretically more suitable for 3D and VR applications than conventional cameras. Due to their structure, they capture an image composed of many micro-images placed in a hexagonal grid, creating patterns that are non-optimal to compress using the JPEG algorithm, even if the image itself presents redundancies that are not exploited. The JPEG algorithm divides the image in blocks then uses the Fourier transform to compute the blocks in the frequency domain. Then, only the most significant frequencies for the human eye are encoded, creating a low-storage representation of the image. To decompress the image, the inverse operation is performed.

Context

The aim of this thesis is to design a compression scheme using a hexagonal lattice for images in plenoptic format, and explore its efficiency. Using block sizes corresponding to the micro-images will simplify the encoding of the hexagonal image structure. Several datasets captured with different plenoptic cameras (in micro-image size, resolution, depth of field) will be tested and compared with the MPEG explorations of lenslet video coding activities.

Objective

At the end of the year, the student must present

An implementation of a hexagonal block-based adaptation of the JPEG compression
Compute its efficiency compared to classical image compression framework with MPEG standards

Prerequisite

C++ / python

Any multimedia course

Contact person

sarah.dury@ulb.be, daniele.bonatto@ulb.be

References

Hexagonal image processing :

L. Middleton et J. Sivaswamy, Hexagonal image processing: a practical approach, Springer. in Advances in pattern recognition, no. Advances in pattern recognition. London: Springer, 2005.

Plenoptic camera :

C. Perwass et L. Wietzke, Single lens 3D-camera with extended depth-of-field, IS&T/SPIE Electronic Imaging, Burlingame, California, USA, 2012, p. 829108. doi: 10.1117/12.909882.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Bonatto Daniele (daniele.bonatto@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Transducer-based quantum algorithms

Description

Transducers are a new framework to design quantum algorithms that has several advantages: it is relatively simple, leads to optimal algorithms in the quantum query complexity model, while also allowing to control quantum time complexity [1], and is inherently error-free which makes it possible to compose subroutines with incurring additional log factors [2].

The goal of this Master Thesis would be to develop new quantum algorithms based on transducers, starting by translating known quantum algorithms in this framework, and potentially leading to new applications.

[1] Aleksandrs Belovs, Stacey Jeffery, and Duyal Yolcu. Taming Quantum Time Complexity. Quantum 8, 1444 (2024). [<https://quantum-journal.org/papers/q-2024-08-23-1444/>]

[2] Aleksandrs Belovs, Stacey Jeffery. Space-Efficient Quantum Error Reduction without log Factors. arXiv:2502.09249. [<https://arxiv.org/abs/2502.09249>]

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Roland Jérémie (Jeremie.Roland@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Automating 3D Geometric Measurement of Mechanical Test Benches Using Structured Scanning and Point Cloud Analysis

Description

Mechanical test benches must meet strict geometric tolerances to ensure that experimental measurements accurately reflect material and structural behavior rather than setup artifacts. Verifying these tolerances manually is a slow and error-prone process that becomes particularly burdensome when benches are frequently reconfigured or when high-precision applications demand exhaustive dimensional audits. This thesis designs and validates an automated system that acquires the complete 3D geometry of a mechanical test bench using a scanning sensor mounted on a motorized positioning stage, and processes the resulting point cloud data to extract quantitative geometric parameters without manual intervention. The system plans acquisition trajectories to ensure full coverage, registers multi-view scans into a unified coordinate frame, and computes deviations from CAD reference geometry to identify misalignments, deformations, and tolerance violations. Output is presented as an interactive 3D deviation map and a structured dimensional report, giving mechanical engineers a rapid, reproducible qualification tool that replaces manual measurement campaigns and supports traceability in accredited testing environments.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Privacy-by-Design People Counting in Lecture Halls Using an Embedded Depth Camera System

Description

This master's thesis addresses the challenge of occupancy monitoring in academic environments through the design of a GDPR-compliant, privacy-by-design vision system capable of counting individuals in a lecture hall without capturing or processing any identifying information. Built around a low-power embedded platform, it requires a lightweight inference pipeline, optimised for constrained hardware, performs robust people detection and counting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

GPS and IMU-Aided Time-Lapse Imaging Platform for Automated Condition Monitoring of Linear Infrastructure

Description

Roads, canals, and other linear infrastructure assets degrade gradually over time, yet systematic visual monitoring of these structures at scale remains logistically complex and costly. This thesis designs and validates a mobile time-lapse camera system that acquires continuous image sequences along linear infrastructure corridors, enriched with GPS position and IMU orientation data at each capture event. By anchoring every frame to a precise spatial reference, the system enables the construction of georeferenced image timelines that can be compared across acquisition campaigns to detect and localize structural changes. Automated analysis modules identify surface deterioration, deformation patterns, and anomalies by applying computer vision techniques to temporally aligned image pairs. The result is a practical, low-cost survey tool that provides infrastructure managers and engineers with a structured, queryable visual record of asset condition, supporting proactive maintenance decisions and regulatory reporting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Machine Learning-Based Digitization of Seismic Traces from Scanned Historical Seismograms for Archival Data Recovery

Description

Seismological observatories worldwide hold vast collections of paper seismograms recording earthquakes and ground motion events going back to the late nineteenth century. This historical data is of exceptional scientific value for long-term seismic hazard assessment, source characterization of pre-instrumental earthquakes, and the calibration of modern seismic models, yet it remains largely inaccessible because converting analog traces into digital waveforms requires expert manual tracing on a record-by-record basis. This thesis builds a machine learning system that automates the recovery of seismic waveform data from scanned seismogram images. Starting from raw scan inputs, the pipeline handles document restoration, trace isolation, and waveform vectorization, translating the visual trace geometry into calibrated time series data that can be ingested by standard seismological software. The system is designed to process large archival collections with minimal human intervention, enabling seismologists to unlock decades of previously inaccessible observational data for modern reanalysis.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Improving sparse wearable motion tracking using IMU and UWB sensor fusion

Description

Wearable motion sensing using inertial measurement units (IMUs) is widely used for motion analysis and ergonomic monitoring. However, accurate motion reconstruction typically requires multiple sensors, which can be intrusive and difficult to deploy in real environments.

Using a reduced number of sensors is more practical, but often leads to reduced accuracy and ambiguities in motion estimation.

In this thesis, the student will investigate how combining IMU measurements with ultra-wideband (UWB) ranging can improve motion tracking using a minimal set of wearable sensors.

The work includes:

- Literature study on wearable motion tracking and sparse sensing
- Exploration of IMU and UWB sensing hardware
- Development of a simple experimental setup combining both modalities
- Collection of motion data during representative upper-body movements
- Implementation of a basic sensor fusion approach
- Evaluation of reconstructed motion against a reference system

The thesis combines sensing, algorithm development and experimental validation, and will be carried out in the AugmentX research infrastructure at VUB. The student will work on a challenging and relevant problem in wearable sensing and motion tracking.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : El Makrini Ilias (ilias.el.makrini@vub.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Flight trajectory-based UAV classification

Description

Context:

Recent conflicts have highlighted the growing operational importance of Unmanned Aerial Vehicles (UAVs) and the urgent need for countermeasures that rely on reliable identification and recognition systems. One promising direction for UAV classification is the analysis of flight trajectories, which can reveal distinct behavioral patterns characteristic of different drone types. Radar-based UAV trajectory classification builds on this principle by using radar systems, typically frequency modulated continuous wave (FMCW) radars, to track airborne targets and extract motion related features.

Objectives:

The goal of this project is to design a reliable UAV classification method based on flight trajectory analysis, combining dynamic motion modeling with deep learning. The approach focuses on describing drones through their motion patterns, since different UAV types often exhibit characteristic behaviors shaped by their design and control systems. To do this, the project will extract key behavioral features from trajectory data - such as velocity changes, acceleration profiles, turning behavior, and maneuverability. These features will then serve as inputs to deep learning models capable of handling time-dependent data, including recurrent neural networks (RNN) such as LSTM or GRU or transformer based architectures.

Methodology :

- Identify main databases of UAV trajectories in the literature and define UAV categories
- Build a radar observation model and extract relevant features
- Train and validate a deep-learning model based on RNN or transformers for UAV classification
- Assess the classification performance with confusion matrices

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Horlin Francois (francois.horlin@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Homecare Radar Fall Detection

Description

Context:

One of today's challenges consists in taking care of elderly persons. In particular, within the

context of society 5.0, it is considered as a real possibility to have elderly people stay longer

at home, which require robust and reliable sensing capabilities to warn relatives about potential issues. Moreover, even when in nursing home, elderly people need to be monitored. In particular, monitoring the fall of people is one of the major issue as it can happen any time.

This monitoring is today based on sensors relying on imaging techniques, which has the main drawback of not preserving the privacy of the people. Moreover, the false alarm rate is too high, which results in a non-trustable solution.

To counter these two aspects, SDR-Engineering has developed a radar platform and the associated signal processing to robustly detect the fall of people.

Objectives:

The project aims to validate and refine existing signal processing algorithms to detect the fall

of (elderly) people using radar signals. The refined algorithms will then be ported on the existing radar platform, and tested in a real environment.

Methodology :

- Understand the existing signal processing algorithms on Matlab.
- Acquire radar signals in various environments.
- Validate & suggest improvements for the existing algorithms based on defined KPIs.
- Implement the improved algorithms.

Langue	EN (english)
Ouvert à d'autres masters	Yes

Masters concernés	M-IRCBS, M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Horlin Francois (francois.horlin@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Design, implementation and testing of an FM-based Wireless CAN protocol

Description

Motivation

The Controller Area Network (CAN) bus protocol is used for cabled broadcast networks in industrial and automation environments. It is favored because it guarantees low latency, prioritization of messages and heavy network loading. One of the unique features of CAN busses is its medium access control protocol, the CSMA/NDA protocol. Thanks to a concept of dominant and recessive bits on the communication bus, the CSMA/NDA implements a protocol that determines which nodes gets access to the medium without losing any time or bandwidth.

It was commonly thought that CSMA/NDA could only be implemented in cabled networks, but we've recently proven that it is possible to define a wireless PHY layer protocol that is compatible with the CSMA/NDA protocol of the MAC layer. In a proof-of-concept experiment, we designed and tested wireless transceivers that are fully compatible with the CAN controller of our microcontroller systems, proving the feasibility of wireless CAN (WiCAN) communications.

However, our current systems has several problems:

- Data rates are limited because of the wireless transceivers that are used;
- The system lacks robustness, as any wireless interferer could impact the WiCAN system.

To tackle these problems, it is proposed to evaluate the feasibility of a Frequency-modulation (FM)-based WiCAN system, where the dominant/recessive bit mechanism is implemented in a digital system. The proof-of-concept demonstrator will be based on simple, off-the-shelf components. Additionally, such a solution would allow to superimpose CDMA to the FM-based WiCAN to increase the robustness of the system

Objective

This Master's thesis will have to perform the following tasks :

- Design a FM-based Wireless CAN system using off-the-shelf components, and integrate it with a commercial CAN controller;
- Design the digital logic in the FPGA using the available logic on PSOC

microcontrollers;

- Add and test the CDMA to the FM-based WiCAN system

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Quitin Francois (francois.quitin@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

[JUNO1] Generative AI for Fast Detector Simulation in Low-Level Trigger Studies

Description

The Jiangmen Underground Neutrino Observatory (JUNO) is a large particle physics experiment whose main goal is to act as a multipurpose observatory for neutrinos produced by artificial and natural sources. JUNO is currently in construction in the Jiangmen underground facility in Southern China.

- **Background:** Accurate simulation of detector response is fundamental for developing and optimizing trigger algorithms in high-energy physics experiments like JUNO. However, traditional Monte Carlo (MC) methods, while precise, are computationally intensive, creating a significant bottleneck for the rapid exploration and tuning of low-level trigger strategies.

- **Objective:** This project aims to develop and validate a fast simulation framework based on Generative AI to produce realistic JUNO detector response data tailored specifically for low-level trigger algorithm research. The goal is to drastically reduce the time needed for data generation compared to full MC simulations, while maintaining sufficient fidelity for trigger-relevant features, thereby accelerating the trigger R&D cycle.

- **Methodology:** The research will leverage JUNO's unique structure (20,000 Photo-Multiplier Tubes (PMTs), representable as a graph) and the availability of high-fidelity MC simulation data for training.

- **Key steps include:**

- Designing and optimizing generative AI models (e.g., Graph Neural Networks combined with GANs, VAEs, or Diffusion Models) capable of capturing the spatio-temporal characteristics of PMT responses.

- Training these models on large datasets generated by the existing, reliable JUNO simulation tools.

- Developing rigorous validation metrics to compare AI-generated data against MC data, focusing on distributions and correlations critical for low-level triggering (e.g., hit times, charge patterns, cluster properties).

- Demonstrating the utility of the fast simulator by integrating it into a typical workflow for trigger algorithm evaluation or optimization.

- **Expected Outcomes:** The primary outcome will be an efficient and validated generative AI model capable of rapidly producing JUNO detector response data. The research will

provide a quantitative assessment of the speed-up factor and the fidelity achieved compared to traditional MC methods.

• Keywords: Generative AI, Deep Learning, Detector Simulation, Fast Simulation, Surrogate Modeling, JUNO, Trigger System, Low-Level Trigger, Monte Carlo Simulation, Graph Neural Networks, High Energy Physics.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Robert Frederic (frederic.robert@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Integrated Communication and sensing with 5G 28 GHz mm-wave beamsteering arrays

Description

Motivation

The 5G standard dedicated several gigahertz of bandwidth around 28 GHz for high-rate, low-range communications. One main characteristic of 28 GHz wireless propagation channels is that they are very sparse and deterministic: there are only a few multipath components, but those multipath are very deterministic and reliable. This makes 28 GHz wireless systems an interesting candidate for Integrated Communication and Sensing (ISAC) systems, where the communication signals are also used to perform sensing of the environment, in a radar-like fashion.

Another advantage of 28 GHz wireless systems is that to overcome the large path loss at millimeter-wave frequencies, large antenna arrays are required. This allows for very directional beamsteering, providing angular information for both communication and sensing operations.

Our previous research has demonstrated the feasibility of 28 GHz ISAC for determining the position and the trajectory of pedestrians in indoor environments, both theoretically and experimentally. The objective of this master thesis will be to determine whether this concept is also feasible in practical deployments.

Objective

This Master's thesis will investigate the ability of a 28 GHz beamsteering system to identify and track obstacles moving through the field of view of a 28 GHz communication system in a practical deployment. The student will need to:

- Propose several scenarios of practical deployments for 28 GHz communication systems, and determine the sensing capabilities for each deployment;
- Learn how to use the 28 GHz software-defined radio setup at the lab for practical experimentations;
- Validate the theoretical predictions of sensing capabilities for various deployments through experimental measurements.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Quitin Francois (francois.quitin@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

[JUNO2] An Intelligent Agent System for Automated Monitoring and Debugging Support of the JUNO Electronics system

Description

The Jiangmen Underground Neutrino Observatory (JUNO) is a large particle physics experiment whose main goal is to act as a multipurpose observatory for neutrinos produced by artificial and natural sources. JUNO is currently in construction in the Jiangmen underground facility in Southern China.

- **Background:** The JUNO Electronics system is a complex, distributed system responsible for processing signals from 20,000 PMTs (photomultipliers). Ensuring its stable operation requires continuous monitoring of performance metrics, analysis of large data volumes, and timely diagnosis of potential hardware faults. Current approaches often rely heavily on manual inspection and expert intervention, which can be time-consuming and difficult to scale, especially with evolving personnel.
- **Objective:** This project aims to develop an Intelligent Agent system designed to automate the monitoring, analysis, and debugging support workflow for the JUNO Electronics system. The agent will act as an "intelligent assistant," proactively analyzing operational data, identifying anomalies, providing contextual information, and streamlining the troubleshooting process for human experts.
- **Methodology:** The research will focus on integrating modern AI agent frameworks with existing analysis tools and domain knowledge.

Key steps include:

- Designing the agent architecture using a framework like AutoGen or LangChain, enabling it to perceive system status, plan analysis steps, and execute actions.
- Implementing automated workflow execution, allowing the agent to orchestrate existing data analysis scripts and algorithms (developed by previous researchers) as callable "tools."
- Developing data-driven anomaly detection modules to continuously monitor key performance indicators and flag statistically significant deviations potentially indicative of hardware issues.
- Building a local JUNO Electronics system knowledge base (from design documents, historical logs, expert notes) and integrating it using Retrieval-Augmented Generation (RAG) with Large Language Models (LLMs) and vector databases. This allows the agent to query the knowledge base to provide context for anomalies or answer expert queries.

-Designing the system with modularity and extensibility in mind, allowing easy integration of new tools, data sources, or diagnostic capabilities.

- Expected Outcomes: The project will deliver a functional prototype of the Intelligent Agent system for JUNO Electronics system monitoring and debugging support, including demonstrated automation of routine analysis tasks, successful identification of predefined anomaly types, effective knowledge retrieval via RAG, and a well- documented, extensible framework. This system aims to significantly enhance operational efficiency, accelerate problem resolution, and preserve critical expert knowledge for the JUNO experiment.

- Keywords: Intelligent Agents, AI Agent, Automation, System Monitoring, Fault Diagnosis, Debugging Support, JUNO, Backend Electronics , Workflow Automation, Knowledge Base, RAG (Retrieval-Augmented Generation), Large Language Models (LLM), Anomaly Detection, High Energy Physics Operations, Extensible Framework.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Robert Frederic (frederic.robert@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Device localization with 5G 28 GHz mm-wave beamsteering arrays

Description

Motivation

The 5G standard dedicated several gigahertz of bandwidth around 28 GHz for high-rate, low-range communications. To overcome the large path loss at millimeter-wave frequencies, large antenna arrays are required. We developed a pair of 28 GHz software-defined radios (SDRs), using conventional SDRs for generating the baseband signals, and a 16-antenna array for beamsteering. With our setup, signals with bandwidths up to 100 MHz can be generated, and the transmitter and receiver beams can be steered in azimuthal and elevation space through a digital control link.

Since the transceiver's beams are quite narrow, it is possible to identify the angle-of-arrival and angle-of-departure of the signal, which eventually allows to locate the transmitter node. High-accuracy localization of transmitters in 28 GHz is one of the many benefits of 28 GHz communications in 5G.

Objective

This Master's thesis will investigate the localization of a 28 GHz Tx in a beamsteering 28 GHz system. The main problem is that the process of changing the beam's direction is not instantaneous, but rather takes between 1 and 10 milliseconds. Performing a full scan of all Tx and Rx directions is not a feasible option in practice. A better approach is to rely on a theory called Design of Experiments, which is an information-theoretic approach to determine future beam directions based on past experiments to allow for real-time tracking of moving transmitters. The algorithm could use only the array at the Rx side, or both Tx and Rx arrays. The proposed algorithms will be implemented and evaluated experimentally using the 28 GHz testbed, and the localization accuracy will be investigated.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Quitin Francois (francois.quitin@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Radar-Based Pedestrian Tracking with Recurrent Neural Networks

Description

Context:

Understanding pedestrian mobility patterns enables better infrastructure planning, reduced congestion, and improved user experience. Tracking pedestrian trajectories in public areas is therefore essential to promote soft mobility. Cameras are often used but suffer from poor performance in low-light conditions and raise privacy concerns. In contrast, radars can accurately detect and track motion under challenging conditions while preserving privacy. They are also low-cost and easy to deploy.

The most common technology is the Frequency Modulated Continuous Wave Radar (FMCW), which estimates target range and Doppler and often uses MIMO antenna arrays to determine target angles. Recent FMCW radars operate at millimeter-wave frequencies. While radar has proven effective for pedestrian tracking, most studies focus on scenarios with only a few individuals and aim mainly at counting or classifying targets. However, critical situations require simultaneously tracking the trajectories of many individuals.

Objectives:

Once the radar system is properly designed and implemented, the detections obtained after radar signal processing must be further processed to enable the recovery of pedestrian trajectories. Classical approaches typically combine a Kalman filter with a data association algorithm. In this work, the use of recurrent neural networks (RNN) designed to process sequential data will be considered for radar-based tracking.

Methodology:

- Understand the physical principles and signal processing of the Frequency-Modulated Continuous Wave Radar.
- Master machine learning concepts in order to rigorously justify the choice of the selected RNN for pedestrian tracking using radar data. Advanced RNN architectures such as the LSTM and GRU will be considered.
- Train the model and validate its performance using both simulations and real-world

measurements (the real-world measurements will be provided).

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Horlin Francois (francois.horlin@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

Design, implementation and testing of a wideband Wireless CAN protocol

Description

Motivation

The Controller Area Network (CAN) bus protocol is used for cabled broadcast networks in industrial and automation environments. It is favored because it guarantees low latency, prioritization of messages and heavy network loading. One of the unique features of CAN busses is its medium access control protocol, the CSMA/NDA protocol. Thanks to a concept of dominant and recessive bits on the communication bus, the CSMA/NDA implements a protocol that determines which nodes gets access to the medium without losing any time or bandwidth.

It was commonly thought that CSMA/NDA could only be implemented in cabled networks, but we've recently proven that it is possible to define a wireless PHY layer protocol that is compatible with the CSMA/NDA protocol of the MAC layer. In a proof-of-concept experiment, we designed and tested wireless transceivers that are fully compatible with the CAN controller of our microcontroller systems, proving the feasibility of wireless CAN (WiCAN) communications.

However, our current systems has several problems:

- Data rates are limited because of the wireless transceivers that are used;
- The system lacks robustness, as any wireless interferer could impact the WiCAN system.

To tackle these problems, it is proposed to evaluate the feasibility of a high-bandwidth WiCAN system, and evaluate its feasibility on a software-defined radio testbed.

Objective

This Master's thesis will have to perform the following tasks :

- Evaluate which type of high-bandwidth system (OFDM, SC-FDE, CDMA) would be the best candidate for high-bandwidth WiCAN systems;
- Prototype a proof-of-concept system on software-defined radios to prove the feasibility of high-bandwidth WiCAN communications. The proof-of-concept prototype will first run offline (i.e. not real-time)
- In order to reach a real-time implementation, the proposed design will be ported to

the FPGA of the software-defined radio.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Quitin Francois (francois.quitin@ulb.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

On-line measurement and validation of thermal gradients during 3D metal printing through IR-camera measurements.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible.

Fig. 2 shows a 3D tower part that has been manufactured in a hybrid way with the MiCLAD machine. During the DED process, the thermal history of the part is very important for the final quality and directly influences the residual stresses. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters and build strategy on the thermal history of the part.

In this context, two thermal cameras (FLIR and SWIR) have been integrated into the machine, and a dedicated tool has been developed to enable in-process thermal gradient monitoring. The use of both cameras allows for broader thermal range coverage, capturing the various temperature the part experiences during the process. The tool enables simultaneous recording from both cameras and provides real-time visualization of thermal gradients through a dedicated application, with the aim of enabling online thermal gradient control in the future. An example of a captured thermal field of the build plate during

process is shown in Fig. 5.

This setup and tool now require further development and validation to assess the accuracy of the results. To this end, an experimental campaign will be conducted under varying

heat input boundary conditions, primarily focusing on laser power and build plate preheating settings. The resulting data will be analyzed to gain a deeper understanding of the thermal history of parts during the DED process and ultimately to reduce the thermal gradient and resulting residual stresses.

In parallel, the measured thermal gradients will be compared with numerical simulations using an existing DED process model. This comparison aims to validate the model as well as the associated material parameters (such as density, latent heat, and heat capacity) and boundary conditions against the experimental results. A specific parameter matrix will be defined for both the experimental and numerical campaigns. The thermal history simulations will be carried out using Morfeo (Manufacturing Oriented Finite Element tOol), an extended finite element (FEM) code developed by the Belgian research center Cenaero [3].

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Post-processor extension to 3D material allocation for metal 3D printing through Directed Energy Deposition manufacturing process.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part/sprocket that has been manufactured with the MiCLAD machine.

Functionally Graded Materials (FGM) are components with gradual changes in composition or structure across their volume, designed to optimize mechanical or thermal performance. In DED, FGMs are produced by dynamically adjusting the metal powder or wire feed rates during the deposition process. This enables smooth transitions between different metal alloys (e.g., stainless steel to copper), reducing residual stresses and improving bonding. Such FGMs are ideal for applications requiring a combination of properties like high strength, corrosion resistance, and thermal stability within a single part.

FGMs are used for example in injection molding molds, as shown in Fig. 3 [3], to optimize performance by combining high thermal conductivity near the mold surface for faster cooling with a tougher core for structural strength. This gradient in properties improves cycle times, reduces wear, and extends mold life. The production of such a part required a

different material allocation in 3 dimensions (x, y, and z), see Fig. 4.

CAD/CAM software (Computer-Aided Design / Manufacturing) plays a crucial role in DED by converting CAD models into toolpaths that guide the deposition head and define process parameters. However, current commercial solutions lack the capability to handle FGMs by assigning specific materials and corresponding process settings to precise locations within a part. To address this, the AM-Lab developed the CamLink post-processor, which serves as a translator between the CAD/CAM software and the CNC machine, enabling advanced control over material deposition.

It allows the generation of machine compatible Gcode from any geometry, incorporating the desired material gradient at specified locations, via a standalone MATLAB application. However, at this stage, material allocation is limited to the -z and -x directions. An example of a composition transition from copper to 316L in the x-direction is shown in Fig. 6–7.

The aim of this master thesis is to further develop the existing CamLink post-processor to enable material allocation in all three spatial dimensions, thereby allowing complete design freedom in the manufacturing of FGMs. In the next phase, this extension will be validated through simple experiments using the DED machine. Subsequently, process parameters will be optimized, based on microstructural analysis, to ensure defect-free transitions between material compositions. Finally, the enhanced post-processor will be validated through the production of a demonstrator part featuring composition gradients in all three directions.

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Numerical study for thermal gradient reduction during 3D printing Directed Energy Deposition process.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part that has been manufactured on the MiCLAD machine.

During the DED process, the thermal history of the part is very important for the final quality and directly influences the residual stresses, see Fig. 3. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters and build strategy on the thermal history of the part. Next to the process parameters, as shown on Fig. 3, buildplate preheating involves heating the baseplate before material deposition begins, is also used to reduce the thermal gradients.

Preheating minimizes the temperature difference between the incoming molten material and the cooler buildplate. This helps controlling the thermal history of the part, and might lead to better overall quality of the printed part.

The aim of this master thesis is to investigate numerically the effect of temperature dependent material parameters (density, latent heat, heat capacity, ...) and build plate

preheating settings on the thermal history of the part.

The DED thermal history simulations are runned with Morfeo (Manufacturing Oriented Finite Element tOol) an eXtended Finite Element (X-FEM) code developed by the Belgian research center Cenaero [4] and compared with the in-situ thermal monitoring tools available on the MiCLAD (pyrometer data and hyperspectral melt pool temperature estimation).

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Thermo-mechanical simulation of milling process on 3D printed metal parts.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part that has been manufactured on the MiCLAD machine.

During the additive and subtractive operations, the thermal history of the part is very important for the final quality and directly influences the residual stresses. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters and build/cutting strategy on the thermal history of the part. The MeMC and MECH departments of the VUB are cooperating to study these effects in the context of the HiPAS SBO project [3].

The DED thermal history simulations are runned with Morfeo (Manufacturing Oriented Finite Element tOol), an eXtended Finite Element (X-FEM) code developed by the Belgian research center Cenaero [4] and compared with the in-situ thermal monitoring tools available on the MiCLAD (pyrometer data and hyperspectral melt pool temperature estimation).

The aim of this master thesis is to extend the existing simulation tool of the DED addition process by investigating numerically the effect of a post milling operation (subtraction process) on the thermal history and residual stresses of a DED part, and to identify the main influencing parameters [5,6].

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Thermo-mechanical simulation of ablation process on 3D printed metal parts.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part that has been manufactured on the MiCLAD machine.

Hybrid Additive Manufacturing is based on the combination of multiple processes improving the cost, quality, functionality, and efficiency of the

parts [3]. Possible examples of additive-subtractive combination are Hybrid-AM by Machining or hybrid-AM by Ablation [4]. The MiCLAD machine is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive milling operations for the production of a part. The lab is also equipped with an external ablation stage that will be soon integrated in the machine.

During the additive and subtractive operations, the thermal history of the part is very important for the final quality and directly influences the residual stresses. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters on the thermal history of the part. The MeMC and MECH departments of the VUB are cooperating to study these effects in the context of the HiPAS SBO project [5].

The DED thermal history simulations are runned with Morfeo (Manufacturing Oriented Finite Element tOol), an eXtended Finite Element (X-FEM) code developed by the Belgian research center Cenaero [6] and compared with the in-situ thermal monitoring tools available on the MiCLAD (pyrometer data and hyperspectral melt pool temperature estimation).

The aim of this master thesis is to extend the existing simulation tool of the DED addition process by investigating numerically the effect of the ablation process (subtraction process) on the thermal history and residual stresses of a DED part, and to identify the main influencing parameters [7].

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Development and test of an in-situ monitoring framework for wire-based Directed Energy Deposition

Description

This master thesis focuses on the implementation of a synchronized in-situ monitoring framework for the LW-DED system at VUB AMRL, the generation of a multi-modal dataset through a structured experimental campaign, and its preliminary analysis using unsupervised learning techniques. The objective is to establish a foundation for future intelligent monitoring and control strategies, ultimately improving process reliability and part quality.

Langue	FR (français)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : De Baere Dieter (dieter.de.baere@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Clean energy & sustainable propulsion: Adjoint optimization for LES of hydrogen flames

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and burner geometries need to be adapted.
- The goal is to couple an adjoint based optimization algorithm with an existing LES framework, which models hydrogen combustion.
- The goal is to apply the developed framework to a particular burner geometry and optimize it, e.g. such that minimal emissions are obtained.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Cybersecurity of electric power systems

Description

Modern power systems have evolved into complex Cyber-Physical Power Systems (CPPS) due to the rapid integration of advanced sensors, communication networks, and computing technologies, which are needed to manage the energy transition (e.g., management of the variability of renewable energy sources). Ensuring the cybersecurity of CPPS has thus become of utmost importance for maintaining the stability and reliability of future electricity grids. This MSc will aim at analyzing the cybersecurity either of a microgrid (option 1) or of a transmission system (option 2), and at proposing solutions to improve it.

Regarding option 1, the idea will be to study experimentally cyber-attacks towards pieces of equipment that are typical of microgrids gathering a few households: smart meters, solar PV systems, batteries, EV chargers, smart loads, etc. based on the smart electric energy systems lab under development within BEAMS.

Option 2 is expected to focus on False Data Injection Attacks (FDIAs). They stealthily manipulate measurement data, potentially bypassing traditional bad data detection mechanisms. A successful FDIA can mislead the State Estimation (SE) process — as a grid monitoring tool — thereby causing incorrect operational decisions and potentially causing serious physical and economic impacts on the power system. The MSc thesis will then aim to conduct a probabilistic cybersecurity assessment of Remote Terminal Units (RTUs) and the State Estimation function under FDIA scenarios. The student will begin by identifying potential vulnerabilities in RTUs and SE through established threat modeling techniques. Building on this analysis, a probabilistic framework will be developed—using methods such as attack trees and attack graphs—to estimate the likelihood of different attack scenarios. In a more advanced phase, the project will involve constructing attack impact assessment models, potentially exploring injection vectors and attacker-defender bi-level optimization approaches to quantify the effects of successful FDIAs on key power system reliability indices.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M- IRPH
Nombre de sujets	2

Supervision

Supervisor : Henneaux Pierre (pierre.henneaux@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Inertia Estimation in Inverter-Dominated Distribution Systems: A Simulation and Machine Learning Perspective

Description

This MSc thesis will address the challenge of inertia estimation in inverter-dominated electric power systems, a growing concern as power systems transition toward renewable energy sources such as solar PV and wind. Traditional power systems rely on the physical inertia of synchronous generators to stabilize frequency during disturbances. In contrast, inverter-based resources lack inherent inertia, leading to faster frequency deviations, reduced stability margins, and higher sensitivity to disturbances.

In modern autonomous distribution systems, inertia is no longer a constant physical parameter but a dynamic, operating-point-dependent characteristic influenced by control delays, power electronics, and load behavior. Classical inertia estimation techniques based on the swing equation are shown to be inadequate, as their assumptions do not reflect inverter-based system dynamics. The objective of this MSc thesis is to analyze and compare inertia estimation approaches and to investigate whether machine learning (ML) can more effectively capture system behavior. A structured review of model-based, measurement-based, and data-driven methods will be conducted to assess their applicability and limitations. The methodology will involve simulating an autonomous distribution system in MATLAB/Simulink, including inverter-based generation, virtual inertia control, response delays, and dynamic loads. Disturbance scenarios will be applied to study frequency response. An ML-based approach will then be implemented using simulation data to estimate inertia-related behavior, and its performance is compared with conventional methods.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Henneaux Pierre (pierre.henneaux@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Clean energy & sustainable propulsion: Machine learning methods in LES of hydrogen flames

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and local flame propagation, which is a key design parameter, is challenging to predict. However, validated simulation tools are indispensable for technology development nowadays
- The goal is to learn the flame propagation from direct numerical simulation (DNS) with machine learning methods
- Apply data-driven model to industrial-relevant large-eddy simulations (LES)

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH
Nombre de sujets	2

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Development of an online thermal imaging framework to detect hot spot during the regular operation of battery modules

Description

The lack of accurate cell-level instrumentation reduces the ability to detect and prevent, in real time, safety-related scenarios during the operation of a battery module or pack. In this context, the implementation of online thermal imaging strategies and their interface with the Battery Management System (BMS) could represent a reliable alternative for detecting irregular temperature profiles across the battery cells comprising a battery module.

The goal of this Master's thesis project is to develop a framework for the real-time analysis of infrared (IR) thermal images to detect hotspots via image processing software in the loop — potentially enhanced by data-driven approaches — with results to be transmitted to a BMS via either Ethernet or Controller Area Network (CAN) bus communication. Therefore, prospective candidates are strongly encouraged to have a solid background in image processing and communication tools.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	2

Supervision

Supervisor : Falcone Paolo (paolo.falcone@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Quantum computing for power system reliability assessment

Description

Power system reliability is a general concept describing its ability to deliver electricity to all points of utilization within acceptable standards and in the amount desired. The predictive assessment of power system reliability is of paramount importance to ensure beforehand that it will meet desired standards. Due to intrinsic uncertainties arising within electric power systems (e.g., failures of pieces of equipment, variability of renewable energy resources, ...), power system reliability is characterized by probabilistic indicators such as the Loss Of Load Probability (LOLP, the probability that the system is not able to supply all the load while fulfilling operational constraints) and the Expected Energy Not Served (EENS, the energy that the system is not able to supply but should have supplied). These indicators are currently estimated mainly through Monte Carlo simulation for real power systems. Although the implementation of Monte Carlo is straightforward, it leads to significant computation times to obtain results with the desired statistical accuracy. In that context, quantum computing could help to estimate in an efficient way power system reliability indicators. The purpose of this MSc thesis will be to develop a methodology based on quantum computing to tackle a specific problem related to power system reliability assessment (e.g., adequacy of the generation system) and to compare its performances with a Monte Carlo simulation.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Henneaux Pierre (pierre.henneaux@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Digital twin simulations of offshore wind turbines

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behaviour. Digital twin are more and more used in the wind industry to predict remaining lifetime, predictive maintenance, and structural integrity. Commonly differentiated in data-driven digital twins, which represents the structure completely based measured inputs, and physics based digital twins, which are build based on existing physical relations. Through their rooting in known physical relations, physics-based digital twins often provide better transparency of their behaviour.

- Objective:

In this Master Thesis you will validate the physics-based digital twin of an offshore wind turbine in the Belgian North Sea with real-world data using the aeroelastic simulation software ASHES.

- Prerequisites/special skills (optional)

An interest in structural dynamics and programming is desired. A good knowledge of numerical methods such as the finite element method as well as prior experience with aeroelastic software such as OpenFast can be advantageous. This master thesis gives you the opportunity to learn about the modelling and dynamic behaviour of Offshore Wind Turbines as well as the work of OWI-lab in the structural health monitoring of wind turbines.

- Other information:

This topic is an umbrella topic in which direction can be given aligned with the student's interests and skillset. E.g. the focus can be put on the control of the turbine, the soil-structure interaction, the performance under anomalous behaviour, the automatic integration between database and simulation, ...

Your thesis work builds on past master thesis's and starts from their latest findings.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Sustainable Aviation Fuels: Controlling Soot Emissions in Aircraft Engines

Description

- Sustainable Aviation Fuels (SAF) are key to decarbonize the aviation sector
- The reduction of soot and other emissions is critical to reduce the environmental impact of the aviation sector
- Soot formation is strongly sensitive to the local flow conditions and combustion process in an aircraft engine
- The goal is to analyze the effect of the flow field on soot formation in laminar well controlled counterflow flames
- In a second step, soot formation in turbulent flames is simulated using LES and a comparison to experimental reference data is performed
- the development of a validated LES framework for industrial applications is key to enable the design of future aircraft engines

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

PEM fuel cells to decarbonize aviation: Modeling liquid water transport

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and requires in-depth understanding of the small-scale processes in the porous media, e.g. liquid water transport
- the goal is to model liquid water transport in macro-homogeneous models and validate the simulations against experimental reference data
- Particular focus lies on the modeling of the channel/GDL interface

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Clean energy & sustainable propulsion: Modeling hydrogen/ammonia flames in LES

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and predictive combustion models for LES are yet not available
- The goal is to analyze detailed data-heavy DNS data, where all turbulent fluctuations are resolved, and to extract the underlying physics regarding the interactions of the flame and turbulence
- The goal is to develop models for unclosed terms in LES and then apply the newly developed models in an LES to show its improvements
- The analysis will be done for different hydrogen/ammonia blends

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

PEM fuel cells to decarbonize aviation: Pore-resolved simulations in porous media

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and requires in-depth understanding of the small-scale processes in the porous media, e.g. liquid water transport
- the goal is to establish a modeling framework for pore-resolved simulations of liquid water transport in PEM fuel cells
- the goal is to apply this framework to relevant questions in flow field and stack design

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Experimental testing of a monitoring hardware for application in floating offshore wind turbines.

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behavior. Floating Offshore Wind Turbines (FOWT) refer to offshore wind turbines mounted on floating platforms, allowing them to be deployed in deeper waters where fixed-bottom turbines are not feasible.

- Objectives of the master thesis;

This master's thesis focuses on building and testing a small-scale experimental setup to evaluate a monitoring hardware system (GNSS/IMU). The objective is to assess the hardware's ability to provide accurate position for an instrumented device—such as a scaled FOWT. When combined with other sensor types, this data will help us better understand the motion characteristics of FOWTs and how they relate to mooring line tensions and overall system dynamics. This project is conducted in collaboration with 24SEA, a company specializing in monitoring solutions for offshore wind turbines.

- Prerequisites/special skills (optional)

An interest in structural dynamics, experimental work and programming is desired. The thesis also includes working with sensors and hardware, and doing experimental validation of the sensor setups. A thesis suitable for someone with a strong 'MacGyver'/'Maker' - spirit.

- Other information

This thesis might require you to travel occasionally to 24SEA, situated just outside Brussels.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH

Nombre de sujets	1
-------------------------	---

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

PEM fuel cells to decarbonize aviation: Modeling degradation in PEM fuel cells

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and handling cell degradation is a key challenge for future technologies
- the goal is to develop a simulation framework to model degradation mechanisms in PEM fuel cells
- the new library will be coupled to CFD solvers to enable predictions of degradation in a 3D realistic cell

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M- IRPH
Nombre de sujets	1

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Speed adaptive control of an active lower-limb prosthesis

Description

Robotic prostheses aim to restore mobility after amputation, with the goal of enabling safe, comfortable, and efficient walking in everyday life. While active prosthetic knees can generate mechanical power and improve mobility, their clinical adoption remains limited by complex control strategies that require time-consuming, user-specific tuning. In parallel, current personalization approaches are typically restricted to a single walking speed, even though gait naturally varies with speed, fatigue, and environment. This gap highlights the need for more adaptive and user-centered control frameworks.

This thesis offers the opportunity to contribute to the development of next-generation control strategies for active lower-limb prostheses. Building on existing work in the lab, you will design and implement a tunable, speed-adaptive controller and evaluate its performance experimentally. The project combines control design, programming (LabVIEW/Python), and hands-on experimentation with a robotic prosthesis. A key objective will be to identify control strategies that are both easy to tune in practice and adaptable to individual user needs.

This project is ideal for students interested in robotics, biomechanics, and human-centered design, and offers the chance to work at the intersection of engineering and healthcare, with direct impact on assistive technologies.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Verstraten Tom (tom.verstraten@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Unified Range-Multispectral-Inertial Odometry (R-VTIO) for Autonomous Drone Navigation

Description

Background:

Standard Visual-Inertial Odometry (VIO) pipelines fuse RGB imagery with IMU data but degrade in two distinct failure modes: visual degradation (fog, smoke, low light) and scale/altitude ambiguity in featureless terrain. Existing work has addressed these failure modes independently. Multispectral VIO (VTIO) introduces thermal-infrared (TIR) imagery as an alternative visual channel, while Range-Visual-Inertial Odometry (RVIO) incorporates LiDAR altimeter range constraints and coarse-to-fine map registration. No published system currently fuses all four modalities (RGB, Thermal, Range, IMU) in a single tightly-coupled estimation framework for UAV navigation. This thesis fills that gap by designing a unified factor-graph-based odometry system: Range-Visual-Thermal-Inertial Odometry (R-VTIO).

Research Questions:

- Does a unified R-VTIO framework outperform the individual VTIO and RVIO baselines in trajectory accuracy and robustness across degraded environments?
- What is the marginal contribution of each sensor modality (RGB, Thermal, Range) to overall odometry accuracy, as measured by an ablation study?

Objectives:

- Implement a unified factor graph (GTSAM or Ceres) that jointly optimises over RGB features, thermal features, IMU pre-integration, and altimeter range factors
- Run a full ablation study: RGB-only, RGB+IMU, RGB+Thermal+IMU (VTIO), RGB+Range+IMU (RVIO), and full R-VTIO
- Collect flight data in at least two degraded scenarios: night flight and high-altitude featureless terrain
- Benchmark against GNSS RTK ground truth and compare with VINS-Fusion and ROVIO baselines

[1] T. Qin, P. Li, and S. Shen, "VINS-Mono: A Robust and Versatile Monocular Visual-Inertial State Estimator," IEEE Transactions on Robotics, vol. 34, no. 4, pp. 1004–1020, 2018.

[2] T. Qin, S. Cao, J. Pan, P. Li, and S. Shen, "A General Optimization-based Framework for

- Global Pose Estimation with Multiple Sensors,” arXiv preprint arXiv:1901.03642, 2019.
- [3] M. Bloesch, S. Omari, M. Hutter, and R. Siegwart, “Robust Visual Inertial Odometry Using a Direct EKF-Based Approach,” in Proc. IEEE/RSJ IROS, pp. 298–304, 2015.
- [4] M. Bloesch, M. Burri, S. Omari, M. Hutter, and R. Siegwart, “Iterated Extended Kalman Filter Based Visual-Inertial Odometry Using Direct Photometric Feedback,” IJRR, vol. 36, no. 10, pp. 1053–1072, 2017.
- [5] N. Khedekar, M. Kulkarni, and K. Alexis, “MIMOSA: A Multi-Modal SLAM Framework for Resilient Autonomy against Sensor Degradation,” in Proc. IEEE/RSJ IROS, pp. 7153–7159, 2022.
- [6] J. Michalczyk, R. Jung, and S. Weiss, “Radar Visual Inertial Odometry and Radar Thermal Inertial Odometry: Robust Navigation even in Challenging Visual Conditions,” in Proc. IEEE/RSJ IROS, 2021.
- [7] M. Nissov, N. Khedekar, and K. Alexis, “Degradation Resilient LiDAR-Radar-Inertial Odometry,” in Proc. IEEE ICRA, pp. 8587–8594, 2024.
- [8] F. Dellaert and GTSAM Contributors, “borglab/gtsam,” Georgia Tech Borg Lab, 2022. Available: <https://github.com/borglab/gtsam>

Langue	EN (english)
Ouvert à d’autres masters	No
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M
Nombre de sujets	2

Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Comparative study of physics-enhanced graph neural network approaches for multiple degrees-of-freedom system response estimation

Description

- Context of the master thesis

Wind turbines are the biggest dynamic, mass-produced, man-made structures. Their structural response to environmental and operational variations is highly complex and non-linear. As such, both physical modelling and data-driven inference have difficulties in accurately estimating the response. The former require simplifications which, along with unknown quantities (e.g. blade geometry), undermine accuracy. The latter may achieve high performance, but are limited to their training space, and extrapolation isn't trustworthy. This is also the case for virtual sensing, where limited instrumentation limits the ability to capture the full dynamics of the system, leading to uncertain predictions at unsensed locations, especially outside observed operational conditions.

In this context, physics-enhanced or hybrid modelling has come to the foreground. The philosophy behind it is straightforward: data-driven algorithms have problem-specific physical knowledge embedded into their architectures (loss function, differentiable equations, etc.) which improve generalization and performance. In this thesis, a comparative study of different approaches into embedding physical knowledge into a data-driven algorithm will be research by analyzing performance over multiple degrees-of-freedom systems (MDOF). These (MDOF), represent idealized reductions of real-world structures (e.g. wind turbines, bridges, etc.) and are extremely convenient, as they have low computational costs and their parametrization enables varied response simulation. The baseline algorithm will be a graph neural network.

- References

§ Haywood-Alexander, Marcus, et al. "Discussing the spectrum of physics-enhanced machine learning: a survey on structural mechanics applications." Data-Centric

Engineering 5 (2024): e30.

§ Cicirello, Alice. "Physics-Enhanced Machine Learning: a position paper for dynamical systems investigations." Journal of Physics: Conference Series. Vol. 2909. No. 1. IOP Publishing, 2024.

§ Mehrjoo, Azin, Eleonora M. Tronci, and Babak Moaveni. "A Physics-Informed Framework for Input Load Estimation in Offshore Wind Turbines." International Conference on Experimental Vibration Analysis for Civil Engineering Structures. Cham: Springer Nature Switzerland, 2025.

- Objectives

§ Review virtual sensing in offshore wind turbines.

§ Identify and review physics-enhanced/hybrid modelling approaches.

§ Generate MDOF systems with varying numbers of degrees and exciting load [both intensity and location] in a Python script.

§ Encode MDOF as a graph, including stiffness, damping and mass matrices.

§ Implement a Graph Neural Network (GNN) virtual sensor baseline in Python.

§ Assess and compare the addition of physics knowledge into the baseline with relation to: performance over unseen numbers of nodes [extrapolation and interpolation] and unseen excitations [intensity and location].

- Prerequisites/special skills

· Basic python programming.

· Knowledge of fundamentals of structural mechanics (e.g. equations of motion, etc.).

· Attendance of Prof. Deraemaker's Dynamics of Structures or Mechanical Vibrations course (<https://structuraldynamics.ulb.be/dynamics-of-structures-2025-2026/>)

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	1

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

AI-enabled robotics for precision farming

Description

The SAAS (Service d'Automatique et Analyse des Systèmes) department at the École polytechnique de Bruxelles (ULB) conducts advanced research in precision agriculture, with a particular focus on modeling, control, and robotics. In this context, we invite applications for a master's thesis project in AI-enabled robotics for precision farming. This project aims to develop a mobile robotic system capable of autonomously inspecting crop fields to support the early detection of plant diseases and enable efficient, sustainable treatment strategies. Building on a knowledge base composed of annotated images of disease symptoms and semantic descriptions of their locations on plants, the student will design motion planning and control algorithms for a robotic manipulator. A camera mounted on the end-effector will be used to perform detailed plant inspections. The proposed algorithms will be implemented and validated on a KUKA LBR iiwa 14 R820 available at the department. The primary application will focus on detecting common tomato diseases, such as The SAAS (Service d'Automatique et Analyse des Systèmes) department at the École polytechnique de Bruxelles (ULB) conducts advanced research in precision agriculture, with a particular focus on modeling, control, and robotics. In this context, we invite applications for a master's thesis project in AI-enabled robotics for precision farming.

This project aims to develop a mobile robotic system capable of autonomously inspecting crop fields to support the early detection of plant diseases and enable efficient, sustainable treatment strategies. Building on a knowledge base composed of annotated images of disease symptoms and semantic descriptions of their locations on plants, the student will design motion planning and control algorithms for a robotic manipulator. A camera mounted on the end-effector will be used to perform detailed plant inspections. The proposed algorithms will be implemented and validated on a KUKA LBR iiwa 14 R820 available at the department. The primary application will focus on detecting common tomato diseases, such as grey mold, alternaria solani, powdery mildew, necrosis, chlorosis. The project will leverage an image database developed in collaboration with the Laboratoire de Production et de Biostimulation des Plantes cultivées (LPBP) at ULB. Early Blight. The project will leverage an image database developed in collaboration with the Laboratoire de Production et de Biostimulation des Plantes cultivées (LPBP) at ULB.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE
Nombre de sujets	2

Supervision

Supervisor : Falcone Paolo (paolo.falcone@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Autonomous Counter-Drone System

Description

Please find the details of the MA proposal on https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested in one of these 5 topics, please contact bryan.convens@vub.be for more information given during a Microsoft Teams meeting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O
Nombre de sujets	3

Supervision

Supervisor : Vanderborgh Bram (bram.vanderborgh@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

World Model for Drone Navigation

Description

Background:

Current VIO pipelines are reactive: they estimate pose from the most recent sensor observations. When those observations suddenly degrade, flying from sunlight into dense fog, or from textured terrain over a featureless lake, the pipeline experiences an abrupt loss of features, often causing tracking failure before any recovery mechanism can act. A predictive approach, inspired by recent advances in world models for robotics (JEPA, Dreamer-V3, diffusion-based latent dynamics), offers a fundamentally different strategy: learn a compressed latent representation of the drone's multispectral environment and use it to anticipate future sensor states. If the world model predicts that visual features will vanish in 2 seconds (e.g., approaching fog), the navigation system can pre-emptively increase reliance on thermal or IMU channels, or adjust the flight trajectory to stay in feature-rich regions. A multispectral drone platform carrying RGB cameras, a thermal core, an IMU, and a range sensor provides a rich, multi-modal data source for training such a model. This thesis investigates whether a learned world model, trained on multispectral drone data, can improve the robustness of drone state estimation and enable predictive, anticipatory navigation rather than purely reactive recovery.

Research Questions

- Can a latent world model trained on multispectral drone data (RGB, thermal, IMU) predict upcoming visual degradation events before they occur and navigate to a given location?
- What latent representation architecture (JEPA-style, VAE, diffusion) best captures the joint dynamics of RGB and thermal imagery from a drone perspective?
- Can the world model generalise across environments not seen during training?

What the Student Does

- Curate and structure flight datasets into a training corpus with synchronised RGB, thermal, IMU, and range streams
- Implement a latent dynamics model (starting with JEPA or Dreamer-V3 architecture) that learns to predict future latent states from current multi-modal observations and drone actions

- Train the world model to navigate to a given location

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M
Nombre de sujets	2

Supervision

Supervisor : munteanu adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Robust vision system for ophthalmic robotics with 3d tool depth estimation and eye motion tracking using stereo vision and monocular camera

Description

Context:

In ophthalmic microsurgery, precise tool positioning is critical to avoid damaging delicate structures such as the retina. While advanced imaging systems like OCT provide accurate depth information, they are complex and costly.

Simpler approaches, such as shadow-based depth estimation, can extract depth from microscope images but lack robustness on their own. Stereo vision offers full 3D reconstruction, while eye motion tracking is essential to compensate for involuntary movements.

This project combines stereo vision, shadow-based cues, and eye tracking into a unified framework, validated through a simple experimental setup.

Objective:

The goal is to develop and validate a vision-based system for:

3D tracking of the surgical tool

Precise tracking of eye motion

Estimation of tool-to-retina distance

The system will be evaluated on a simplified prototype setup.

Methods:

Calibrate a stereo vision system and implement 3D triangulation

Detect and track the tool tip in stereo images

Implement shadow-based depth estimation as a complementary method

Track eye motion using visual features (e.g., pupil or trocar)

Fuse measurements to improve robustness

Validate accuracy using a simple experimental setup

Prerequisites:

Programming: Python or MATLAB

Basic knowledge of image processing and computer vision

Fundamentals of linear algebra and geometry

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	2

Supervision

Supervisor : Verstraten Tom (Tom.Verstraten@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Teaching Robots Skills via Human-Machine Interfaces and Imitation Learning

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O
Nombre de sujets	3

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Constraint-Based Control for Multi-Contact Manipulation

Description

Robotics manipulation tasks often involve multiple simultaneous contacts between the robot, object, and environment. These interactions are inherently coupled through shared force and motion constraints, making control significantly more complex.

Recent advances in multi-contact and reactive manipulation show that coordinating distributed contact forces while respecting friction and contact constraints is key to achieving stable and dexterous behaviors. However, ensuring safe transitions, force redistribution, and constraint satisfaction across multiple contacts remains an open challenge.

The goal of this project is to achieve safe, model-based control of multi-contact manipulation by simultaneously enforcing multiple contact constraints and coordinating distributed contact forces.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	2

Supervision

Supervisor : Van de Perre Greet (greet.van.de.perre@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Touch-sensing method for wall reconstruction in Construction

Description

In wall-construction with robotic system, it is crucial to have a precise localization of the robot with respect to the target wall. However, using camera systems to achieve this under construction settings is not possible. Typically, the accuracy of such systems under lab light conditions, would be ± 5 cm of error. Since the robotic arm is very accurate due to its joint sensors, we propose to use the robotic arm for autonomous tactile surface mapping of partially constructed walls to correctly estimate the target pose for the placement of the next block.

Objectives:

- Develop a tactile exploration strategy for wall reconstruction;
- Improve localization using a touch probe;
- Correct and refine point cloud and camera-based measurements;
- Enable accurate target pose estimation for autonomous construction.

Methodology:

The robot explores the wall using a touch probe to collect precise contact measurements, which are fused with camera-based point cloud data. A correction framework aligns and refines noisy visual measurements using tactile feedback. The resulting model enables accurate estimation of wall geometry and target poses for block placement as well as wall re-construction.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS
Nombre de sujets	2

Supervision

Supervisor : Garone Emanuele (emanuele.garone@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

Explicit Reference Governors ensure constraint satisfaction by predicting future system behavior and evaluating a Dynamic Safety Margin (DSM) that quantifies the distance to constraint violation. In current implementations, safety margins are typically defined using fixed worst-case bounds on modeling uncertainty and force-estimation errors. While this guarantees safety, it often leads to conservative robot behavior and reduced performance.

The objective of this thesis is to develop an adaptive tightening mechanism that adjusts the safety margin online based on measurable uncertainty indicators such as force-estimation residuals, prediction error, or disturbance dynamics. The proposed method will be integrated into an existing force-regulated ERG framework for robotic manipulators.

The student will:

Analyze the baseline ERG and DSM formulation

Design an adaptive uncertainty bound for force and motion prediction

Integrate the adaptive margin into the ERG safety mechanism

Validate the approach through simulation and experimental evaluation

Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-E

Nombre de sujets	1
-------------------------	---

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Virtual Assembly Validation of Complex CAD Systems with Haptic Feedback

Description

Context

Modern mechanical systems (e.g., turbine engines, robotic manipulators) consist of many tightly packed components. While CAD tools provide geometric modeling and basic collision checks, they lack intuitive means to physically validate (dis)assembly feasibility, especially in constrained spaces and when tools (e.g., wrenches) are involved. Purely visual inspection is often insufficient, and physical prototyping is costly. Haptic-enabled virtual environments offer a promising alternative by allowing users to feel contacts and constraints, enabling more realistic and efficient validation of (dis)assembly processes.

Objective

This thesis aims to develop a haptic-assisted virtual assembly system for:

- Interactive manipulation of CAD components in a virtual environment
- Real-time collision detection with force feedback
- Verification of assembly feasibility and tool accessibility

The system will enable users to detect collisions both visually and through touch, ensuring that parts and required tools can be assembled without interference.

Methods

3D CAD models will be converted into interactive 3D objects within a virtual environment (e.g., Unity or an OpenGL-based framework), including appropriate collision meshes. An operator will be able to select and manipulate individual components within the assembly. During interaction, object interpenetration will be prevented in the virtual environment. Simultaneously, when collisions occur, the haptic device will generate force feedback, providing the user with a realistic sense of contact.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS

Nombre de sujets	2
-------------------------	---

Supervision

Supervisor : Verstraten Tom (Tom.Verstraten@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

AI-based sign language recognition through EMG and Vision

Description

Hand gestures play a central role in sign language, but vision-based recognition often struggles with visually ambiguous poses (e.g., letters with similar handshapes) and occlusions (e.g., when the hand is partially covered). This project aims to enhance sign language recognition by combining vision-based hand tracking with surface electromyography (sEMG) signals captured from the forearm muscles. By leveraging both modalities, the system will evaluate whether EMG can provide discriminative information that complements video input and improves recognition accuracy in challenging conditions. The student will develop a pipeline for synchronized acquisition of RGB video and sEMG signals, preprocess the data, and implement machine learning models for gesture classification and multimodal fusion.

Context:

Sign language is the primary means of communication for millions of deaf and hard-of-hearing individuals worldwide. Automatic Sign Language Recognition (ASLR) has the potential to bridge communication barriers between signing and non-signing communities, enabling more inclusive human-computer interaction in domains such as healthcare, education, and assistive technology. Current state-of-the-art approaches predominantly rely on computer vision techniques, leveraging RGB cameras and hand landmark estimation frameworks such as MediaPipe, to capture the spatial configuration of the hand. While these methods have shown promising results under controlled conditions, they remain brittle in real-world scenarios where lighting variability, background clutter, self-occlusion, or visually similar handshapes introduce significant ambiguity. Surface electromyography (sEMG) offers a complementary sensing modality: by recording the electrical activity of forearm muscles during hand and finger movements, sEMG captures neuromuscular intent independently of visual conditions. Unlike cameras, sEMG is inherently robust to occlusion and can differentiate between gestures that appear visually identical but involve distinct muscular activation patterns. The integration of these two modalities, visual and myoelectric, into a unified multimodal framework represents an emerging research direction with strong potential to improve the accuracy, robustness, and generalizability of gesture recognition systems. This thesis explores that direction,

contributing both a synchronized multimodal dataset and a comparative study of fusion strategies.

Objectives:

- **Data acquisition:** Design and record a structured dataset of sign language handshapes and/or isolated words covering approximately 10 gesture classes. The dataset will deliberately include visually similar gestures (e.g., handshapes sharing the same finger configuration but differing in muscle tension) and occluded conditions (e.g., partial hand coverage or non-frontal orientations). Data will be collected synchronously using an RGB camera and a multi-channel sEMG armband, with attention to temporal alignment, participant variability (multiple subjects), and session reproducibility. A data collection protocol and annotation scheme will be defined and documented.
- **Preprocessing & feature extraction:** Process raw video streams to extract hand landmarks and relevant spatial descriptors using frameworks such as MediaPipe, and apply signal conditioning to sEMG recordings (filtering, segmentation, normalization). Extract time-domain features from EMG signals (e.g., mean absolute value, root mean square, zero-crossing rate, waveform length) and, optionally, frequency-domain or time-frequency features. Ensure that both modalities are represented by consistent, well-aligned feature vectors suitable for downstream classification.
- **Model development:** Train and evaluate unimodal classifiers independently on vision and EMG data to establish individual performance baselines. Implement at least one multimodal fusion strategy, early fusion (concatenating feature vectors before classification) and/or late fusion (combining the outputs of independently trained classifiers). Candidate models include traditional machine learning approaches (e.g., SVM, Random Forest) as well as neural network architectures (e.g., MLP, CNN, or LSTM depending on the input representation).
- **Evaluation:** Assess classification performance using standard metrics including accuracy, precision, recall, and F1-score, reported per class and overall. Analyse results across gesture subgroups, particularly visually ambiguous and occluded gestures, to determine whether and to what extent EMG improves recognition where vision alone fails. Compare the performance of vision-only, EMG-only, and fused models to quantify the added value of multimodal integration.
- (Optional) Investigate more advanced fusion mechanisms (e.g., attention-based weighting of modalities) or extend the gesture vocabulary. Conduct a user study or robustness analysis under varying occlusion levels to further characterise system limitations and strengths.

Pre-requisites:

- Basic knowledge of signal processing and machine learning.
- Programming skills in Python (PyTorch/Scikit-learn, OpenCV).
- Interest in human–computer interaction or biomedical signal processing.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Verstraten Tom (tom.verstraten@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Degradation-Aware Autonomous Mode Switching for Multi-Sensor VIO for Drone Navigation

Description

Two complementary VIO pipelines address different failure modes of UAV state estimation: VTIO (thermal + RGB + IMU) is optimised for visual degradation, while RVIO (range + RGB + IMU) is optimised for scale ambiguity and altitude uncertainty. In practice, a drone encounters both failure modes during a single mission, and sometimes simultaneously. A fixed pipeline cannot handle this. What is needed is a meta-system that monitors sensor health in real time and autonomously reconfigures the active estimation pipeline. This thesis builds a degradation detection and mode-switching layer that sits above the VTIO and RVIO pipelines. It continuously evaluates sensor-specific health indicators (RGB feature count and distribution, thermal contrast, altimeter return quality, IMU vibration level) and selects the optimal pipeline configuration: full R-VTIO when all sensors are healthy, VTIO-only when range data is unreliable, RVIO-only when thermal adds no value, or a minimal IMU-propagation fallback during total sensor dropout. The switching must be seamless, no state discontinuities at transitions.

Research Questions

- What sensor health metrics most reliably predict imminent pipeline failure, and how far in advance can failure be detected?
- Can mode switching be performed without introducing state discontinuities or jumps in the estimated trajectory?
- What is the optimal switching strategy: hard mode selection, soft blending of pipeline outputs, or dynamic factor graph reconfiguration?
- How does the autonomous switching system compare against a fixed R-VTIO pipeline and against manual operator intervention in edge-case scenarios?

What the Student Does

- Define and implement real-time health indicators for each sensor modality: RGB (feature count, spatial distribution, reprojection error), thermal (contrast ratio, feature stability), range (return signal strength, consistency with visual depth), IMU (vibration spectrum, bias drift rate)
- Design a mode-switching controller: implement and compare three strategies: (a) rule-based thresholding, (b) learned classifier (lightweight MLP or decision tree trained on

labelled degradation data), and (c) soft blending via dynamic covariance scaling in the factor graph

- Implement seamless state handover between pipeline configurations: when switching from RVIO to VTIO, the thermal channel must be initialised consistently with the current state estimate

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE
Nombre de sujets	1

Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Vision-Language-Action Model for Autonomous Drone Mission Execution

Description

Background

Classical autonomous drone mission planning relies on a hand-engineered stack: a mission planner generates waypoints, a path planner finds collision-free trajectories, and a low-level controller tracks them. This pipeline is brittle: it cannot reason about abstract goals (“survey the tree line while avoiding foggy areas”), adapt to unexpected environmental conditions described in natural language, or leverage the rich semantic understanding embedded in modern foundation models. Vision-Language-Action (VLA) models, such as RT-2 and OpenVLA, have demonstrated the ability to map language instructions and visual observations directly to robot actions in manipulation tasks. However, their application to aerial robotics remains largely unexplored. This thesis investigates whether a VLA can serve as a high-level mission executor for a drone equipped with multispectral sensors. The VLA receives natural language mission commands and onboard camera streams (RGB and thermal) and outputs action commands (velocity setpoints or waypoints). A tightly-coupled RVIO pipeline provides metric grounding, ensuring that the VLA’s outputs remain geometrically consistent and safe.

Research Questions

- Can a VLA model fine-tuned on drone flight data convert natural language mission descriptions into executable action sequences with acceptable spatial accuracy?
- Does grounding the VLA’s output through the RVIO metric pipeline prevent the geometric inconsistencies (scale drift, altitude errors) typical of end-to-end vision-to-action models?

What the Student Does

- Survey existing VLA architectures (RT-2, OpenVLA, Octo) and select one suitable for adaptation to the aerial domain, considering compute constraints and action space differences
- Design the action space interface: the VLA outputs high-level velocity commands or waypoint deltas; the RVIO pipeline provides real-time metric state for closed-loop control

Langue	EN (english)
--------	--------------

Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE
Nombre de sujets	2

Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Deep learning for estimation of instrument tip force from surface EMG signals

Description

Proper tissue handling is crucial in laparoscopic surgery, where surgeons must be mindful of the forces applied to and by their instruments to avoid tissue damage or procedural errors. By capturing muscle activation data from surface electromyographic (sEMG) sensors placed on the surgeon's arm, this project aims to estimate the force exerted at the tip of laparoscopic instruments. This thesis focuses on developing a model to estimate the force at the instrument's tip based on the muscle activity detected by sEMG sensors. A 1D force load cell is already integrated at the tip of a laparoscopic tool, and sEMG sensors will be placed on the operator's arm. The student will work on both the refinement of the hardware setup and the full software development pipeline, using neural network architectures such as recurrent neural networks (RNNs) and LSTMs, with the goal of mapping the relationship between muscle activation and instrument tip force.

Context:

Minimally invasive surgery, and laparoscopic surgery in particular, has transformed modern surgical practice by significantly reducing patient trauma, recovery time, and post-operative complications. However, it also introduces unique challenges: surgeons operate through small incisions using long rigid instruments, which drastically reduces tactile feedback and proprioceptive awareness compared to open surgery. This loss of haptic information makes it difficult to gauge the forces being applied to delicate tissues, increasing the risk of accidental damage such as perforation or excessive compression. Sensorised surgical instruments equipped with force transducers at the tool tip offer a direct means of measuring interaction forces, but their integration into clinical workflows remains limited by cost, sterilisation constraints, and mechanical complexity. An alternative and complementary approach lies in estimating tip force indirectly from the neuromuscular signals generated by the surgeon's own musculature. Surface electromyography (sEMG) is a non-invasive technique that records the electrical activity of muscles during contraction, and has been widely used in prosthetics, rehabilitation, and human-robot interaction for gesture and force estimation. Applying sEMG-based force

estimation to the surgical context is an emerging research direction: if the relationship between forearm muscle activation and instrument tip force can be reliably learned, it becomes possible to infer force continuously and non-intrusively without modifying the surgical tool beyond its existing load cell, which here serves as the ground truth signal for training. Deep learning models, in particular sequential architectures such as RNNs and LSTMs, are well suited to capture the temporal dynamics of sEMG signals and their mapping to force output. This thesis addresses that challenge, contributing both an experimental data acquisition protocol and a trained deep learning model for instrument tip force estimation from surface EMG.

Objectives:

- **Data acquisition:** Familiarise with the existing hardware setup (sEMG sensors and laparoscopic tool with integrated load cell), contribute to refining sensor placement and synchronisation, and collect a structured dataset of synchronised sEMG and tip force recordings across multiple subjects and controlled task conditions.
- **Preprocessing & feature extraction:** Apply signal conditioning to raw sEMG recordings (filtering, segmentation, normalisation) and extract relevant time-domain features. Prepare the force signal as a continuous regression target, ensuring temporal alignment with the EMG windows.
- **Model development & evaluation:** Train and evaluate deep learning models (RNN, LSTM) to map sEMG signals to instrument tip force. Compare against baseline approaches and assess generalisation using standard regression metrics (RMSE, MAE, R^2) across subjects and task types.
- (Optional) Explore real-time inference feasibility or more advanced architectures such as Temporal Convolutional Networks or Transformers.

Pre-requisites:

- Experience with data acquisition and sensor integration.
- Familiarity with signal processing.
- Basics of programming skills in Python

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS
Nombre de sujets	1

Supervision

Supervisor : Verstraten Tom (tom.verstraten@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive airflow-based robotic gripper for delicate raspberry harvesting

Description

1) Objectives of the project

Raspberry harvesting is a labor-intensive and costly process because high-quality raspberries must typically be harvested manually to avoid damage. While vibration-based harvesting machines are used in fields, they are not suitable for delicate fruits such as fully matured raspberries for eating. As a result, soft robotic grippers have been increasingly explored as an alternative for automated harvesting. However, most existing soft grippers rely on direct contact forces to grasp the fruit, which still introduces the risk of bruising or damaging these highly fragile fruits.

An even gentler method than mechanical contact is the use of fluidic forces, where airflow can be used to drag the fruit without applying significant mechanical pressure. This approach has strong potential for delicate fruit harvesting. However, several key challenges remain. First, high suction flow rates are often required to generate sufficient lifting force, leading to poor energy efficiency. Second, once the fruit is lifted, an adaptive structure is needed to securely hold and stabilize the raspberry without damaging it.

In our previous research, we developed origami-inspired elastomer actuators that can be fabricated using elastomer 3D printing or molding. These structures allow programmable shape change. Building on this technology, this project aims to design an adaptive orifice structure with a tunable diameter, inspired by origami mechanisms, to efficiently control suction airflow and gently capture raspberries. Such a system has strong potential to address challenges in the rapidly growing agricultural robotics sector, particularly within the raspberry market valued at approximately €3 billion.

The final goal is to develop a prototype suction-based adaptive gripper capable of gently picking raspberries energy-efficiently and improving reliability.

2) Methodology

This project focuses on designing adaptive airflow structures that combine fluidic suction and compliant mechanical response. The project will include:

- i) Literature study on robotic harvesting of delicate fruits and suction-based gripping technologies.
- ii) Design of origami-inspired tunable orifice structures capable of dynamically adjusting opening diameter.
- iii) Fabrication of prototypes using elastomer 3D printing or molding techniques.
- iv) Integration of suction airflow systems with the adaptive orifice structure.
- v) Experimental evaluation of airflow efficiency, fruit handling stability, and damage reduction performance using the raspberry.

To support this project, we already have experience with origami-inspired elastomer actuators and elastomer fabrication methods. The student will build upon these existing technologies and contribute to developing next-generation agricultural robotic solutions.

3) The prerequisites needed to succeed in this project

We are looking for students who have interests in:

- i) CAD design and mechanical design
- ii) 3D printing or molding of soft materials
- iii) Basic knowledge of mechanics
- iv) Hands-on prototyping and experimental testing
- v) Interest in robotics, agriculture, or bio-inspired design

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE
Nombre de sujets	1

Supervision

Supervisor : Wang Zhanwei (Zhanwei.Wang@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Unified Range-Multispectral-Inertial Odometry for Autonomous Drone Navigation

Description

Background

Standard Visual-Inertial Odometry (VIO) pipelines fuse RGB imagery with IMU data but degrade in two distinct failure modes: visual degradation (fog, smoke, low light) and scale/altitude ambiguity in featureless terrain. Existing work has addressed these failure modes independently: Multispectral VIO (VTIO) introduces thermal-infrared (TIR) imagery as an alternative visual channel, while Range-Visual-Inertial Odometry (RVIO) incorporates LiDAR altimeter range constraints and coarse-to-fine map registration. No published system currently fuses all four modalities (RGB, Thermal, Range, IMU) in a single tightly-coupled estimation framework for UAV navigation. This thesis fills that gap by designing a unified factor-graph-based odometry system. Range-Visual-Thermal-Inertial Odometry (R-VTIO). The Tarot 990 platform, equipped with two FLIR Blackfly cameras, a thermal core, a radar altimeter, and an IMU, provides the hardware foundation.

Research Questions

- Does a unified R-VTIO framework outperform the individual VTIO and RVIO baselines in trajectory accuracy and robustness across degraded environments?
- What is the marginal contribution of each sensor modality (RGB, Thermal, Range) to overall odometry accuracy, as measured by an ablation study?

What the Student Does

- Implement a unified factor graph (GTSAM or Ceres) that jointly optimises over RGB features, thermal features, IMU pre-integration, and altimeter range factors
- Run a full ablation study: RGB-only, RGB+IMU, RGB+Thermal+IMU (VTIO), RGB+Range+IMU (RVIO), and full R-VTIO — on identical flight logs

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M
Nombre de sujets	2

Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Design, Fabrication and Experimental Evaluation of an Ultra-Fast Racing Drone

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O
Nombre de sujets	3

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

The measurement of elastomers self-healing efficiency using Electrical Impedance Tomography sensing

Description

1) the objectives of the project

Self-healing materials are emerging as a promising technology for improving the durability and reliability of soft robotic systems, flexible electronics, and wearable devices. When damage occurs, such materials can autonomously recover their mechanical and electrical properties, extending the lifetime of components and reducing maintenance requirements. However, monitoring the healing process and evaluating the healing efficiency remain significant challenges, especially when the damage occurs inside soft materials and cannot be directly observed.

In our previous research, we developed a self-healing Electrical Impedance Tomography (EIT) sensor, which can reconstruct conductivity distributions inside soft materials and detect damage such as cuts or cracks. Based on this technology, we discovered that EIT sensing can also be used to monitor the recovery process of damaged materials, providing valuable insight into the healing status and efficiency over time.

This project aims to further investigate the use of EIT sensing as a non-invasive method to monitor the healing status of self-healing materials. The objective is to develop a sensing system capable of tracking damage and healing evolution inside soft materials, and to evaluate how effectively the material restores its functionality after damage. Such technology can be broadly useful for soft robotics, structural health monitoring, wearable devices, and smart materials.

2) the methodology

This project focuses on developing experimental methods to monitor self-healing processes using EIT sensing. The project will include:

(i) A literature study on self-healing materials and Electrical Impedance Tomography

sensing methods.

(ii) Fabrication of self-healing material samples integrated with electrode arrays for EIT measurement.

(iii) Implementation of damage and healing experiments, including controlled cutting and healing cycles.

(iv) Use our data acquisition and image reconstruction methods to visualize healing evolution inside the material.

(v) Quantitative evaluation of healing efficiency based on electrical and mechanical recovery.

To support this project, we already have experience with EIT-based sensing and self-healing materials, as demonstrated in our previous publications. The student will build upon existing experimental platforms and contribute to advancing smart sensing technologies for monitoring material health.

3) Prerequisites needed to succeed in this project

(i) Electronics and sensor systems

(ii) Programming and data processing

(iii) Interest in experimental testing and hands-on engineering

(iv) Interest in smart materials, sensing, or health monitoring systems

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IRMAE, M-IRIFS, M-IRELE
Nombre de sujets	1

Supervision

Supervisor : Wang Zhanwei (Zhanwei.Wang@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Multi-robot localisation

Description

This thesis topic is a broad collection of subtasks that can be undertaken within multi-robot localisation research.

This includes topics such as:

- Multi-agent SLAM.
- UWB Anchored localisation
- Relative pose estimation
- Map sharing
- ODOMetry sensors: IMU, Camera, VIO, LiDAR, LIO.

And this on multiple different robots:

- AGVs
- Humanoids
- Drones.

In case you want to discuss possibilities in this research field please contact yuri.durodie@vub.be for more details.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Nombre de sujets	5

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Constraint-Based Control for Friction-Induced Manipulation

Description

Many real-world manipulation tasks involve hybrid contact behaviors, where objects transition between sticking, sliding, and separation. While most non-prehensile manipulation approaches assume a single contact mode (typically sticking), this assumption limits their applicability.

Recent work highlights that controlled sliding can be exploited as a manipulation strategy, but introduces hybrid dynamics and complex constraint enforcement challenges [1–3]. Explicitly modeling friction constraints and managing transitions between contact modes is therefore essential for achieving robust and safe manipulation. The goal of this project is to enable safe and controlled sliding manipulation.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE
Nombre de sujets	2

Supervision

Supervisor : Van de Perre Greet (greet.van.de.perre@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Multispectral Visual Place Recognition for Long-Range Drone Loop Closure for Autonomous Drone Navigation

Description

Visual Place Recognition (VPR) is the ability to recognise a previously visited location from its visual appearance, enabling loop closure in SLAM systems and bounding long-term drift. State-of-the-art VPR methods (NetVLAD, AnyLoc, CosPlace) operate exclusively on RGB images and degrade significantly under appearance changes caused by lighting variation (day vs. dusk), weather (clear vs. fog), or seasonal shifts. From an aerial platform, these appearance changes are even more severe due to altitude-dependent viewpoint variation. Thermal-infrared imagery offers a complementary signal: thermal signatures of buildings, roads, vegetation, and water bodies remain far more stable across illumination and weather changes than their RGB appearance. This thesis develops a multispectral VPR system that learns joint descriptors from RGB and thermal images, producing place signatures that are robust to the appearance variations encountered during long-duration GNSS-denied drone flights. The resulting VPR module is integrated as a loop closure backend into a VTIO or R-VTIO pipeline, correcting accumulated drift on flights of 10 minutes or more.

- Does fusing thermal and RGB features into a joint VPR descriptor significantly improve place recognition recall under appearance changes (day/night, clear/fog) compared to RGB-only baselines?
- Which fusion strategy works best: early fusion (concatenated image input), mid-level fusion (shared backbone with modality-specific heads), or late fusion (separate descriptors combined at retrieval)?
- How much drift reduction does multispectral loop closure provide on flights exceeding 10 minutes, compared to DBoW2 and AnyLoc RGB-only loop closure?

What the Student Does

- Collect a multispectral place recognition dataset: fly repeated trajectories over the same area at different times of day, weather conditions, and altitudes, recording synchronised RGB and thermal imagery with GNSS RTK ground truth for place identity labels
- Implement and compare three fusion architectures: (a) early fusion — 4-channel

input (RGB+T) to a modified NetVLAD/AnyLoc backbone, (b) mid-level fusion — dual-encoder with cross-attention, (c) late fusion — separate RGB and thermal descriptors combined via learned weighting



- Train on the collected dataset and evaluate recall@1, recall@5 against RGB-only AnyLoc and NetVLAD baselines under matched and cross-condition (day-query/night-database) retrieval
- Integrate the best-performing model as a loop closure module in the VTIO or R-VTIO pipeline (replacing DBoW2 in VINS-Fusion or equivalent)

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-M
Nombre de sujets	2

Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

 Building the Safety Intelligence Layer for Physical AI: A Multi-Disciplinary Robotics Challenge (In partnership with coera — 5 positions available) 

Description

Robots are leaving their cages. But the world they're entering wasn't designed for them — it was designed for us. What's missing isn't better robots. It's a layer of intelligence that doesn't exist yet.

This project, in collaboration with coera, tackles that challenge across five interconnected research tracks — from how a robot perceives and interprets the unpredictable humans around it, to how it decides, reacts, and physically interacts with the world. You'll work on real-time perception, sensor fusion, adaptive control, compliant mechanism design, or structural optimization — each a piece of a larger puzzle that very few teams in the world are trying to solve.

If you're looking for a thesis that sits at the intersection of mechanical engineering, AI, and something that will actually reshape how robots enter society — this is it.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCNE, M-IRIFS, M-IRELE
Nombre de sujets	5

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Power consumption estimation for legged mobile robots (humanoids or quadrupeds)

Description

Context:

Modern robotics is relying increasingly on legged mobile robots, such as humanoids and quadrupeds, because of their ability to operate in complex and unstructured environments. Compared with wheeled robots, legged systems offer greater mobility on uneven terrain, stairs, and obstacle-rich spaces, making them attractive for inspection, logistics, search and rescue, and service applications.

However, this improved mobility comes with higher energy demand and more complex power consumption patterns. The power usage of legged robots changes significantly depending on the mission, locomotion mode, terrain, payload, and task duration.

Understanding and predicting this power consumption is important for mission planning, battery sizing, energy-aware control, and robot reliability.

Objective:

The objective of this thesis is to create a power consumption dataset for legged mobile robots and develop a data-driven model to estimate and characterize their energy demand during operation.

The thesis will address the following research questions:

- How does a legged robot's mission profile affect its power consumption?
- How does the power load profile evolve during a mission, and which energy-related features best distinguish one mission from another in terms of power consumption?
- Is it possible to classify mission power requirements based on the observed power profile?

Methodology:

The student will collect and organize a dataset of power consumption measurements from an available legged mobile robots, with focus on humanoid or quadruped platforms, under different operating conditions and mission profiles. The dataset may include information such as robot state, locomotion mode, mission type, speed, terrain condition, actuators load, battery variables, and measured power consumption.

Based on this dataset, the student will develop and evaluate data-driven models for power consumption estimation. The work will also investigate how mission characteristics

influence the power load profile, identify meaningful energy-related features, and assess whether different mission types or power demand levels can be classified from the recorded profiles.

Requirements:

Preferred student qualifications include experience in AI modeling, knowledge of ROS (Robotic Operating System), and coding proficiency with Python and/or C++. A passion for multidisciplinary research and a willingness to learn and enhance their skills in these areas are essential.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IRELE, M-IREMR-E
Nombre de sujets	2

Supervision

Supervisor : VANDERBORGHT Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Dynamic Dual-Arm Grabbing and Throwing of Objects

Description

Dynamic manipulation tasks such as catching and throwing require precise coordination, timing, and force control. Unlike static grasping, these tasks involve dynamic interactions and prediction of object motion.

In this project the student will have to solve the problem of grabbing an object (i.e., box) and throw it to a particular location.

This thesis addresses the problem of enabling a dual-arm robotic system (Franka Panda) to:

- Grabb an object (e.g., a box)
- Throw it accurately to a desired target

Objectives

- Develop a real-time catching strategy for moving objects
- Design a dual-arm coordination framework for shared manipulation
- Generate throwing methodology ensuring accurate landing
- Validate the approach on real robot hardware

Methodology: Rigid-body modelling and development of a grabbing strategy. Dual-arm coordination is achieved through constraint-consistent control ensuring stable grasp and force distribution during manipulation. Throwing is performed via optimized release timing and velocity.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IRIFS
Nombre de sujets	2

Supervision

Supervisor : Garone Emanuele (emanuele.garone@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Optimal Fidelity Level for a Battery Digital Twin in Robotic Applications

Description

Context:

Mobile robots operate in dynamic environments and rely on batteries as their main energy source. Because battery capacity is limited, energy availability directly affects mission duration, task execution, and system reliability. For efficient robot operation, it is important to estimate battery behavior accurately during runtime.

A battery digital twin can provide a virtual representation of the battery state and behavior by combining models with real-time data. In robotic applications, such a digital twin can support energy-aware operation, improve monitoring, and enable better prediction of remaining performance. However, higher model fidelity often increases computational cost and integration complexity. This creates a trade-off between model accuracy and real-time usability in robotic systems.

Objective:

This thesis focuses on determining the optimal fidelity level of a battery digital twin for robotic applications and integrating it into Robotic Operating System (ROS) for evaluation under representative robot operating conditions. The final digital twin will be validated on the ROS-based mobile robots available in the group

The thesis will address the following research questions:

- Which battery digital twin fidelity level achieves the best trade-off between estimation accuracy and computational cost when deployed on a mobile robot platform?
- To what extent can a battery digital twin model be adapted to different battery chemistries and pack configurations while maintaining acceptable modelling effort and estimation performance?
- How strongly do different robotic tasks and operating conditions affect the performance of pre-trained battery digital twin models, and when is model re-tuning or retraining required?

Methodology:

The student will use standard battery datasets and a robotic-specific battery dataset to train and validate battery digital twin models. Deep learning methods will be used to capture nonlinear battery behavior and degradation under realistic robotic operating conditions.

The models will be evaluated in terms of accuracy, computational efficiency, and robustness across different fidelity levels, battery chemistries, and robot task profiles. Their feasibility for practical deployment will then be assessed through implementation in ROS and testing on the group's mobile robots, with consideration of both cloud and edge platforms with limited computational capacity.

Requirements:

Preferred student qualifications include experience in AI modeling, knowledge of ROS (Robotic Operating System), and coding proficiency with Python and/or C++. A passion for multidisciplinary research and a willingness to learn and enhance their skills in these areas are essential.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-E
Nombre de sujets	2

Supervision

Supervisor : VANDERBORGHT Bram (Bram.Vanderborght@vub.be)

Real-Time Weather and Forecast Analysis - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Weather significantly impacts Brussels' traffic safety, flow, and signal performance. Integrating meteorological data into traffic operations is essential for proactive, climate-resilient management.

Motivation & Impact: A centralized dashboard linking weather conditions/forecasts with traffic metrics enables operators to anticipate weather-induced disruptions, adjust speed limits, modify signal plans, and issue timely public warnings.

Available Data: Real-time weather station data, meteorological forecasts (precipitation, temperature, wind, visibility), traffic FCD/loop/ANPR streams, historical weather-traffic correlation datasets, incident logs.

Technical Challenge: managing mutli-modal weather and traffic data stream, aligning disparate temporal/spatial resolutions of different streams. Supporting efficient query and join operations over multiple streams, actionable dashboard tailored to operational workflows.

Tools, Techniques & Methods: Data stream management systems, MEOS for spatiotemporal data processing, data engineering pipelines (Apache Kafka, Nebulastream), spatiotemporal data alignment, dashboard development (Grafana, Power BI, Streamlit), API integration with RT DataHub.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Zimanyi Esteban esteban.zimanyi@ulb.be

Delayed Traffic Status Analysis for Assessment - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Post-event evaluation and routine performance monitoring are vital for Brussel Mobilité's to derive lessons learned and support network managers.

Motivation & Impact: Consolidating past traffic data into explanatory reports provides a structured view of network performance, disruption causes, and network management action effectiveness, enabling data-driven continuous improvement.

Available Data: Archived FCD, detector counts, ANPR, incident/roadworks logs, weather archives, [mobility manager log / SAGT-U log ?].

Technical Challenge: Automating the aggregation, normalization, and narrative generation of heterogeneous historical data. Ensuring reports are both technically rigorous and accessible to decision-makers while handling retrospective data quality issues.

Tools, Techniques & Methods: Spatiotemporal data warehousing & ETL pipelines, statistical summarization & trend analysis, visualization, BI integration, Data stream management systems, MEOS for spatiotemporal data processing, data engineering pipelines (Apache Kafka, Nebulastream), API integration with RT DataHub.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Zimanyi Esteban esteban.zimanyi@ulb.be

Impact Measurement of Incidents and Roadworks - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: With ~100k annual roadworks and frequent incidents, Brussel Mobilité needs objective metrics to evaluate disruption severity and the effectiveness of traffic management measures.

Motivation & Impact: Quantifying speed loss, flow reduction, duration, and latency effects enables evidence-based planning, accountability, and continuous improvement of incident response and work zone management strategies.

Available Data: Pre- and post-event FCD/loop/ANPR data, roadworks scheduling database, incident logs, network topology, [mobility manager log / SAGT-U log ?].

Technical Challenge: Isolating event-specific impacts from usual traffic variability and recurrent disruptions. Developing standardized impact metrics, handling missing data during events, and accurately attributing effects to adjacent links.

Tools, Techniques & Methods: Data stream management systems, MEOS for spatiotemporal data processing, data engineering pipelines (Apache Kafka, Nebulastream), causal inference methods, automated impact scoring, API integration with RT DataHub.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Zimanyi Esteban esteban.zimanyi@ulb.be

Temporal Point Cloud Processing for Vehicle Classification and Counting at Signalized Intersections Using MobilityDB - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussels Mobilité Interest: Urban mobility agencies like Brussels Mobilité increasingly rely on 3D data from diverse sources—intersection sensors, mobile mapping, drone surveys—for monitoring, planning, and operations. However, managing, querying, and analyzing these heterogeneous, time-stamped point clouds at scale remains a technical challenge.

Motivation & Impact: Developing flexible data management tools for spatio-temporal point clouds benefits a wide range of users, including Brussels Mobilité. Such tools enable efficient storage, fast querying, and seamless integration of 3D data with spatiotemporal traffic datasets, supporting applications such as intersection analytics directly in the database.

Available Data: Intersection LiDAR cameras, complementary traffic data: FCD, ANPR, loop detectors, signal timing, road network topology, 3D buildings. **Technical Challenge:** Designing storage and indexing strategies for point clouds, Enabling efficient spatio-temporal queries over large point cloud collections, Providing developer-friendly APIs and visualization hooks for diverse end-user applications

Tools, Techniques & Methods: MobilityDB, PDAL for format conversion and filtering, Potree, PostGIS for 2D/3D spatial operations, Apache Kafka for streaming ingest, Docker/Kubernetes for scalable deployment.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Zimanyi Esteban esteban.zimanyi@ulb.be

Automated Traffic Status Reporting - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Standardized communication towards operational and decision-making teams is critical for coordination across the multiple stack-holders of Brussel Mobilité's as well as citizens.

Motivation & Impact: Automatically generating periodic or event-based traffic reports reduces manual reporting effort, ensures consistency, highlights key trends/incidents, and frees BM team for other tasks.

Available Data: RT DataHub, major incident logs, observed congestion events, weather incidents, roadworks status, [mobility manager log / SAGT-U log ?].

Technical Challenge: Structuring operational data into coherent narratives, dynamically adjusting report depth based on audience, and ensuring technical accuracy alongside readability for non-technical stakeholders.

Tools, Techniques & Methods: LLM integration, Spatiotemporal data warehousing & ETL pipelines, statistical summarization & trend analysis, visualization, BI integration, Data stream management systems, MEOS for spatiotemporal data processing, data engineering pipelines (Apache Kafka, Nebulastream), API integration with RT DataHub, version-controlled report templates, CI/CD for scheduled generation.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Zimanyi Esteban esteban.zimanyi@ulb.be

Scalable Spatio-Temporal Data Management Tools for Point Cloud in Urban Mobility Applications - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussels Mobilité Interest: Urban mobility agencies like Brussels Mobilité increasingly rely on 3D data from diverse sources—intersection sensors, mobile mapping, drone surveys—for monitoring, planning, and operations. However, managing, querying, and analyzing these heterogeneous, time-stamped point clouds at scale remains a technical challenge.

Motivation & Impact: Developing flexible data management tools for spatio-temporal point clouds benefits a wide range of users, including Brussels Mobilité. Such tools enable efficient storage, fast querying, and seamless integration of 3D data with spatiotemporal traffic datasets, supporting applications such as intersection analytics directly in the database.

Available Data: Intersection LiDAR cameras, complementary traffic data: FCD, ANPR, loop detectors, signal timing, road network topology, 3D buildings. **Technical Challenge:** Designing storage and indexing strategies for point clouds, Enabling efficient spatio-temporal queries over large point cloud collections, Providing developer-friendly APIs and visualization hooks for diverse end-user applications

Tools, Techniques & Methods: MobilityDB, PDAL for format conversion and filtering, Potree, PostGIS for 2D/3D spatial operations, Apache Kafka for streaming ingest, Docker/Kubernetes for scalable deployment.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Zimanyi Esteban esteban.zimanyi@ulb.be

City-Scale Traffic Count Estimation - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussel Mobilité manages regional road networks, traffic signals, and tunnels across Brussels. Accurate traffic volume data is essential for signal optimization, capacity planning, and network performance monitoring, yet many road sections remain uninstrumented with sensors.

Motivation & Impact: Estimating flows at non-sensorized locations enables holistic network visibility and data-driven decision-making. Besides the sensors that BM installs and maintains in selected sections of the network, floating car data (e.g., Tomtom) also provide vehicle counts. FCD data is however limited to the its fleet, e.g., only the vehicles that have tomtom app. By establishing a mapping between FCD and ground-truth counts from sensors at reference points, we may be able to extrapolate reliable flow estimates across the entire network.

Available Data: Floating Car Data (TomTom/Waze), reference counting points (loop detectors, manual counts, ANPR where available), road network topology, speed limit/segment definitions.

Technical Challenge: Translating sparse, provider-biased FCD into accurate volumetric estimates. Addressing segment resolution (e.g., different speed limits), spatial proximity, changing network properties, events and emergent situations.

Tools, Techniques & Methods: Spatial interpolation (ordinary/universal kriging, variogram modeling), ratio-based calibration (the rule of three), GenAI, regression analysis, geospatial analysis, statistical validation, cross-validation against ground-truth counts.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Scalable Spatio-Temporal Data Management Tools for Point Cloud in Urban Mobility Applications - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussels Mobilité Interest: Urban mobility agencies like Brussels Mobilité increasingly rely on 3D data from diverse sources—intersection sensors, mobile mapping, drone surveys—for monitoring, planning, and operations. However, managing, querying, and analyzing these heterogeneous, time-stamped point clouds at scale remains a technical challenge.

Motivation & Impact: Developing flexible data management tools for spatio-temporal point clouds benefits a wide range of users, including Brussels Mobilité. Such tools enable efficient storage, fast querying, and seamless integration of 3D data with spatiotemporal traffic datasets, supporting applications such as intersection analytics directly in the database.

Available Data: Intersection LiDAR cameras, complementary traffic data: FCD, ANPR, loop detectors, signal timing, road network topology, 3D buildings. **Technical Challenge:** Designing storage and indexing strategies for point clouds, Enabling efficient spatio-temporal queries over large point cloud collections, Providing developer-friendly APIs and visualization hooks for diverse end-user applications

Tools, Techniques & Methods: MobilityDB, PDAL for format conversion and filtering, Potree, PostGIS for 2D/3D spatial operations, Apache Kafka for streaming ingest, Docker/Kubernetes for scalable deployment.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Esteban Zimanyi (esteban.zimanyi@ulb.be)

Impact Measurement of Incidents and Roadworks - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: With ~100k annual roadworks and frequent incidents, Brussel Mobilité needs objective metrics to evaluate disruption severity and the effectiveness of traffic management measures.

Motivation & Impact: Quantifying speed loss, flow reduction, duration, and latency effects enables evidence-based planning, accountability, and continuous improvement of incident response and work zone management strategies.

Available Data: Pre- and post-event FCD/loop/ANPR data, roadworks scheduling database, incident logs, network topology, [mobility manager log / SAGT-U log ?].

Technical Challenge: Isolating event-specific impacts from usual traffic variability and recurrent disruptions. Developing standardized impact metrics, handling missing data during events, and accurately attributing effects to adjacent links.

Tools, Techniques & Methods: Data stream management systems, MEOS for spatiotemporal data processing, data engineering pipelines (Apache Kafka, Nebulastream), causal inference methods, automated impact scoring, API integration with RT DataHub.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Esteban Zimanyi (esteban.zimanyi@ulb.be)

Data Analysis for Event Risk Detection / Forecasting - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussels Mobility's operations cell must detect emerging risks before they cascade into network-wide disruptions. Early warning systems are critical for maintaining safety and flow.

Motivation & Impact: Identifying weak signals in traffic, weather, calendar, and operational data enables preemptive alerts, optimized resource deployment, and reduced incident severity.

Available Data: Real-time FCD, loop/ANPR counts, weather forecasts, event calendars, roadworks schedules, traffic light status, historical incident logs.

Technical Challenge: Distinguishing normal traffic fluctuations from true anomalies in noisy, multi-modal streams; defining context-aware thresholds; producing interpretable risk scores for human operators.

Tools, Techniques & Methods: multivariate time-series change detection, rule-based expert systems combined with ML, deep autoencoders, self-supervised contrastive learning for representation of normal traffic patterns, graph-based change-point detection using GNNs, explainable AI for operator-facing risk justification.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Short-Term Traffic Forecasting Based on Reference and Real-Time Data - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussel Mobilité oversees real-time traffic operations across the Brussels regional network, including signal control, tunnel management, and incident response by redirecting traffic. Enhancing forecasting capabilities supports the transition toward more anticipatory, data-driven traffic management and strengthens the observatory and operations cells.

Motivation & Impact: Reliable short-term predictions of speed, flow, and congestion (up to a 2-hour horizon) enable more informed decision-making, dynamic adjustment of traffic signals, and optimized coordination of operational resources. This contributes to smoother traffic flow, reduced travel time variability, and improved resilience during peak periods or unexpected events.

Available Data: Historical reference traffic speeds and counts, real-time Floating Car Data (FCD), loop detector streams, ANPR data, weather feeds, and roadworks/incidents. Prior collaborative work with IMEC explored single-sensor autoregressive models for counting; this thesis aims to extend that foundation by incorporating multi-source inputs and network-wide context.

Technical Challenge: Advancing from univariate autoregressive approaches to multivariate, network-aware forecasting models. Key aspects include integrating ANPR data for Origin-Destination validation, capturing non-linear traffic dynamics, and maintaining predictive accuracy across a 2-hour horizon despite fluctuating demand, roadworks, and evolving network conditions.

Tools, Techniques & Methods: Spatiotemporal deep learning architectures (LSTM, GRU, Temporal Fusion Transformers), graph neural networks for traffic (ST-GNN), statistical baselines (ARIMAX/SARIMAX), feature engineering for multi-modal inputs, and Python-based frameworks (PyTorch, TensorFlow, Darts). Validation via rolling-horizon evaluation and operational KPIs ensures relevance for real-world deployment.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

City-Scale Correction / Enhancement of Floating Car Data Using Other Data Sources - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: With around 100,000 roadworks per year and a constantly changing network, Brussel Mobilité needs reliable, continuous traffic data at the city scale for planning, Origin-Destination studies, and forecasting. Single-source FCD has spatial biases, temporal gaps, and representativeness issues.

Motivation & Impact: Enriching FCD with complementary sources fills data gaps, smooths artifacts, and produces robust traffic indicators for strategic and operational decision-making. At a city-scale, accuracy requirements are relaxed (e.g., compared to tunnel-level analysis) favoring coverage and consistency across the whole region.

Available Data: Multi-provider FCD, loop detector counts, ANPR data, roadworks databases, incident logs, public transport data, traffic signal timing, network topology.

Technical Challenge: Fusing heterogeneous data with different frequencies, granularities, and spatial coverage; correcting systematic FCD biases; handling missing data and artifacts caused by roadworks or special events.

Tools, Techniques & Methods: spatio-temporal interpolation (kriging), adaptive source weighting, data pipelines with automated quality checks, multimodal fusion transformers for heterogeneous input integration, graph representation learning for network-aware imputation, self-supervised pre-training on unlabeled FCD streams.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Traffic Count Estimation at Any Location - in collaboration with Brussel Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussel Mobilité manages regional road networks, traffic signals, and tunnels across Brussels. Accurate traffic volume data is essential for signal optimization, capacity planning, and network performance monitoring, yet many road sections remain uninstrumented with sensors.

Motivation & Impact: Estimating flows at non-sensorized locations enables holistic network visibility and data-driven decision-making. Besides the sensors that BM installs and maintains in selected sections of the network, floating car data (e.g., Tomtom) also provide vehicle counts. FCD data is however limited to the its fleet, e.g., only the vehicles that have tomtom app. By establishing a mapping between FCD and ground-truth counts from sensors at reference points, we may be able to extrapolate reliable flow estimates across the entire network.

Available Data: Floating Car Data (TomTom/Waze), reference counting points (loop detectors, manual counts, ANPR where available), road network topology, speed limit/segment definitions.

Technical Challenge: Translating sparse, provider-biased FCD into accurate volumetric estimates. Addressing segment resolution (e.g., different speed limits), spatial proximity, changing network properties, events and emergent situations.

Tools, Techniques & Methods: Spatial interpolation (ordinary/universal kriging, variogram modeling), ratio-based calibration (the rule of three), GenAI, regression analysis, geospatial analysis, statistical validation, cross-validation against ground-truth counts.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Learn a Robot Arm to Manipulate Objects through Qualitative Modeling.

Program : Computer science and engineering - M-IRIFS

Description

We can program robots perfectly to perform tasks, but only in known environments. Pre-programmed robots struggle to handle new situations. To enable robots to operate in uncontrolled environments, they must be capable of learning. This is where the scientific field of self-learning robots comes into play. In this master's thesis, you will apply this concept to a robotic arm that must learn to manipulate objects: moving, stacking, cleaning up, and more. Our innovative approach, based on qualitative models, will lead to improved manipulation compared to the current state of the art.

The robotic arm (see figure) will be controlled based on camera images. The objects are identified and analyzed within these images, from which the important properties are extracted. During the exploration phase, the robot will try out various actions ("play"), using the observed data to learn a qualitative model that it can then use to perform tasks (the exploitation phase).

Link : <http://parallel.vub.ac.be/learningrobots/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRELE, M-IREMR-M
Number of topics	1

Supervision

Supervisor : Jan Lemeire (jan.lemeire@vub.be)

Learn a Robot to Tackle a Gymnasium Robotic Challenge with Qualitative models.

Program : Computer science and engineering - M-IRIFS

Description

Autonomous robots must be able to solve problems on their own. For this purpose, OpenAI has standardized a set of challenges in a benchmark: <https://gymnasium.farama.org/>. For example, a car must reach the top of the mountain (by “swinging”), a cart must keep a pole upright, and a lunar lander must land between the flags. To solve such a challenge, a learning model is used. This model uses information from the task environment— in the second case, the angle of the pole— to then propose an action: changing the speed. The model must then learn a strategy to move the cart in such a way that it can keep the pole upright for as long as possible. This can be tested in simulation via Gymnasium.

The default approach is reinforcement learning, which trains a neural network by trial-and-error. This, however, has several drawbacks: a lot of training, no explanation is given (a neural network is a black box), and it just works in the environment it was trained in (no generalization or abstraction).

We propose an alternative method based on qualitative models describing relationships in a more abstract and general form:

“Turning the steering wheel clockwise makes the car turn right.”

“Pressing the gas pedal increases the car’s speed.”

“Picking up an object allows it to be moved elsewhere.”

These models can be learned with fewer interactions than traditional reinforcement learning techniques and are typically more transferable across tasks and domains.

Link : <http://parallel.vub.ac.be/learningrobots/>

Language	EN (english)
Open to other master’s programs	Yes
Eligible master’s programs	M-IREMR-M
Number of topics	2

Supervision

Supervisor : Jan Lemeire (jan.lemeire@vub.be)

Security and Privacy in Next-Generation Mobile Networks

Program : Computer science and engineering - M-IRIFS

Description

Modern mobile networks are undergoing a major transformation: from closed, hardware-driven systems to open, software-based, and cloud-native architectures. This shift enables faster innovation, flexibility, and the integration of intelligent applications. Open Radio Access Networks (Open RAN) are at the forefront of this evolution, allowing multiple vendors and software components to interoperate in a highly distributed environment. While this openness creates opportunities for innovation, it also expands the attack surface and raises important questions around trust, data protection, and system integrity.

This thesis investigates security and privacy challenges in Open RAN environments, with flexibility to focus on one or more of the following directions:

- Trust, Authentication, and Access Control
- Runtime Integrity and Attestation
- Privacy Leakage Analysis
- Security for Management and Control Systems
- Post-Quantum Cryptography (PQC) Integration

The thesis will involve:

- Literature review and threat modeling of Open RAN systems
- Design and evaluation of security or privacy-enhancing mechanisms
- Implementation and experimentation

References and further reading

1. O-RAN Work Group 1, "O-RAN Architecture Description," O-RAN ALLIANCE e.V, Tech. Rep. R004-v15.00, October 2025. <https://specifications.o-ran.org/download?id=1013>
2. O-RAN Work Group 11, "Study on Security for Near Real Time RIC and xApps," O-RAN ALLIANCE e.V, Tech. Rep. TR.0-R004-v06.00, October 2025 - <https://specifications.o-ran.org/download?id=1076>
3. M. Polese, L. Bonati, S. D'Oro, S. Basagni and T. Melodia, "Understanding O-RAN: Architecture, Interfaces, Algorithms, Security, and Research Challenges," in IEEE Communications Surveys & Tutorials, vol. 25, no. 2, pp. 1376-1411, Second quarter 2023, doi: 10.1109/COMST.2023.3239220. <https://ieeexplore.ieee.org/document/10024837>
4. M. Liyanage, A. Braeken, S. Shahabuddin, and P. Ranaweera, "Open RAN security: Challenges and opportunities," Journal of Network and Computer Applications, vol. 214, p. 103621, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1084804523000401>.

5. P. Fernando, P. Porambage, M. Liyanage, K. Steenhaut, and A. Braeken, "Securing xApps in Open RAN: A Hierarchical Approach to Authentication and Authorisation," in 2025 IEEE Conference on Communications and Network Security (CNS), 2025, pp. 1-9.
<https://ieeexplore.ieee.org/document/11195058>

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	2

Supervision

Supervisor : An Braeken (an.braeken@vub.be)

Co-supervisor : Pramitha Fernando (pramitha.fernando@vub.be)

City-Scale Traffic Count Estimation - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussel Mobilité manages regional road networks, traffic signals, and tunnels across Brussels. Accurate traffic volume data is essential for signal optimization, capacity planning, and network performance monitoring, yet many road sections remain uninstrumented with sensors.

Motivation & Impact: Estimating flows at non-sensorized locations enables holistic network visibility and data-driven decision-making. Besides the sensors that BM installs and maintains in selected sections of the network, floating car data (e.g., Tomtom) also provide vehicle counts. FCD data is however limited to the its fleet, e.g., only the vehicles that have tomtom app. By establishing a mapping between FCD and ground-truth counts from sensors at reference points, we may be able to extrapolate reliable flow estimates across the entire network.

Available Data: Floating Car Data (TomTom/Waze), reference counting points (loop detectors, manual counts, ANPR where available), road network topology, speed limit/segment definitions.

Technical Challenge: Translating sparse, provider-biased FCD into accurate volumetric estimates. Addressing segment resolution (e.g., different speed limits), spatial proximity, changing network properties, events and emergent situations.

Tools, Techniques & Methods: Spatial interpolation (ordinary/universal kriging, variogram modeling), ratio-based calibration (the rule of three), GenAI, regression analysis, geospatial analysis, statistical validation, cross-validation against ground-truth counts.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Scalable Spatio-Temporal Data Management Tools for Point Cloud in Urban Mobility Applications - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussels Mobilité Interest: Urban mobility agencies like Brussels Mobilité increasingly rely on 3D data from diverse sources—intersection sensors, mobile mapping, drone surveys—for monitoring, planning, and operations. However, managing, querying, and analyzing these heterogeneous, time-stamped point clouds at scale remains a technical challenge.

Motivation & Impact: Developing flexible data management tools for spatio-temporal point clouds benefits a wide range of users, including Brussels Mobilité. Such tools enable efficient storage, fast querying, and seamless integration of 3D data with spatiotemporal traffic datasets, supporting applications such as intersection analytics directly in the database.

Available Data: Intersection LiDAR cameras, complementary traffic data: FCD, ANPR, loop detectors, signal timing, road network topology, 3D buildings. **Technical Challenge:** Designing storage and indexing strategies for point clouds, Enabling efficient spatio-temporal queries over large point cloud collections, Providing developer-friendly APIs and visualization hooks for diverse end-user applications

Tools, Techniques & Methods: MobilityDB, PDAL for format conversion and filtering, Potree, PostGIS for 2D/3D spatial operations, Apache Kafka for streaming ingest, Docker/Kubernetes for scalable deployment.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Esteban Zimanyi (esteban.zimanyi@ulb.be)

Impact Measurement of Incidents and Roadworks - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: With ~100k annual roadworks and frequent incidents, Brussel Mobilité needs objective metrics to evaluate disruption severity and the effectiveness of traffic management measures.

Motivation & Impact: Quantifying speed loss, flow reduction, duration, and latency effects enables evidence-based planning, accountability, and continuous improvement of incident response and work zone management strategies.

Available Data: Pre- and post-event FCD/loop/ANPR data, roadworks scheduling database, incident logs, network topology, [mobility manager log / SAGT-U log ?].

Technical Challenge: Isolating event-specific impacts from usual traffic variability and recurrent disruptions. Developing standardized impact metrics, handling missing data during events, and accurately attributing effects to adjacent links.

Tools, Techniques & Methods: Data stream management systems, MEOS for spatiotemporal data processing, data engineering pipelines (Apache Kafka, Nebulastream), causal inference methods, automated impact scoring, API integration with RT DataHub.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Esteban Zimanyi (esteban.zimanyi@ulb.be)

Data Analysis for Event Risk Detection / Forecasting - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussels Mobility's operations cell must detect emerging risks before they cascade into network-wide disruptions. Early warning systems are critical for maintaining safety and flow.

Motivation & Impact: Identifying weak signals in traffic, weather, calendar, and operational data enables preemptive alerts, optimized resource deployment, and reduced incident severity.

Available Data: Real-time FCD, loop/ANPR counts, weather forecasts, event calendars, roadworks schedules, traffic light status, historical incident logs.

Technical Challenge: Distinguishing normal traffic fluctuations from true anomalies in noisy, multi-modal streams; defining context-aware thresholds; producing interpretable risk scores for human operators.

Tools, Techniques & Methods: multivariate time-series change detection, rule-based expert systems combined with ML, deep autoencoders, self-supervised contrastive learning for representation of normal traffic patterns, graph-based change-point detection using GNNs, explainable AI for operator-facing risk justification.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Short-Term Traffic Forecasting Based on Reference and Real-Time Data - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussel Mobilité oversees real-time traffic operations across the Brussels regional network, including signal control, tunnel management, and incident response by redirecting traffic. Enhancing forecasting capabilities supports the transition toward more anticipatory, data-driven traffic management and strengthens the observatory and operations cells.

Motivation & Impact: Reliable short-term predictions of speed, flow, and congestion (up to a 2-hour horizon) enable more informed decision-making, dynamic adjustment of traffic signals, and optimized coordination of operational resources. This contributes to smoother traffic flow, reduced travel time variability, and improved resilience during peak periods or unexpected events.

Available Data: Historical reference traffic speeds and counts, real-time Floating Car Data (FCD), loop detector streams, ANPR data, weather feeds, and roadworks/incidents. Prior collaborative work with IMEC explored single-sensor autoregressive models for counting; this thesis aims to extend that foundation by incorporating multi-source inputs and network-wide context.

Technical Challenge: Advancing from univariate autoregressive approaches to multivariate, network-aware forecasting models. Key aspects include integrating ANPR data for Origin-Destination validation, capturing non-linear traffic dynamics, and maintaining predictive accuracy across a 2-hour horizon despite fluctuating demand, roadworks, and evolving network conditions.

Tools, Techniques & Methods: Spatiotemporal deep learning architectures (LSTM, GRU, Temporal Fusion Transformers), graph neural networks for traffic (ST-GNN), statistical baselines (ARIMAX/SARIMAX), feature engineering for multi-modal inputs, and Python-based frameworks (PyTorch, TensorFlow, Darts). Validation via rolling-horizon evaluation and operational KPIs ensures relevance for real-world deployment.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

City-Scale Correction / Enhancement of Floating Car Data Using Other Data Sources - in collaboration with Bruxelles Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: With around 100,000 roadworks per year and a constantly changing network, Brussel Mobilité needs reliable, continuous traffic data at the city scale for planning, Origin-Destination studies, and forecasting. Single-source FCD has spatial biases, temporal gaps, and representativeness issues.

Motivation & Impact: Enriching FCD with complementary sources fills data gaps, smooths artifacts, and produces robust traffic indicators for strategic and operational decision-making. At a city-scale, accuracy requirements are relaxed (e.g., compared to tunnel-level analysis) favoring coverage and consistency across the whole region.

Available Data: Multi-provider FCD, loop detector counts, ANPR data, roadworks databases, incident logs, public transport data, traffic signal timing, network topology.

Technical Challenge: Fusing heterogeneous data with different frequencies, granularities, and spatial coverage; correcting systematic FCD biases; handling missing data and artifacts caused by roadworks or special events.

Tools, Techniques & Methods: spatio-temporal interpolation (kriging), adaptive source weighting, data pipelines with automated quality checks, multimodal fusion transformers for heterogeneous input integration, graph representation learning for network-aware imputation, self-supervised pre-training on unlabeled FCD streams.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Traffic Count Estimation at Any Location - in collaboration with Brussel Mobilité

Program : Computer science and engineering - M-IRIFS

Description

Context & Brussel Mobilité Interest: Brussel Mobilité manages regional road networks, traffic signals, and tunnels across Brussels. Accurate traffic volume data is essential for signal optimization, capacity planning, and network performance monitoring, yet many road sections remain uninstrumented with sensors.

Motivation & Impact: Estimating flows at non-sensorized locations enables holistic network visibility and data-driven decision-making. Besides the sensors that BM installs and maintains in selected sections of the network, floating car data (e.g., Tomtom) also provide vehicle counts. FCD data is however limited to the its fleet, e.g., only the vehicles that have tomtom app. By establishing a mapping between FCD and ground-truth counts from sensors at reference points, we may be able to extrapolate reliable flow estimates across the entire network.

Available Data: Floating Car Data (TomTom/Waze), reference counting points (loop detectors, manual counts, ANPR where available), road network topology, speed limit/segment definitions.

Technical Challenge: Translating sparse, provider-biased FCD into accurate volumetric estimates. Addressing segment resolution (e.g., different speed limits), spatial proximity, changing network properties, events and emergent situations.

Tools, Techniques & Methods: Spatial interpolation (ordinary/universal kriging, variogram modeling), ratio-based calibration (the rule of three), GenAI, regression analysis, geospatial analysis, statistical validation, cross-validation against ground-truth counts.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRIFS
Number of topics	2

Supervision

Supervisor : Mahmoud SAKR (mahmoud.sakr@ulb.be)

Learn a Robot Arm to Manipulate Objects through Qualitative Modeling.

Program : Computer science and engineering - M-IRIFS

Description

We can program robots perfectly to perform tasks, but only in known environments. Pre-programmed robots struggle to handle new situations. To enable robots to operate in uncontrolled environments, they must be capable of learning. This is where the scientific field of self-learning robots comes into play. In this master's thesis, you will apply this concept to a robotic arm that must learn to manipulate objects: moving, stacking, cleaning up, and more. Our innovative approach, based on qualitative models, will lead to improved manipulation compared to the current state of the art.

The robotic arm (see figure) will be controlled based on camera images. The objects are identified and analyzed within these images, from which the important properties are extracted. During the exploration phase, the robot will try out various actions ("play"), using the observed data to learn a qualitative model that it can then use to perform tasks (the exploitation phase).

Link : <http://parallel.vub.ac.be/learningrobots/>

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRELE, M-IREMR-M
Number of topics	1

Supervision

Supervisor : Jan Lemeire (jan.lemeire@vub.be)

Learn a Robot to Tackle a Gymnasium Robotic Challenge with Qualitative models.

Program : Computer science and engineering - M-IRIFS

Description

Autonomous robots must be able to solve problems on their own. For this purpose, OpenAI has standardized a set of challenges in a benchmark: <https://gymnasium.farama.org/>. For example, a car must reach the top of the mountain (by “swinging”), a cart must keep a pole upright, and a lunar lander must land between the flags. To solve such a challenge, a learning model is used. This model uses information from the task environment— in the second case, the angle of the pole— to then propose an action: changing the speed. The model must then learn a strategy to move the cart in such a way that it can keep the pole upright for as long as possible. This can be tested in simulation via Gymnasium.

The default approach is reinforcement learning, which trains a neural network by trial-and-error. This, however, has several drawbacks: a lot of training, no explanation is given (a neural network is a black box), and it just works in the environment it was trained in (no generalization or abstraction).

We propose an alternative method based on qualitative models describing relationships in a more abstract and general form:

“Turning the steering wheel clockwise makes the car turn right.”

“Pressing the gas pedal increases the car’s speed.”

“Picking up an object allows it to be moved elsewhere.”

These models can be learned with fewer interactions than traditional reinforcement learning techniques and are typically more transferable across tasks and domains.

Link : <http://parallel.vub.ac.be/learningrobots/>

Language	EN (english)
Open to other master’s programs	Yes
Eligible master’s programs	M-IREMR-M
Number of topics	2

Supervision

Supervisor : Jan Lemeire (jan.lemeire@vub.be)

Security and Privacy in Next-Generation Mobile Networks

Program : Computer science and engineering - M-IRIFS

Description

Modern mobile networks are undergoing a major transformation: from closed, hardware-driven systems to open, software-based, and cloud-native architectures. This shift enables faster innovation, flexibility, and the integration of intelligent applications. Open Radio Access Networks (Open RAN) are at the forefront of this evolution, allowing multiple vendors and software components to interoperate in a highly distributed environment. While this openness creates opportunities for innovation, it also expands the attack surface and raises important questions around trust, data protection, and system integrity.

This thesis investigates security and privacy challenges in Open RAN environments, with flexibility to focus on one or more of the following directions:

- Trust, Authentication, and Access Control
- Runtime Integrity and Attestation
- Privacy Leakage Analysis
- Security for Management and Control Systems
- Post-Quantum Cryptography (PQC) Integration

The thesis will involve:

- Literature review and threat modeling of Open RAN systems
- Design and evaluation of security or privacy-enhancing mechanisms
- Implementation and experimentation

References and further reading

1. O-RAN Work Group 1, "O-RAN Architecture Description," O-RAN ALLIANCE e.V, Tech. Rep. R004-v15.00, October 2025. <https://specifications.o-ran.org/download?id=1013>
2. O-RAN Work Group 11, "Study on Security for Near Real Time RIC and xApps," O-RAN ALLIANCE e.V, Tech. Rep. TR.0-R004-v06.00, October 2025 - <https://specifications.o-ran.org/download?id=1076>
3. M. Polese, L. Bonati, S. D'Oro, S. Basagni and T. Melodia, "Understanding O-RAN: Architecture, Interfaces, Algorithms, Security, and Research Challenges," in IEEE Communications Surveys & Tutorials, vol. 25, no. 2, pp. 1376-1411, Second quarter 2023, doi: 10.1109/COMST.2023.3239220. <https://ieeexplore.ieee.org/document/10024837>
4. M. Liyanage, A. Braeken, S. Shahabuddin, and P. Ranaweera, "Open RAN security: Challenges and opportunities," Journal of Network and Computer Applications, vol. 214, p. 103621, 2023. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1084804523000401>.

5. P. Fernando, P. Porambage, M. Liyanage, K. Steenhaut, and A. Braeken, "Securing xApps in Open RAN: A Hierarchical Approach to Authentication and Authorisation," in 2025 IEEE Conference on Communications and Network Security (CNS), 2025, pp. 1-9.
<https://ieeexplore.ieee.org/document/11195058>

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	2

Supervision

Supervisor : An Braeken (an.braeken@vub.be)

Co-supervisor : Pramitha Fernando (pramitha.fernando@vub.be)