

# Exploration of Novel Optical Sensing Techniques for Next-Generation PPG Systems

*Program : Electrical engineering - M-IRELE*

## Description

### Introduction

Photoplethysmography (PPG) is an optical sensing technique used to measure volumetric changes in blood circulation within biological tissue. It is widely used in pulse oximeters and wearable health devices to estimate physiological parameters such as heart rate, respiratory rate, and blood oxygen saturation.

Traditional PPG systems rely on conventional photodetectors to measure variations in reflected or transmitted light from tissue. However, recent advances in optical sensing technologies open new opportunities to improve the sensitivity, resolution, and information content of PPG measurements.

At ETRO-VUB, we are exploring novel sensing approaches to advance the next generation of PPG technology. One research direction focuses on the use of Single-Photon Avalanche Diode (SPAD) sensors as highly sensitive optical detectors for PPG measurements. These sensors may enable improved signal detection and new measurement capabilities compared to conventional photodetectors.

In parallel, we are investigating a novel technique, speckle-PPG, that analyzes speckle patterns generated by the interaction of coherent light with biological tissue. This approach may provide additional insight into the physical mechanisms underlying PPG signals and the interaction of light with tissue structures.

### Objectives of this work

The objective of this thesis is to explore new sensing techniques that could enhance the performance and capabilities of future PPG systems.

The work focuses on evaluating emerging sensing technologies and investigating how they can provide improved signal quality or additional physiological information compared to conventional PPG sensing approaches.

This is an exploratory research topic that requires a high degree of independence and curiosity. The student will investigate the fundamental principles of PPG measurements, including optical sensing, light-tissue interaction, and the physical origins of PPG signals.

### Description of Work

This work can comprise the following activities:

- Literature review on PPG fundamentals and optical sensing technologies
- Study of SPAD sensor technology and its potential use in PPG measurements

- Design and characterization of experimental sensing setups
- Exploration of speckle-based PPG measurement techniques
- Experimental data collection and signal analysis
- Investigation of the interaction between light and biological tissue
- Evaluation of potential advantages and limitations of novel sensing approaches

#### Location

The thesis will take place in Etterbeek, VUB K building. A hybrid presence is allowed but a high level of interaction with the student is expected.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

#### Supervision

Supervisor : Johan Stiens (johan.stiens@vub.be)

Co-supervisor : Angel Sole Morillo (angel.sole.morillo@vub.be)

## Design and development of advanced drones for water quality assessment.

*Program : Electrical engineering - M-IRELE*

### Description

This thesis develops further on previous theses in which drones have been developed for water quality assessment. Two types of drones have been developed. An aerial drone and a vessel based drone. For students from EM, this thesis will be about the optimisation of the drones and the development of algorithm for energy optimised way point planning. For students from electric engineering and computerscience the focus will be on the development of algorithms for fleet management and multi-drone co-operative measurement campaigns.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
Number of topics	2

### Supervision

Supervisor : Abdellah Touhafi (abdellah.touhafi@gmail.com)

# 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)

# Efficient computation and optimisation of large-scale computer-generated holograms for physical fabrication

*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 depth cues by reproducing the full wavefield of light, including both amplitude and phase information. Unlike stereoscopic or light field displays, holographic displays can reproduce correct focus cues, occlusion, and motion parallax simultaneously, making them a long-term target for immersive 3D visualization. Computer-generated holograms (CGHs) can reproduce full 3D scenes by encoding a physical interference pattern that reconstructs this complete wavefield. Fabricating such holograms physically imposes strict requirements on the computed fringe pattern: the hologram must be very large (gigapixel scale), encoded in a format compatible with the fabrication process (typically phase-only or binary amplitude), and optically correct across multiple wavelengths for color reproduction. While significant progress has been made in CGH algorithms, efficiently computing and optimizing large-scale holograms that meet these fabrication constraints remains an open challenge. This thesis investigates computational methods for generating high-resolution CGHs optimized for physical fabrication, with the goal of eventual printing in collaboration with external partners.

### Research activities and goals

The student will first study wave optics, existing CGH algorithms, and the constraints imposed by physical fabrication processes such as binary quantization and phase-only encoding. Building on the research group's existing hologram generation pipeline, the student will investigate methods for scaling computation to very large hologram sizes, optimizing fringe patterns for binary or phase-only fabrication formats, and reproducing color through multi-wavelength hologram design. Large-scale holographic stereograms may also be explored as a computationally tractable approach to high-resolution 3D content. The work includes literature review, algorithm development and implementation in Python or CUDA, quantitative evaluation of reconstruction quality, and preparation of hologram data for external fabrication.

### Expected Student Profile:

- Strong programming skills (MATLAB or Python, C/C++)
- Familiarity with 3D graphics or rendering is a plus, but not strictly required
- Interest in experimental physical research and evaluation (visual and optical testing)

### References and further reading

Matsushima, K. and Nakahara, S., "Extremely high-definition full-parallax computer-generated hologram created by the polygon-based method," *Appl. Opt.* 48, H54–H63 (2009).

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/2722/>

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

### **Supervision**

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

Co-supervisor : Bilal Fares (Bilal.Moussa.Fares@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. "rdgs. 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)

# Linear picosecond delays for state-of-the art time-domain laser and imaging systems

Program : *Electrical engineering - M-IRELE*

## Description

This master's thesis explores the design and implementation of precise picosecond delay generation systems for ultrafast laser and time-resolved imaging applications. The work focuses on developing electronic architectures capable of producing stable, tunable, and linearly controlled delays in the picosecond regime, addressing a critical need in synchronization and timing for high-speed optical systems.

The proposed approach combines FPGA-based phase-locked loops (PLLs) with external fine delay elements to achieve both coarse and ultra-fine temporal resolution. The FPGA PLLs provide flexible and programmable timing control, while dedicated delay buffers enable sub-nanosecond adjustment. A key aspect of the research involves characterizing and exploiting the dependence of propagation delay on voltage, current, and temperature, allowing controlled tuning of delay elements with high precision.

The project includes circuit design, PCB development, and potentially the exploration of integrated circuit (IC) solutions for compact and scalable implementations. Emphasis will be placed on minimizing jitter, ensuring linearity of delay steps, and achieving repeatable calibration across environmental variations. Measurement and validation will be conducted using high-speed instrumentation to verify timing accuracy and stability.

Ultimately, this work aims to deliver a robust and adaptable delay generation platform suitable for applications such as pump-probe experiments, time-correlated single-photon counting, and advanced imaging systems. The results will contribute to improving temporal resolution and synchronization capabilities in next-generation ultrafast optical and photonic technologies.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

## Supervision

Supervisor : Hans Ingelberts (hans.ingelberts@vub.be)

## Application of a time-of-flight distance camera in turbid, underwater environments

*Program : Electrical engineering - M-IRELE*

### Description

Distance cameras are imagers that can capture the distance to an object across a wide field of view and have a very wide range of applications, ranging from Face ID and AR to robotics and self-driving cars. Yet, a less developed area within this field is the use of these cameras in underwater environments, where the technology could help map underwater environments and fauna. However the use of traditional systems underwater comes with many challenges, such as light absorption, distortion, and multi-path effects.

At ETRO, we have developed a novel distance camera based on time-of-flight (ToF) principle. This technique measures the delay of the reflection of the laser pulse of the target. In an underwater environment, the measurement could be distorted by absorption of the laser pulse by the water or by early returns of the laser pulse caused by reflections from particles such as dirt or sand in the water. Our camera has the potential to address this by implementing time-gating systems or by modelling the environment and compensating for its effects.

In practice, this thesis will first consist of a thorough literature study to learn the principles behind ToF cameras and the effect that a (turbid) underwater environment could have on their performance. Then the student can use these concepts to first develop software simulations of the system and eventually perform experimental measurements in a controlled environment, with the goal of developing a method to extract the distance to a target.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

### Supervision

Supervisor : Wannes Nevens (Wannes.willem.nevens@vub.be)

# Underwater wireless communication based on single-photon detection for underwater drone swarms

Program : *Electrical engineering - M-IRELE*

## Description

Underwater wireless communication (UWC) is gaining significant popularity for wireless data transmission in applications such as underwater drones, naval vehicles, marine surveillance, and navigation. Due to the high absorption of radio waves in water, UWC typically relies on acoustic waves (sonar) for data transmission. However, acoustic communication suffers from limited bandwidth and low data rates, prompting growing interest in optical wireless communication as an alternative.

Optical signals, while offering higher data rates, face significant challenges underwater due to attenuation and various non-idealities such as turbulence and scattering. These factors severely impact the signal-to-noise ratio (SNR), making it difficult for conventional optical receivers to perform effectively.

At ETRO, we have developed a highly sensitive data receiver based on single-photon avalanche diodes (SPADs), capable of achieving high SNR even under conditions of strong noise and signal attenuation. While this technology has shown promise in free-space applications, we are now also exploring its potential for establishing underwater optical wireless communication (UOWC) links. The objective of this thesis is to investigate and develop reliable UOWC methods using SPAD-based receivers. The student will begin by analyzing the channel characteristics of a SPAD-based UOWC system. Following this, an experimental setup will be designed and implemented to validate the theoretical model in a laboratory environment.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

## Supervision

Supervisor : Jan Coosemans (jan.matei.coosemans@vub.be)

# Enhancing data rates and robustness for a SPAD-based optical wireless communication technology in harsh environments

Program : *Electrical engineering - M-IRELE*

## Description

Due to its inherent resilience to electromagnetic interference optical wireless communication (OWC) is gaining interest as an alternative wireless communication technology for outdoor applications such as satellite communications, unmanned autonomous vehicles (drones, drone swarms) and smart infrastructure. However, optical signals suffer from severe attenuation along the channel resulting in a very low optical power at the receiver side. Additionally, other light sources, such as the sun further compromise the Signal-to-Noise Ratio (SNR) by adding extra ambient photons to the received light.

At ETRO, we have developed a highly sensitive data receiver based on single-photon avalanche diodes (SPADs), capable of achieving high SNR even under conditions of strong noise and signal attenuation. Just as any technology, SPADs have certain trade-offs which limit the achieved bandwidth of the communication link (e.g. quantum efficiency, dead time, etc.).

The aim of this thesis is to explore novel ways to cope with the limitations and trade-offs and enhance data rates while keeping the superior robustness to signal attenuation and ambient light. The student will first investigate the state-of-the-art of SPAD-based communication. Next, the student can develop new methods for modulation/demodulation, receiver dynamic range and multiplexing through simulations and modelling. Then, the student will develop novel circuitry implementing the designed methods. The student will finally characterize the new methods and circuits and validate performance with the simulation results.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	1

## Supervision

Supervisor : Jan Coosemans (jan.matei.coosemans@vub.be)

# Measurement Synchronization for Fluorescence Lifetime Imaging using Image Recognition for In-Vivo Imaging

Program : *Electrical engineering - M-IRELE*

## Description

With the unique ETRO CAPS nanosecond gated camera, it is possible to image the nanosecond time behavior of fluorescence: the fluorescence lifetime. This enable tumors which have been marked with fluorescent contrast agents to be imaged with better contrast. ETRO has built a complete imaging system, consisting of such a CAPS camera and a laser to excite the fluorescence and this system is currently in use for cancer research on mice and dogs.

During these in vivo experiments, it has been observed that the acquired measurements are often affected by motion artefacts originating from the subject. These artefacts are mainly caused by physiological movements, such as breathing, and can significantly distort the measured temporal fluorescence signals.

The objective of this thesis is to investigate image recognition-based methods to compensate for these motion-induced artefacts and to enable accurate reconstruction of the fluorescence time behavior.

Motion information can be obtained using the integrated color camera (part of the gated camera system), by detecting and tracking the breathing cycle. This information can then be used to guide the reconstruction process. Several reconstruction approaches can be considered. These include methods based on analytical models, as well as data-driven approaches such as deep learning. A key challenge is the co-registration of the CAPS gated sensor and the color sensor, using either the integrated distance sensor or feature-based alignment. Additionally, for ex vivo specimens, the fluorescence and color images can be co-registered on a 3D map obtained from tabletop 3D scanner (e.g. einstar 3D scanner).

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

## Supervision

Supervisor : Thomas Van den Dries (Thomas.van.den.dries@vub.be)

Co-supervisor : Loris Giordano (loris.giordano@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](mailto: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](mailto:jean-francois.determe@ulb.be))

# Adaptive modulations for underwater acoustic communications

Program : *Electrical engineering - M-IRELE*

## Description

### Context

The use of Adaptive Modulations (AM) for underwater acoustic communication is a recent research endeavour, whose principle is to dynamically adapt modulation parameters (e.g., the modulation order) or even switch between fundamentally different modulations (e.g., switch from PSK to FSK). Triggering a switch from one modulation to another depends on environmental data (e.g., bathymetry data) and communication data (e.g., estimated signal-to-noise ratio and channel impulse response) and is triggered in such a way that the “best” modulation is chosen at any given time; if correctly designed, adaptive modulation should translate into throughputs that are higher than those obtained with a fixed modulation.

A few representative papers about adaptive modulations are [Pelekanis, 2018] (based on boosted regression trees), [Huang, 2020] (based on support vector machines), [Kojima, 2021] (based on convolutional neural networks) and [Su, 2019] as well as [Cui, 2023]) (based on reinforcement learning).

Given that underwater acoustic channels are complex and that real-world experiments are difficult to carry out, researchers increasingly rely on modern acoustic propagation simulators (e.g., the world oceanic simulation system (WOSS) [Casari, 2014])—a simulation tool which our group has installed on our computing server.

### Objectives and steps

The main goal of the master’s thesis is to implement (and possibly extend), simulate underwater communications and investigate the benefits of AM. The steps are i) to get familiar with underwater communications and WOSS, ii) to implement some modulation schemes and simulate them in WOSS, iii) to implement (at least) one modern adaptive modulation algorithms on WOSS (extending it/them to a wider breadth of modulations than originally designed for is encouraged) and iv) to asses the benefits of each investigated AM technique on communication reliability.

### Student profile

Any interested student should ideally have followed the courses “Modulation and coding” and “Communication channels”. Having followed or following a course on machine learning (e.g., “Machine Learning and Big Data Processing”) is also a plus.

### References

[Casari, 2014] Casari, Paolo et al. "Open source suites for underwater networking: WOSS and DESERT underwater." *IEEE Network* 28, no. 5 (2014): 38-46.

[Cui, 2023] Cui, Xuerong et al. "Reinforcement learning-based adaptive modulation scheme over

underwater acoustic OFDM communication channels." *Physical Communication* 61 (2023): 102207.

[Huang, 2020] Huang, Jianchun, and Roe Diamant. "Adaptive modulation for long-range underwater acoustic communication." *IEEE Transactions on Wireless Communications* 19, no. 10 (2020): 6844-6857.

[Kojima, 2021] Kojima, Shun et al. "CNN-based joint SNR and Doppler shift classification using spectrogram images for adaptive modulation and coding." *IEEE Transactions on Communications* 69, no. 8 (2021): 5152-5167.

[Pelekanis, 2018] Pelekanakis, Konstantinos, and Luca Cazzanti. "On adaptive modulation for low SNR underwater acoustic communications." In *OCEANS 2018 MTS/IEEE Charleston*, pp. 1-6. IEEE, 2018.

[Su, 2019] Su, Wei et al. "Reinforcement learning-based adaptive modulation and coding for efficient underwater communications." *IEEE access* 7 (2019): 67539-67550.

## Contact

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Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
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  $\mu$ 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

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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)

# A Benchmark for V2V Interaction and Cooperative Perception in CARLA

Program : *Electrical engineering - M-IRELE*

## Description

### Subject

The way we train and evaluate self-driving systems today relies on closed-loop benchmarks, settings in which the environment continuously reacts to the agent's behavior, requiring real-time decision-making. Existing benchmarks such as Bench2Drive or NAVSIM focus primarily on single-vehicle driving, even when they explore highly challenging or unrealistic scenarios. However, modern autonomous driving increasingly depends on cooperative perception, where multiple vehicles share information via V2V communication to improve safety and awareness.

This thesis shifts the focus from single-agent evaluation to multi-vehicle interaction scenarios. The goal is to design and implement a closed-loop V2V benchmark in CARLA that captures complex, real-world situations where cooperation is essential, such as emergency vehicle handling, roundabouts, occlusions at intersections, and dense traffic negotiation. These scenarios will require the student to define meaningful use cases where collaboration between vehicles provides a measurable advantage. In a second stage, the benchmark will be used to evaluate existing perception and driving models, establishing baseline performance and enabling systematic comparison between individual and cooperative approaches.

### Kind of Work

The student will:

- Design a suite of closed-loop V2V interaction scenarios in CARLA, moving beyond single-vehicle benchmarks.
- Implement multi-agent simulations where vehicles must react to each other and the environment dynamically.
- Define and model cooperative perception use cases, such as:
  - o emergency vehicle right-of-way,
  - o roundabout coordination,
  - o occluded object detection,
  - o long-range awareness via shared information.
- Develop evaluation protocols and metrics for:
  - o task success,
  - o safety and collision avoidance,
  - o reaction to other agents,
  - o benefits of cooperation vs. single-agent perception.
- Integrate and run existing autonomous driving / perception models within the benchmark.
- Produce baseline results comparing:
  - o individual perception vs. cooperative perception,
  - o performance under varying communication assumptions.

### Expected Outcome

- A novel benchmark suite for V2V interaction scenarios in CARLA.
- A set of realistic, reproducible cooperative driving tasks.
- Baseline evaluations of existing models in multi-agent settings.
- Insights into when and how cooperative perception improves performance.

Expected Student Profile

- Strong background in Computer Vision and/or Robotics.
- Experience with Python; familiarity with simulation tools is beneficial.
- Interest in autonomous driving, multi-agent systems, and 3D perception.
- Bonus: prior exposure to CARLA, V2V/V2X systems, or autonomous driving

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

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

### Supervision

Supervisor : Nikos Deligiannis (Nikos.Deligiannis@vub.be)

Co-supervisor : Tzoulio Chamiti (tzoulio.chamiti@vub.be)

# Out-of-Distribution Detection for Medical Image Analysis

*Program : Electrical engineering - M-IRELE*

## Description

### Context

Machine learning models are typically trained on data from a specific source or distribution. When deployed on data coming from a different source, their performance can drop significantly — a phenomenon known as distribution shift. To anticipate this, several metrics have been proposed to measure the distance between datasets helping practitioners decide whether a model needs to be retrained or fine-tuned before deployment.

However, this challenge has become considerably harder with the rise of foundation models — large models pre-trained on massive, often partially undisclosed datasets. Because the exact composition of their training data is unknown, it is difficult to predict when such a model will fail to generalize to a new domain, and classical dataset distance metrics lose much of their practical relevance.

This problem is particularly acute in medical imaging. Unlike natural images, medical images are highly sensitive to acquisition conditions: the same anatomical structure can look drastically different depending on the imaging modality (MRI, CT, PET), the scanner manufacturer, the acquisition protocol, or the clinical site. A model trained on images from one hospital or one type of scanner may silently underperform on images from another, with potentially serious clinical consequences. Detecting such failures before they impact patient care is therefore a critical safety requirement.

Out-of-distribution (OOD) detection offers a principled framework to address this: rather than assuming a model will generalize, the goal is to automatically identify input samples that fall outside the distribution the model was trained on, and flag them as unreliable.

### Objectives

The main objective of this thesis is to develop and validate an out-of-distribution detection approach tailored to medical image analysis, capable of identifying samples on which a model is likely to fail.

A secondary objective is to design a metric to quantify the degree of out-of-distribution, going beyond a binary in/out decision and providing a continuous, interpretable score that could be used to rank or triage samples in a clinical pipeline.

### Description of Work

- Literature review: conduct a comprehensive review of OOD detection methods, both in the general machine learning literature and in the medical imaging domain specifically. This includes a survey of existing approaches, available benchmarks, and evaluation metrics used to assess OOD detection performance.
- Development of an OOD detection approach : design and implement an OOD detection method adapted to the constraints of medical imaging — in particular, its ability to handle heterogeneous acquisition sources and limited labeled data. The approach should be compatible with modern deep learning architectures, including foundation models.

- Development of an OOD quantification metric : propose a metric to quantify how far a given sample is from the training distribution, providing a continuous and interpretable score. This metric should be meaningful across different medical imaging contexts and robust to common sources of variability (scanner, protocol, site).
- Evaluation and comparison with state of the art: evaluate the proposed approach and benchmark it against existing OOD detection methods.

#### Expected Student Profile

- Strong knowledge of machine learning, deep learning, and AI, with a specific focus on computer vision
- Solid experience in Python programming and the PyTorch deep learning framework
- Familiarity with medical imaging concepts is a plus, but not required
- Ability to work independently, conduct a literature review, and implement research-level code

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

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

### Supervision

Supervisor : Nikos Deligiannis (Nikos.Deligiannis@vub.be)

Co-supervisor : Rebecca Leygonie (Rebecca.leygonie@vub.be)

# Building reliable Multimodal Foundation Models for Cooperative Perception

*Program : Electrical engineering - M-IRELE*

## Description

### Context

Cooperative perception in V2X systems enables multiple agents — vehicles, infrastructure, and other sensors — to collaboratively perceive their environment by sharing complementary information. This paradigm has the potential to significantly improve robustness and safety in autonomous driving, particularly in complex and occluded scenarios.

In recent years, numerous V2V, V2I, and V2X datasets have been introduced, covering a wide range of sensor modalities such as cameras, LiDAR, radar, and even aerial or dronebased observations. However, these datasets remain fragmented: they differ in formats, annotation standards, sensor configurations, and underlying assumptions, which limits their joint exploitation.

At the same time, the success of foundation models in computer vision has demonstrated the value of training large-scale models on diverse and heterogeneous data. Extending this paradigm to cooperative perception requires aggregating and harmonizing multiple datasets into a unified training framework, while handling multimodal inputs and crossdomain variability. This represents a key step toward building general-purpose, robust cooperative perception systems.

### Objectives

The main objective of this thesis is to aggregate and harmonize existing V2V/V2I/V2X datasets into a unified multimodal dataset suitable for large-scale training.

A secondary objective is to design and train a multimodal cooperative perception foundation model leveraging this aggregated data, and to evaluate its generalization capabilities across datasets and modalities.

### Description of Work

- Literature review: conduct a comprehensive review of existing cooperative perception datasets, multimodal learning approaches, and foundation models in computer vision and autonomous driving. Identify key challenges in dataset aggregation and cross-dataset generalization.
- Dataset aggregation and harmonization: collect and integrate multiple public V2X datasets. This includes unifying data formats, aligning coordinate systems, standardizing annotations, and handling heterogeneous sensor modalities (e.g., LiDAR, radar, cameras, aerial views).
- Multimodal model design and training: design and implement a multimodal architecture capable of ingesting heterogeneous inputs. Train a large-scale model on the aggregated dataset, leveraging recent advances in representation learning and foundation models.
- Evaluation and benchmarking: evaluate the trained model across multiple datasets and modalities. Assess its generalization capabilities, robustness to domain shifts, and performance compared to single-dataset or single-modality

baselines.

#### Expected Student Profile

- Strong knowledge of machine learning, deep learning, and computer vision
- Solid experience in Python programming and deep learning frameworks (e.g., PyTorch)
- Interest in multimodal learning, large-scale models, and autonomous systems
- Ability to work independently, conduct a literature review, and implement research-level code

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

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

#### Supervision

Supervisor : Nikos Deligiannis (Nikos.Deligiannis@vub.be)

Co-supervisor : Alexandre Stenger (Alexandre.stenger@vub.be)

# Building Next-Generation V2X Cooperative Perception Datasets and Deep Learning Methods

*Program : Electrical engineering - M-IRELE*

## Description

### Context

Cooperative perception in connected and autonomous systems (V2X) aims to improve scene understanding by sharing information between multiple agents such as vehicles, roadside units, and infrastructure sensors. By aggregating complementary viewpoints, these systems can overcome occlusions and extend perception range, which is critical for safe autonomous driving.

However, the performance of such systems strongly depends on the availability of high-quality annotated datasets. Unlike standard single-agent perception, V2X data introduces additional complexity: multiple synchronized viewpoints, heterogeneous sensors, communication constraints, and dynamic environments. As a result, curating and annotating such datasets is significantly more challenging and remains a major bottleneck for research progress.

While several cooperative perception datasets have been proposed, there is still a lack of standardized annotation protocols, consistent labeling across agents, and comprehensive benchmarks to evaluate models in realistic multi-agent settings. Ensuring dataset quality and defining proper evaluation procedures are therefore essential steps toward reliable and reproducible research in this domain.

### Objectives

The main objective of this thesis is to curate and annotate a V2X cooperative perception dataset, ensuring high-quality, consistent, and scalable labeling across multiple agents and sensor modalities. A secondary objective is to design and implement benchmarking protocols to evaluate cooperative perception models on the curated dataset, providing meaningful and reproducible performance metrics.

### Description of Work

- Literature review: conduct a review of existing V2X and cooperative perception datasets, annotation strategies, and benchmarking protocols. This includes identifying current limitations in dataset quality, labeling consistency, and evaluation methodologies.
- Dataset curation and annotation: contribute to the acquisition, organization, and annotation of a multi-agent perception dataset. This includes defining labeling guidelines, ensuring temporal and cross-agent consistency, and possibly developing or adapting annotation tools and pipelines.
- Quality assessment and validation: design methods to assess annotation quality and consistency across agents and annotators. This may include automated checks, visualization tools, or agreement metrics.
- Benchmark design and evaluation: define evaluation protocols and metrics for cooperative perception tasks (e.g., detection, tracking, fusion). Implement baseline models and benchmark their performance on the curated dataset.

### Expected Student Profile

- Strong knowledge of machine learning, deep learning, and computer vision
- Solid experience in Python programming and deep learning frameworks (e.g., PyTorch)
- Interest in autonomous systems, multi-agent perception, or dataset engineering
- Ability to work independently, conduct a literature review, and implement research-level code

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

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

### Supervision

Supervisor : Nikos Deligiannis (Nikos.Deligiannis@vub.be)

Co-supervisor : Alexandre Stenger (Alexandre.stenger@vub.be)

# Developing Cooperative Perception Systems for Autonomous Driving under Realistic V2X Communication Constraints

*Program : Electrical engineering - M-IRELE*

## Description

### Context

Cooperative perception is a key enabler of next-generation autonomous driving systems, allowing multiple vehicles to share information and jointly understand their environment. By exchanging sensor data or learned features, vehicles can “see beyond line-of-sight,” improving safety in complex urban scenarios with occlusions, dynamic objects, and limited visibility. Most existing research in cooperative perception assumes ideal communication between vehicles—instantaneous, reliable, and high-bandwidth data exchange. However, in real-world deployments, communication is far from perfect. Factors such as latency, packet loss, bandwidth limitations, and transmission errors can significantly affect how well vehicles collaborate and make decisions.

At the same time, recent advances in deep learning have made cooperative perception models increasingly powerful and flexible. This opens an exciting research question: how do communication constraints shape the design of the next generation perception systems in autonomous driving, and how can autonomous vehicles adapt to imperfect communication conditions?

### Objective

This thesis aims to build a realistic learning-aware communication pipeline and to integrate it into the CARLA autonomous driving simulator. This integration creates a strong testbed for the cooperative perception community and the autonomous driving industry to develop safer nextgeneration

perception systems, robust against communication imperfections.

### Description of Work

The thesis will be structured into the following steps:

- Literature Review:

Review existing work on state-of-the-art cooperative perception, multi-agent deep learning, and vehicle-to-everything (V2X) communication. Special focus will be given to methods that consider bandwidth constraints, feature sharing, and robustness to missing or delayed information.

- Simulation Framework Development:

Extend the CARLA autonomous driving simulator by integrating a modular V2X communication pipeline. This pipeline will simulate:

- o Communication latency and delays
- o Bandwidth limitations and rate constraints
- o Packet loss and bit/symbol errors
- o Variable communication quality across agents

- Integration with AI Models:

Implement or adapt state-of-the-art cooperative perception models (e.g., feature fusion or intermediate representation sharing). Connect these models to the communication

pipeline to enable realistic multi-agent interaction.

- **Experimental Analysis:**

Evaluate how different communication conditions affect perception and planning performance in autonomous driving (e.g., object detection accuracy, tracking stability).

Analyze trade-offs between communication cost and AI performance.

- **Exploration of Learning-Based Improvements (Optional/Advanced):**

Investigate strategies to improve robustness in perception and planning, such as:

- o Learning what information to transmit (adaptive feature compression)

- o Handling missing or delayed data using temporal models

Expected Student Profile

- Strong knowledge of machine learning and deep learning
- Solid experience with Python and frameworks such as PyTorch
- Interest in autonomous systems, AI, and robotics
- Willingness to work with simulation tools and in a vibrant team

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

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

## Supervision

Supervisor : Nikos Deligiannis (Nikos.Deligiannis@vub.be)

Co-supervisor : Pourya Behmandpoor (pourya.behmandpoor@vub.be)

# DAGU: DATA ATTRIBUTION FOR GENERATIVE MODELS VIA UNLEARNING

*Program : Electrical engineering - M-IRELE*

## Description

Recent text-to-image models achieve impressive visual quality, but their training process remains largely opaque. A key open question is which training samples most strongly influence a generated image. Data attribution addresses this by identifying influential training examples, while machine unlearning offers a practical mechanism to simulate the removal of data from a trained model. Recent work shows that unlearning a synthesized image can reveal which training images are most responsible for its generation. This topic combines explainable AI and generative modeling, with applications in transparency, copyright, dataset auditing, and responsible AI use.

The thesis will study data attribution methods for text-to-image generative models, with a particular focus on unlearning-based attribution. The central research question is how machine unlearning can be used to identify influential training samples in a way that is accurate, computationally feasible, and interpretable. A first objective is to review the literature on data attribution, influence functions, diffusion models, and machine unlearning, and to position unlearning-based attribution relative to feature-matching and gradient-based approaches.

A second objective is to reproduce and analyze a recent unlearning-based attribution framework for text-to-image models. This includes understanding the role of Fisher-based regularization, the choice of trainable parameters, and the effect of catastrophic forgetting during unlearning. The goal will be to investigate how attribution quality is measured, for example through reconstruction loss changes, retrieval metrics, or counterfactual leave-kout evaluations.

A third objective is to explore one or more research extensions. Possible directions include improving the efficiency of attribution, studying the effect of alternative regularization schemes, extending attribution from whole images to local regions or semantic attributes, or analyzing interactions between groups of training samples rather than ranking images independently. Another possible direction is to compare unlearning-based attribution with influence-function-based baselines under a common evaluation setup.

The expected outcome is a clear experimental and methodological study of unlearning for data attribution, together with an assessment of its strengths, limitations, and possible improvements. The thesis should result in a reproducible implementation, a critical comparison of methods, and concrete recommendations for future work on interpretable and trustworthy generative AI.

## References and further reading

[1] Main paper of the topic: Wang, S.-Y., Hertzmann, A., Efros, A. A., Zhu, J.-Y., & Zhang, R. (2025). Data attribution for text-to-image models by unlearning synthesized images (arXiv:2406.09408v3) - pdf

- [2] Robin Rombach, Andreas Blattmann, Dominik Lorenz, Patrick Esser, and Björn Ommer. Highresolution image synthesis with latent diffusion models. In IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2022. – pdf
- [3] Sheng-Yu Wang, Alexei A. Efros, Jun-Yan Zhu, and Richard Zhang. Evaluating data attribution for text-to-image models. In IEEE International Conference on Computer Vision (ICCV), 2023. - pdf
- [4] Pang Wei Koh and Percy Liang. Understanding black-box predictions via influence functions. In International conference on machine learning, pages 1885–1894. PMLR, 2017. - pdf
- [5] Chuan Guo, Tom Goldstein, Awni Hannun, et al. Certified data removal from machine learning models. In International Conference on Machine Learning (ICML), 2020. - pdf
- [6] James Kirkpatrick, Razvan Pascanu, Neil Rabinowitz, Joel Veness, Guillaume Desjardins, Andrei A Rusu, Kieran Milan, John Quan, et al. Overcoming catastrophic forgetting in neural networks. Proceedings of the National Academy of Sciences (PNAS), 2017 – pdf

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

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	M-IRELE
Number of topics	1

## Supervision

Supervisor : Nikos Deligiannis (nikos.deligiannis@vub.be)

Co-supervisor : Ioannis Dilmperis (Ioannis.Dilmperis@vub.be)

Topics offered to students by other  
master's programs

**TARGET PROGRAM**

**Electrical 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. Baczyzmaliski, 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)

## 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).

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)

# Electrical engineering - M-IRELE

**Master Thesis Topics**  
**Academic year 2026-2027**

## Privacy preserving Wi-Fi sensing

Program : Electrical engineering - M-IRELE

### Description

#### Context

Wi-Fi modems continue to evolve to meet growing demands for higher data rates. The latest 802.11 amendment, 11be (EHT), enables operation below 7 GHz, uses up to 320 MHz channels, and supports as many as 16 spatial streams—allowing speeds of up to 50 Gbps. In parallel, the 11bf amendment introduces Wi-Fi sensing in addition to communication. It leverages the channel measurements already used for data transmission to characterize the surrounding environment, enabling new applications that enhance home security and autonomy. Wi-Fi sensing builds on earlier work in Wi-Fi based passive radar, which detects environmental changes by capturing existing Wi-Fi signals.

#### Objectives:

Despite its benefits, Wi-Fi sensing also raises major security concerns. Because signals can be captured even through walls, nearby eavesdroppers could detect a person's presence, track their movements, or infer their activities by exploiting the sensing transmissions. The goal of this master thesis is to design countermeasures - implemented directly in the legitimate Wi-Fi sensing devices (modem and terminals) - to prevent such unauthorized sensing by eavesdroppers.

#### Methodology :

- Assess the risk of eavesdropping Wi-Fi sensing (sensing through the wall)
- Conceive channel adaptation and noise injection techniques to degrade the SNR at the eavesdropper
- Conceive key-based pilot randomization to prevent signal recovery at the eavesdropper
- Assess and compare the performance of the proposed methods by simulations

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

#### Supervision

Supervisor : Francois Horlin

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## Improving sparse wearable motion tracking using IMU and UWB sensor fusion

Program : Electrical engineering - M-IRELE

### 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.

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

Supervision

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## Hardware requirements for Wi-Fi communications and sensing

Program : Electrical engineering - M-IRELE

### Description

Context:

Wi Fi modems continue to evolve to meet growing demands for higher data rates. The latest 802.11 amendment, 11be (EHT), enables operation below 7 GHz, uses up to 320 MHz channels, and supports as many as 16 spatial streams - allowing speeds of up to 50 Gbps. In parallel, the 11bf amendment introduces Wi Fi sensing in addition to communication. It leverages the channel measurements already used for data transmission to characterize the surrounding environment, enabling new applications that enhance home security and autonomy. Wi Fi sensing builds on earlier work in Wi Fi based passive radar, which detects environmental changes by capturing existing Wi Fi signals.

Objectives:

With Wi Fi sensing integrated into the modem, communication and sensing will be coordinated: they will share the same spectrum and hardware but rely on dedicated signals transmitted in separate time slots. Because they estimate different parameters (data symbols vs. channel characteristics), they may require distinct hardware capabilities. The goal of this master thesis is to build an advanced experimental setup using recent X410 USRP software defined radios and to experimentally validate the two functionalities using real life signals. The hardware requirements in the two cases will be compared.

Methodology :

- Settle the experimental setup based on Ettus X410 and Matlab wireless testbench toolbox
- Investigate the impact of hardware imperfections on communications and sensing functionalities analytically and by simulations
- Design hardware compensation algorithms
- Validate the communication and sensing chains over-the air

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	nan
Number of topics	1

Supervision

Supervisor : Francois Horlin

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## Flight trajectory-based UAV classification

Program : Electrical engineering - M-IRELE

### 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

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

Supervision

Supervisor : Francois Horlin

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## Homecare Radar Fall Detection

Program : Electrical engineering - M-IRELE

### 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.

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

Supervision

Supervisor : Francois Horlin

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## FMCW radar design and implementation

Program : Electrical engineering - M-IRELE

### 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:

Before implementing a pedestrian tracking filter, the Frequency-Modulated Continuous Wave Radar system must first be properly designed and implemented. This includes both the hardware setup and the radar signal processing required to generate the Range–Angle–Doppler Cube (RADC) from the raw radar measurements.

Methodology:

- Design a mechanical support for the radar (3D printing may be used if desired). The support should be portable and easily deployable at any location.
- Implement the MIMO-TDM radar signal processing in MATLAB. The Range–Angle–Doppler Cube (RADC) should be generated from the raw radar measurements. A deep understanding of the Frequency-Modulated Continuous Wave Radar will be required.
- Acquire real-world measurements using an experimental setup by the end of the thesis. Real-world pedestrian tracking can be performed using a provided tracking algorithm.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	nan
Number of topics	1

Supervision

Supervisor : Francois Horlin

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

Program : Electrical engineering - M-IRELE

### 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

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

#### Supervision

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## Data driven modeling on Intensive care patients

Program : Electrical engineering - M-IRELE

### Description

When patients end up in an intensive care unit (ICU), they are in a life-critical state. For that reason, the status of the lungs must be continuously monitored, to detect when the patients deteriorate.

In this thesis, you will develop measurement and modelling techniques that helps determining the respiratory systems impedance, utilizing multisine excitation and data-driven modelling.

Respiratory system impedance measurements can provide insight into the mechanical state of the lung. Having this insight as a physician is known to be incredibly helpful in preventing deterioration but in the current state-of-the-art, techniques are lacking that enable the impedance measurements.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	nan
Number of topics	3

Supervision

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

Program : Electrical engineering - M-IRELE

### 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.

Language	EN (english)
Open to other master's programs	Yes

Eligible master's programs	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH
Number of topics	1

Supervision

Supervisor : Frederic Robert

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Lien : [https://en.wikipedia.org/wiki/Jiangmen\\_Underground\\_Neutrino\\_Observatory](https://en.wikipedia.org/wiki/Jiangmen_Underground_Neutrino_Observatory)

## Mitigating Mutual Interference between mm Wave MIMO Automotive Radars

Program : Electrical engineering - M-IRELE

### Description

Radar is a key technology for applications that require precise 3D detection with compact sensors. In the automotive sector, modern mm-wave radars combine large bandwidths with small antenna apertures. This enables high range resolution, fine angular estimation through multiple input multiple output (MIMO) techniques, and accurate Doppler velocity measurements. Together, these capabilities provide a detailed and reliable perception of the surrounding environment.

Automotive radars are active sensors: they transmit a waveform into the environment and process the reflected echoes with a sensitive receiver to detect fixed and moving objects and estimate their range, azimuth, elevation, and speed. This active nature is both “a blessing and a curse.” The transmitted power enables long detection ranges and excellent resolution, but the same waveform can inadvertently be picked up by nearby radars. This phenomenon, called mutual interference (MI), can severely degrade detection performance.

Historically, MI has received limited attention because radars were sparsely deployed. Automotive radars could effectively “live in their own world,” focusing solely on their own transmitted signal. This contrasts with the wireless communication world, where devices must detect signals from others, and coexistence mechanisms have been part of the design from the beginning. As the number of radars and their sensitivity increase, MI is rapidly becoming a critical challenge.

One classical solution is to share the time-frequency resources among multiple radars. While effective at preventing interference, this approach comes at a high cost: each radar can only use a fraction of the available bandwidth or time, leading to reduced resolution. Moreover, resource sharing does not solve compatibility issues with existing radars, nor does it provide robustness against intentional jammers.

This thesis aims to investigate how novel radar waveform modulation techniques and signal processing algorithms can be combined with time-frequency resource allocation to reduce or suppress mutual interference without sacrificing radar performance. The proposed solution will be validated through the Matlab simulation environment developed by Imec.

You will join a large interdisciplinary IMEC team working on next generation radar systems. The group brings together experts in mm-wave analog and digital design, radar theory, wireless communication techniques, and advanced signal processing. This environment will give you exposure to both theoretical methods and practical system implementation.

Required background: Strong understanding of signal processing and linear algebra. Proficiency with Matlab. Some knowledge of radar concepts is a plus.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	nan
Number of topics	1

#### Supervision

Supervisor : Francois Horlin

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## DVB-T based passive radar for wide coverage UAV detection

Program : Electrical engineering - M-IRELE

### Description

Context:

Low flying Class 1 drones represent a growing threat to critical infrastructures such as airbases, airports, and energy facilities. To mitigate these risks, wide area detection systems capable of providing early alerts are essential.

Passive radars are an attractive solution because they use illuminators of opportunity - such as broadcast television and communication signals - allowing surveillance over a wide area without resorting to dedicated transmitters. Recent research highlights the strong potential of passive radars for UAV detection using continuous, high power, and widely deployed DVB T signals. They enable long range UAV detection, with demonstrations achieving detection distances of up to 5 km, including direction of arrival (DoA) estimation.

Objectives:

The project aims to design, develop, and demonstrate a DVB-T based passive radar system capable of detecting and locating mid size UAVs (approximately 50 cm). The system will be validated using a software defined radio (SDR) receiver, enabling flexible signal acquisition and adaptation to different operational scenarios.

Methodology :

- Investigate the properties of DVB-T signals when used as illuminators of opportunity
- Acquire the DVB-T signal over-the-air with the USRP setup and implement the decoder
- Build the DVB-T-based passive radar and simulate it in Matlab
- Validate the passive radar experimentally for the detection of a mid-size UAV at varying distances from the radar

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IREMR-M, M- IRPH
Number of topics	3

Supervision

Supervisor : Francois Horlin

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

Program : Electrical engineering - M-IRELE

### 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.

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

#### Supervision

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## Space Geodesy & VLBI

Program : Electrical engineering - M-IRELE

### Description

Why Geodesy Matters:

Geodesy is the science of measuring and monitoring the shape, orientation, and gravity field of the Earth to extend our understanding of climate change, sea level rise, polar ice dynamics, and tectonic plate motion. The accuracy of these measurements depends critically on the quality of the International Terrestrial Reference Frame (ITRF), the global coordinate system used by GPS, satellite altimetry, and potentially all Earth observation missions. Improving the precision and stability of the ITRF by even a fraction of a millimetre (/ millimetre per year) translates directly into more reliable climate records and better-informed policy decisions. This precision requires combining multiple space geodetic techniques: GNSS (GPS and its counterparts), Satellite Laser Ranging (SLR), DORIS, and Very Long Baseline Interferometry (VLBI).

### The GENESIS Mission and Space VLBI

Geodetic techniques are also used to determine the orientation of the earth (the so called earth orientation parameters or EOP). Systematic errors are however observed when comparing the results of different techniques which have not been explained so far, and impact the quality of the ITRF. GENESIS is an ESA mission designed to co-locate all four space geodetic techniques on a single satellite with the goal to answer those questions and thus improve the precision and stability of the ITRF itself. Belgium plays a leading role in the VLBI component of this mission. VLBI traditionally works by simultaneously observing distant quasars (quasi-stellar radio sources billions of light-years away) from antennas separated by thousands of kilometres. The tiny difference in signal arrival time between stations (the interferometric delay) encodes the precise distance between them. In GENESIS, the quasar is replaced by an onboard radio transmitter: the satellite itself becomes a calibrated, controlled source. At the same time, this new technology and observation geometry bring unique challenges in signal design, delay modelling, and hardware characterisation.

### Internship (12 weeks, July–October)

The internship focuses on laboratory validation of existing simulations. Working within ROB's GENESIS team, you will participate to the development of VLBI RF test bench. The main tasks include:

- RF chain characterisation: frequency response (amplitude and phase), phase noise analysis, and frequency stability measurements.
- Experimental VLBI bench: transmission of a Gaussian noise VLBI signal within several sub-bands, baseband conversion, and correlation using existing software tools.

- Thermal testing: oven-based measurements of group delay variations as a function of temperature, and derivation of a theoretical transmitter group delay.
- Validation of antenna phase centre compensation.

Master Thesis (following the internship)

The thesis extends the internship work into one of the following research directions:

- Single-station ranging. While VLBI has always been a differential measurement technique, the presence of a VLBI transmitter allows to perform single station measurements similarly to GNSS. Waveform design for optimal correlation precision, multi-band strategies, and sensitivity to clock and atmospheric modelling errors are among the topics to be investigated
- Frequency transfer: using the VLBI emitter to compare and transfer ultra-stable atomic clock signals between ground stations is one of the potential side service that can be performed with GENESIS.
- System imperfection modelling: incorporating realistic hardware imperfections (orbital dynamics, clock instabilities, antenna calibration errors, thermal drifts) into the simulation chain, and designing estimation and compensation algorithms.

Profile

- Electrical or physical engineering

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

Supervision

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

Program : Electrical engineering - M-IRELE

### 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.

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

Supervision

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Lien : [https://en.wikipedia.org/wiki/Jiangmen\\_Underground\\_Neutrino\\_Observatory](https://en.wikipedia.org/wiki/Jiangmen_Underground_Neutrino_Observatory)

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

Program : Electrical engineering - M-IRELE

### 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.

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

#### Supervision

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## Radar-Based Pedestrian Tracking with Recurrent Neural Networks

Program : Electrical engineering - M-IRELE

### 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).

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

Supervision

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## Design, implementation and testing of a wideband Wireless CAN protocol

Program : Electrical engineering - M-IRELE

### 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.

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

#### Supervision

Supervisor : Francois Quitin

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Co-supervisor : Michel Osée

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## [JUNO3] Nanosecond-Scale Clock Distribution in the Base-Edge-Core Architecture for Particle Physics Experiments

Program : Electrical engineering - M-IRELE

### 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.

- The Base-Edge-Core (BEC) architecture is a hierarchical framework developed at IIHE for cost-effective multichannel data aggregation in particle physics experiments. A key design principle of BEC is the decoupling of functional layers: Base, Edge, and Core can evolve independently, minimizing adaptation cost when requirements change.
- In its current deployment within the JUNO experiment, the BEC system uses 125 Mbps GPIO links between back-end and front-end electronics, with IEEE 1588 Precision Time Protocol providing clock synchronization at 8 ns precision. Recent tests have demonstrated that the Edge layer can be upgraded to optical links operating at up to 1 Gbps, with an asymmetric physical layer: SelectIO (GPIO) on the BEC side and a Multi-Gigabit Transceiver (GTX) on the front-end side.
- The objective of this thesis is to study clock distribution and synchronization techniques under this asymmetric link architecture. The student will analyze the existing PTP implementation, investigate how state-of-the-art approaches — such as the White Rabbit protocol — can be adapted to the deterministic, point-to-point BEC context, and evaluate the achievable timing precision. If time permits, a prototype implementation on the optical BEC platform will be carried out.

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

Supervision

Supervisor : Frederic Robert

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Co-supervisor : Barbara Clerbaux

Contact : Barbara.clerbaux@ulb.be

Lien : [https://en.wikipedia.org/wiki/Jiangmen\\_Underground\\_Neutrino\\_Observatory](https://en.wikipedia.org/wiki/Jiangmen_Underground_Neutrino_Observatory)

## Development of new technology for the abatement of CO2

Program : Electrical engineering - M-IRELE

### Description

Carbon dioxide is one of the most important greenhouse gases; its emissions should be drastically reduced. At the Chemical Engineering Department (VUB), new technologies for the separation of CO<sub>2</sub> from industrial gas streams, biogas, indoor air and the atmosphere are developed. We are implementing novel methods and materials to replace classical processes by electrified heating methods, such as microwave and inductive heating. This will lead to more efficient processes at lower energy intensity and allows to use renewable energy. Several master thesis subjects are available (experimental, theoretical, modeling). As an example, we are developing novel structured adsorbents to be heated using microwaves or alternating magnetic fields (induction heating), as an energy-efficient CO<sub>2</sub> capture method. A first thesis focusses on the use of induction and resistive heating as a method to regenerate the adsorbent and desorb CO<sub>2</sub>. In a second thesis, we will develop a novel approach that allows to use waste heat to drive the carbon capture processes. Waste heat is generated in many industrial processes in huge amounts and is currently unused. Recovery of such waste heat would have a very large on CO<sub>2</sub> emissions. Many aspects (material development and characterization, heat and mass transfer, adsorption and diffusion in the nanopores of the adsorbent, cycle optimization,...) of the process can be investigated in a master thesis on this topic.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	nan
Number of topics	1

Supervision

Supervisor : Joeri Denayer

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Co-supervisor : Mohsen Gholami

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Topics offered to students by other master's  
programs

**TARGET PROGRAM**

Electrical 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.

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

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

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

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

### Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@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.

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

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

#### Supervision

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

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

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

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

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

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

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

### Supervision

Supervisor : Debeir Olivier (olivier.debeir@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.

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

### Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@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.

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

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

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

### Supervision

Supervisor : Nonclercq Antoine (antoine.nonclercq@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.

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

### Supervision

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

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

## Process parameter optimization for 3D printing of Functionally Graded rocket nozzle through 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 specific 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 3-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, and the melt pool (high intensity spot) are visible.

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.

Rocket nozzles need FGMs to withstand extreme thermal and mechanical stresses by gradually transitioning from heat-resistant materials at the throat to tougher structural metals, improving durability, reducing thermal mismatch, and preventing failure. This is why rocket nozzles are manufactured with a graded transition from 316L or Inconel to copper as shown on Fig. 2-3.

The BE Rocket Team [3] is a Belgian inter university student initiative (VUB, KU Leuven, ULB, RMA, Liège, Mons, Bruges) aiming to design, build, test, and launch amateur solid fuel

rockets to compete in the European Rocketry Challenge (EuRoC). The 21st of October 2024, Be-Rocket successfully launched their first rocket, Bossart-I, at the military base of Elsenborn in Belgium. Fig. 4-6 shows the rocket during boost phase, and the nozzle design that was used for the tests. However, the nozzle has been conventionally manufactured and doesn't rely yet on the FGM technology.

In parallel at the AM-Lab of VUB, preliminary experiments have been performed for the production of miniature rocket nozzles. During the DED process, the thermal history of the part is critical to the final quality and directly influences residual stresses. Many interconnected physical phenomena occur, and the process is defined by several parameters such as laser power, scan speed, powder feed rate, scanning path, track overlap, and more. When printing FGMs, these parameters increase in number and must be actively tuned during the build as the material transitions from one type to another. The results of the manufacturing of the miniature FGM rocket nozzle are shown in Fig. 7-10. However, several processing challenges remain, including dripping, crack formation, lack of fusion, and other microstructural defects. These issues highlight the need for further process optimization to produce a high-quality rocket nozzle.

The aim of this master thesis will be to manufacture a structurally sound rocket nozzle for the next Be-Rocket student rocket, the design of which is shown in Fig. 6. The work will involve conducting an extensive parametric study to enable the production of a high-quality miniature nozzle demonstrator, meeting criteria such as dimensional accuracy, appropriate microstructure, and minimal defects like pores, cracks, or lack of fusion. Various manufacturing strategies available in our lab must be considered and explored (for example regulation of melt pool temperature, etc.).

The results of these strategies will need to be compared to identify the most efficient manufacturing approach for manufacturing a real size nozzle. The best demonstrator will then be on the test bench for solid rocket motors at the rocket propulsion test facility of the ULB, as shown on Fig. 11-12.

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

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

## Supervision

Supervisor : Jardon Zoé ([zoe.jardon@vub.be](mailto:zoe.jardon@vub.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.

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

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

### Supervision

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

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

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

### 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.

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

Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@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.

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

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

### Supervision

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

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

### On intransitive indifference relations and PROMETHEE methods

#### 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](mailto: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.

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

## Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

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

### Non-compensatory grading methods for university exams

#### 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.

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

#### Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

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

### Explainability of decisions from PROMETHEE based models

#### 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.

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

## Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

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

### Learning preferences of students towards course practices

#### 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.

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

## Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

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

## Development of a thermal PID closed-loop controller for 316L/CuCr1Zr functionally graded additive materials

### Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future. However, ensuring that each alloy composition (of a multi-material) is processed in the optimal manner requires the development of a dedicated and advanced (thermal) closed-loop controller.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will first perform system identification for the different materials / mixtures considered in the framework of this thesis. The student will develop a model between the laser power input and thermal response of the melt, highlighting the differences that exist depending on the processed mixture. The student will then develop, simulate and implement a (PI) controller and perform practical tests to evaluate the controller's actions, depending on the processed mixture. The student will evaluate the necessity of a mixture-specific controller, and will propose a framework as to how to adjust controller parameter based on varying compositions (e.g. additional controller input). The student may suggest machine modifications with the purpose of enhancing the quality of the produced multi-material samples through closed-loop control.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
<b>Nombre de sujets</b>	2

### Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.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 an 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.

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

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

## Supervision

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

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

## Processing and characterization of a 316L to CuCr1Zr functionally graded additive materials

### Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will engage in the explorative research regarding the process-material-property relationship of this multi-material. Especially the effect of ultrasound excitation during the DED processing of such 316L/CuCr1Zr multi-material will be explored. Samples with varying/gradient compositions will be manufactured and mechanically/microstructurally characterized to further optimize the processing conditions. The effects on corrosion resistance will be evaluated as well. The student will suggest process parameter optimizations and machine modifications with the purpose of enhancing the quality of the produced multi-material samples.

Practically, coupons will be produced under varying processing conditions, amongst which the amplitude of the ultrasonic excitation, after which metallurgical evaluation will reveal the obtained microstructure. The work will then continue to print larger coupons with gradient microstructures, which will then be metallurgically and mechanically characterized. Additionally, corrosion testing will be conducted macroscopically, and at localized regions to carefully evaluate the performance along the build direction. The functional properties (thermal/mechanical/corrosion) will be compared to reference conditions without ultrasound excitation.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRMAE, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : Hinderdael Michaël ([michael.hinderdael@vub.be](mailto:michael.hinderdael@vub.be))

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

## Measurement, modelling and compensation of a modulated high power fiber laser for metal 3D-print applications

### Description

Context of the master thesis:

Additive manufacturing (AM), particularly selective laser melting, and directed energy deposition have a significant potential impact on the production of complex parts and components. The ability to create intricate geometries layer by layer offers advantages in various industries, from aerospace to medical devices. Conventionally, continuous-wave lasers have been the workhorses for metal AM, operating at high power levels. However, emerging new fiber laser technologies present an exciting opportunity to enhance the precision and efficiency of this process. Continuous wave lasers have been evaluated with calorimetric measurement solutions. Since calorimetry is based on a thermal process, its time constant is relatively high compared to the time constants associated with lasers. This implies that the calorimeter effectively behaves as a lowpass filter, filtering out any laser dynamics, i.e. only statements concerning the average laser power can be made. The new available thin film sensor technology enables a significant extension of the dynamic range (10 kHz) without jeopardizing laser damage resistance property. Two dynamic laser effects are distinguished in literature viz. 'steady state power variation' and 'switching behaviour'. Continuous lasers, while effective, lack the fine-grained control necessary for intricate AM processes. The modulated laser is a dynamic light source that allows precise modulation of output power. By adjusting the amplitude, duty cycle and/or the modulation frequency, we can tailor the energy deposition during the AM. The aim of the master's thesis is to measure, model and compensate for the dynamic behaviour of a modulated laser source. More specifically you will:

Tasks:

- Use a modulated laser system and optimized input excitations signals to characterize its behaviour using advanced laser power and PXI measurement equipment. Here it is key to accurately measure the dynamic behaviour of the laser, including power fluctuations, modulation frequency, and other relevant parameters during AM experiments.
- Apply system identification tools to model the laser's dynamic response to the modulation input.
- Develop a compensation algorithm based on the earlier retrieved model to compensate for the dynamic behaviour of the laser.

Don't hesitate to reach out to us if you want more information!

See also external link

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-M
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : De Baere Dieter (dieter.de.baere@vub.be)

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

## Development of a MIMO closed-loop controller for 316L/CuCr1Zr functionally graded additive materials

### Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future. However, ensuring that each alloy composition (of a multi-material) is processed in the optimal manner requires the development of a dedicated and advanced closed-loop controller.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will first investigate the particular challenges related to the development of a closed-loop process controller for multi-materials. By utilizing the existing closed-loop controller (only laser power control), the student will compare samples against open loop trials. The existing closed-loop controller will then be further optimized (PID parameter tuning, setpoint, temperature estimation models), challenged for different geometries and extended (e.g. including scan speed control). The student may suggest machine modifications with the purpose of enhancing the quality of the produced multi-material samples through closed-loop control.

The student will characterize the process (system identification) and develop a state-space model of the process. A Model Predictive Controller (MPC), based on Matlab/Python scripting, will be developed. The student will be involved in the practical integration, machine control implementation and parameter tuning of the to-be-developed closed-loop process controller. Coupons will then be produced under varying controlling strategies (open loop, existing closed-loop, new solution) after which metallurgical evaluation will reveal the obtained part quality. Machine modifications may be suggested towards further enhancing the DED process.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : Hinderdael Michaël ([michael.hinderdael@vub.be](mailto:michael.hinderdael@vub.be))

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

## Development of a ML-based controller for 316L/CuCr1Zr functionally graded additive materials

### Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future. However, ensuring that each alloy composition (of a multi-material) is processed in the optimal manner requires the development of a dedicated and advanced closed-loop controller.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will first investigate the particular challenges related to the development of a closed-loop process controller for multi-materials. The student will select and train multiple regression-based machine-learning (ML) models and compare their performance to classify coaxial melt-pool images with varying alloy compositions. A real-time process controller will be implemented to control the DED-LB process, thereby utilizing the ML model classification as input to know how to process the alloy optimally (e.g. target melt-pool temperature, adjust powder feed rates). A comparison between open-loop processing, traditional closed-loop control and ML-based controller is planned (target composition (EDS), and part quality (metallurgical analysis)).

The student will propose processing trials in which melt-pool images are captured to train a regression-based ML model. The developed model will be evaluated against an unseen set of melt-pool images with varying compositions to evaluate the estimation accuracy and pinpoint classification errors. The resulting coupons will be metallurgically characterized (EDS) and serve as the ground truth for classification purposes. A second part of the thesis will then involve the development of a control loop in which the actual melt-pool composition is compared to the targeted one, allowing to change the powder feed rates and utilize the optimal processing conditions for the actual melt pool composition.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes

<b>Masters concernés</b>	M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@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.

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

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

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

## Supervision

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

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

## Temperature estimation methods study for metal 3D-printing.

### Description

Context of the master thesis:

Metal 3D-printing or Additive Manufacturing (AM) of metallic structures is an emerging technology for making solid 3D object from a digital file. The design, fabrication, distribution of products and the use of components made with AM techniques are low carbon consuming and highly efficient in their use of virgin material [1]. Airbus and other aerospace companies have denoted AM as a game changing technology for 21 century. An article by The Economist [2] details "The third industrial revolution". Additive manufacturing is highlighted as the production technology of the future, enabling mass customization instead of mass production. To obtain good quality manufactured parts in AM, temperature control of the printing process is required. Therefore, one of key challenges resides on the temperature estimation method. The objective of the master thesis is to get acquainted with different temperature estimation methods, identify the advantages and disadvantages of each method, and define what methods are suitable for monitoring the AM process.

Tasks:

- Literature review of different temperature estimation methods
- Understanding of hyperspectral cameras
- Development of temperature estimation algorithms
- Temperature estimation methods assessment

See also external link

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-M, M- IRPH
<b>Nombre de sujets</b>	2

### Supervision

Supervisor : De Baere Dieter (dieter.de.baere@vub.be)

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

## Metallurgical, mechanical & corrosion characterization of ultrasonic assisted additively manufactured 316L

### Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future.

The current thesis proposal targets the processing of single 316L alloy, yet Functionally Graded, constituting of a microstructural gradient by grain refinement through ultrasonic assisted additive manufacturing. Without such ultrasound assistance, grains tend to grow to elongated and larger grains during the solidification step, typically resulting in undesired, anisotropic material properties. The ultrasound excitation perturbs the melt pool during the solidification step, causing an interrupted grow of these elongated grains, and leading to a more refined and more isotropic material properties. The student will engage in the explorative research regarding the process-material property relationship through the addition of ultrasound excitation.

Practically, the student will be involved in the practical integration and machine control implementation of an ultrasonic stack to harmonically work alongside the additive manufacturing process. Coupons will then be produced under varying processing conditions, including primarily the amplitude of the ultrasonic excitation, after which metallurgical evaluation will reveal the obtained microstructure. The work will then continue to print larger coupons with gradient microstructures, which will then be metallurgically and mechanically characterized. The anisotropy of the mechanical properties will be compared to reference conditions without ultrasound excitation. Besides, a systematic microstructural characterization will be conducted by SEM to evaluate, not only the grain structure, but also the sub-granular micro-segregation cell structure and inclusion formation along the build direction; since these aspects have a very important impact on the properties of the material.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRMAE, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.be)

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

## Process parameter optimization for 3D printing of single alloy rocket nozzle through 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 specific 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 3-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, and the melt pool (high intensity spot) are visible.

Rocket nozzles must be extremely resistant to withstand the intense thermal and mechanical loads experienced during launch, see Fig. 2-3. They are exposed to temperatures exceeding 3000 °C and high-pressure exhaust gases moving at supersonic speeds. In addition, they endure significant thermal gradients, vibrations, and mechanical stresses from the combustion chamber and external aerodynamic forces. As a result, nozzle materials and designs must ensure high thermal conductivity, oxidation resistance, mechanical strength, and structural integrity throughout the mission.

Producing the rocket nozzle using DED offers significant advantages. It allows for precise control over material deposition, enables the fabrication of complex geometries, function integration minimizes material waste, and supports rapid iteration.

The BE Rocket Team [3] is a Belgian inter university student initiative (VUB, KU Leuven, ULB, RMA, Liège, Mons, Bruges) aiming to design, build, test, and launch amateur solid fuel rockets to compete in the European Rocketry Challenge (EuRoC). The 21st of October 2024, Be-Rocket successfully launched their first rocket, Bossart-I, at the military base of

Elsenborn in Belgium. Fig. 4-6 shows the rocket during boost phase, and the nozzle design that was used for the tests. However, the nozzle has been conventionally manufactured and not with additive manufacturing techniques.

In parallel at the AM-Lab of VUB, preliminary experiments have been performed for the production of miniature rocket nozzles. During the DED process, the thermal history of the part is critical to the final quality and directly influences residual stresses. Many interconnected physical phenomena occur, and the process is defined by several parameters such as laser power, scan speed, powder feed rate, scanning path, track overlap, and more. The results of the manufacturing of the miniature rocket nozzle are shown in Fig. 7-10. However, several processing challenges remain, including dripping due to the printing on inclined surfaces, lack of fusion, and other microstructural defects. These issues highlight the need for further process optimization to produce a high-quality rocket nozzle.

This master thesis will aim to manufacture a structurally sound rocket nozzle for the next Be-Rocket student rocket, the design of which is shown in Fig. 6. The work will involve conducting an extensive parametric study to enable the production of a high-quality miniature nozzle demonstrator, meeting criteria such as dimensional accuracy, appropriate microstructure, and minimal defects like pores or lack of fusion. Various manufacturing strategies available in our lab must be considered and explored (for example remelting, controlled cooling to reduce cracking, regulation of melt pool temperature, etc.).

The results of these strategies will need to be compared to identify the most efficient manufacturing approach for manufacturing a real size nozzle. The best demonstrator will then be on the test bench for solid rocket motors at the rocket propulsion test facility of the ULB, as shown on Fig. 11-12.

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

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

## Supervision

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



Master's program offering the topic: EM - Energy - M-IREMR-E

## Critical Parameter Identification for Low-Temperature Cycling of Lithium-Ion Batteries for safety reasons.

### Description

Cycling lithium-ion batteries at low temperatures induces characteristic degradation effects, including increased internal resistance, lithium plating, change SEI behavior, and modified heat-generation patterns. This thesis investigates how these parameters evolve under controlled low-temperature cycling conditions. The student will perform cycling experiments at selected ambient temperatures, analyze the resulting changes in key electrochemical parameters, and identify which of them have the strongest influence on thermal-runaway initiation and progression. The dominant low-temperature effects will then be formulated in a simplified representation suitable for integration into an existing thermal runaway model, enabling more accurate prediction of aged-cell behavior under abuse conditions.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

### Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Developing a Physics-Based Pack-Level Digital Twin Using Network-Coupled Single Particle Models (SPM)

### Description

#### Description

Electric vehicles and renewable energy storage rely heavily on Battery Management Systems (BMS). However, current commercial BMS software often uses simplified "black box" models that ignore the actual physical chemistry happening inside the battery cells. To improve performance and safety, the industry is rapidly shifting toward Digital Twins—highly accurate, virtual replicas of battery packs that predict state-of-charge and degradation in real time.

This thesis offers the opportunity to build the fast, physics-based models required to make these digital twins a reality. Using the highly efficient Single Particle Model (SPM), you will simulate the internal electrochemical behavior of a single lithium-ion cell and scale it up to model an entire networked battery pack. This project provides highly sought-after, hands-on experience designing the next generation of smart battery software.

#### Objectives

- **Develop:** Build a baseline Single Particle Model (SPM) to capture a single cell's core electrochemistry.
- **Scale:** Connect individual SPM cells into a series/parallel pack network to simulate system-level electrical behavior.
- **Validate:** Test the pack-level digital twin's accuracy and speed against standardized lab drive-cycle data.

#### Methodology

The project will proceed through the following key steps:

- **Review:** Study the Single Particle Model and its application in battery digital twins.
- **Build:** Use standard tools (COMSOL, MATLAB/Simulink, Python, or PyBaMM) to develop the cell SPM and scale it into a pack network.
- **Simulate & Validate:** Run dynamic simulations (e.g., standard EV driving profiles) and validate the model's accuracy against existing laboratory test results.

#### Pre-requisites

The candidate is expected to have the following experience/skills:

- Basic knowledge of electrochemistry, lithium-ion battery fundamentals, and differential equations.
- Familiarity with simulation and modeling tools e.g., COMSOL, MATLAB/Simulink, Py-

thon, or PyBaMM is an added advantage.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

## Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Specific Heat Capacity Characterization of Lithium-Ion Batteries Using Hybrid Methodology and ARC Validation.

### Description

Accurate knowledge of the specific heat capacity ( $C_p$ ) of lithium-ion batteries is essential for reliable thermal modelling and prediction of thermal runaway behavior. This thesis investigates a novel methodology for determining  $C_p$  under controlled conditions and compares its results with measurements obtained through Accelerating Rate Calorimetry (ARC). The student will characterize several Li-ion cell types, quantify discrepancies between methods, and assess the influence of state-of-charge and temperature. The experimentally derived  $C_p$  values will then be integrated into an existing thermal runaway model to evaluate their impact on simulation accuracy and safety-critical predictions.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

### Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Grid-Forming Droop Control with Seamless Islanding Transition for a Battery-Based Vehicle-To-Grid Unit

### Description

The ability of a vehicle-to-grid (V2G) unit to transition seamlessly between grid-connected and islanded operation is critical for microgrid resilience. This thesis will design a droop-based grid-forming controller that detects islanding and autonomously reconfigures its control loops, validated experimentally using the battery-connected inverter as the grid-forming source and a machine as a local load.

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

### Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Fast diagnostic feasibility of EV battery modules to determine SoH and Remaining Useful Life.

### Description

A fast diagnosis methodology using already available data.

Design and development of the battery model, SoC/SoH estimation, thermal runaway, and battery aging model.

Validation of EoL battery decision-making methodology using tested modules to simulate real-world conditions, to establish criteria for reuse or recycling of modules.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

### Supervision

Supervisor : Berecibar Uribe Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Shared Battery and PV Optimisation for Flat Buildings in the Context of Sibelga's Energy Sharing Framework in Brussels.

### Description

The growing deployment of rooftop photovoltaic (PV) systems in urban multi-family buildings has renewed interest in shared battery storage as a means of maximising local renewable self-consumption and reducing energy costs for residents. Simulation studies consistently demonstrate that community-level battery systems, when coupled with shared PV, outperform individual per-unit configurations: collective storage can reduce total required battery capacity by up to ~37% while cutting sharing losses by ~55%, and self-sufficiency rates exceeding 60% have been reported for apartment building case studies. Techno-economic analyses further show that peer-to-peer (P2P) energy trading combined with shared battery storage can reduce average electricity costs by approximately 8–10% per resident, with self-consumption rates reaching ~69% and payback periods below five years under realistic assumptions. Beyond purely economic gains, shared energy systems have been shown to generate social co-benefits when allocation mechanisms are designed with fairness principles in mind. The role of the distribution system operator (DSO) is critical in this context: as prosumption and bidirectional flows increase, DSOs must adapt their network management, tariff structures, and coordination interfaces to accommodate local energy communities.

In Brussels, this transition is actively supported by Sibelga, which has established a regulatory and technical framework for energy sharing in three modalities: peer-to-peer exchange, within-building sharing (energiesdelen in eenzelfde gebouw), and broader energy communities (energiegemeenschappen). Sibelga's smart meter infrastructure and electricity perimeter request process provide the operational backbone for allocating shared production among participants, making the Brussels context technically ready for shared battery integration. However, despite the growing body of international simulation literature on shared PV and battery systems for apartment buildings, no study to date has specifically modelled or evaluated such configurations within the Brussels regulatory environment, accounting for Sibelga's allocation methodology, local tariff structures, or the dense urban apartment typology characteristic of the Brussels housing stock. This research gap represents a clear opportunity: a simulation study tailored to the Brussels-Sibelga context could quantify the technical and economic benefits of a shared battery system for flat building residents, assess the impact of PV integration under local irradiation

conditions, and provide actionable recommendations for DSO-facilitated energy sharing in a dense urban capital region.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE
<b>Nombre de sujets</b>	1 to 2

## Supervision

Supervisor : Cedric De Cauwer (Cedric.De.Cauwer@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Evaluation of Time-Series Models for State of Health and Remaining Useful Life Estimation Using Real-World EV Fleet Data

### Description

Description of the thesis work:

This thesis dives into one of the most critical challenges in electric mobility: understanding and predicting battery health using real-world EV data. You'll work with large-scale fleet data and apply modern time-series models to estimate battery State of Health (SOH) and predict Remaining Useful Life (RUL). Unlike ideal lab conditions, field data reflects real driving, charging behavior, and environmental effects—making the problem both challenging and highly relevant. The idea of this thesis combines energy systems knowledge with cutting-edge AI, giving you hands-on experience at the intersection of battery technology, data science, and next-generation EV innovation.

Objectives:

- Develop a structured pipeline to preprocess and extract time-series data from EV fleet datasets.
- Implement and benchmark multiple time-series.
- Evaluate model performance for SOH estimation and RUL prediction tasks.
- Analyze model generalization across unseen vehicles and operating conditions.
- Investigate robustness against noise, missing data, and irregular sampling.

Goals:

- Provide a comprehensive benchmark of time-series models for battery health estimation.
- Identify the most robust and generalizable models for real-world EV applications.
- Contribute insights into the limitations of existing approaches under field conditions.
- Support the development of reliable battery management systems (BMS) using real-world data.

Methodology:

This research will employ a quantitative methodology. The workflow includes:

1. Data Acquisition & Preprocessing: Cleaning and structuring Open Source EV fleet data, handling missing values and noise.
2. Representation learning vs Feature Extraction: Creating time-series inputs from operational data.
3. Model Development: Implementing and benchmarking various time-series models such as TimesFM.

4. Training & Evaluation: Using multiple evaluation strategies including vehicle-wise splits and robustness testing.
5. Performance Analysis: Comparing models' performance.

The goal is to establish a realistic evaluation framework for battery health estimation in real-world scenarios.

Prerequisites needed:

- Basic understanding of battery concepts: voltage, current, temperature, SOC, SOH.
- Strong knowledge of Machine Learning and Deep Learning.
- Experience with Python and data analysis libraries.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

## Supervision

Supervisor : Berecibar Maitane (Maitane.Berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Evaluation of Time-Series Models for State of Health and Remaining Useful Life Estimation Using Real-World EV Fleet Data

### Description

Description of the thesis work:

This thesis dives into one of the most critical challenges in electric mobility: understanding and predicting battery health using real-world EV data. You'll work with large-scale fleet data and apply modern time-series models to estimate battery State of Health (SOH) and predict Remaining Useful Life (RUL). Unlike ideal lab conditions, field data reflects real driving, charging behavior, and environmental effects—making the problem both challenging and highly relevant. The idea of this thesis combines energy systems knowledge with cutting-edge AI, giving you hands-on experience at the intersection of battery technology, data science, and next-generation EV innovation.

Objectives:

- Develop a structured pipeline to preprocess and extract time-series data from EV fleet datasets.
- Implement and benchmark multiple time-series.
- Evaluate model performance for SOH estimation and RUL prediction tasks.
- Analyze model generalization across unseen vehicles and operating conditions.
- Investigate robustness against noise, missing data, and irregular sampling.

Goals:

- Provide a comprehensive benchmark of time-series models for battery health estimation.
- Identify the most robust and generalizable models for real-world EV applications.
- Contribute insights into the limitations of existing approaches under field conditions.
- Support the development of reliable battery management systems (BMS) using real-world data.

Methodology:

This research will employ a quantitative methodology. The workflow includes:

1. Data Acquisition & Preprocessing: Cleaning and structuring Open Source EV fleet data, handling missing values and noise.
2. Representation learning vs Feature Extraction: Creating time-series inputs from operational data.
3. Model Development: Implementing and benchmarking various time-series models such as TimesFM.

4. Training & Evaluation: Using multiple evaluation strategies including vehicle-wise splits and robustness testing.
5. Performance Analysis: Comparing models' performance.

The goal is to establish a realistic evaluation framework for battery health estimation in real-world scenarios.

Prerequisites needed:

- Basic understanding of battery concepts: voltage, current, temperature, SOC, SOH.
- Strong knowledge of Machine Learning and Deep Learning.
- Experience with Python and data analysis libraries.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

## Supervision

Supervisor : Berecibar Maitane (Maitane.Berecibar@vub.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.

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

## Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Three-phase Active Power Filter for Vehicle-To-Grid Applications

### Description

Harmonic pollution injected into the grid by nonlinear loads is a well-known power quality issue, and V2G inverters can be leveraged to actively suppress these harmonics without relying on heavy and expensive passive filters. Building directly on experience already acquired with single-phase proportional-resonant (PR) controllers for active filtering, this thesis extends the concept to the three-phase case using the existing bench inverter and MicroLabBox II platform. The student will implement selective harmonic compensation using parallel resonant controllers tuned to the 5th, 7th, and 11th harmonics in a synchronous reference frame, and validate the results experimentally with a nonlinear load.

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

### Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Impact of temperature in Calendar Aging of Lithium-Ion Batteries for SEI formation.

### Description

Temperature plays a central role in calendar aging of lithium-ion batteries, particularly through its influence on the growth, composition, and stability of the solid electrolyte interphase (SEI) layer. This thesis examines how elevated storage temperatures accelerate SEI evolution by synthesizing insights from existing literature and developing temperature-dependent aging expressions based on established kinetic frameworks. The student will identify the temperature ranges most relevant for SEI-dominated degradation and formulate an Arrhenius-type relationship suitable for integration into thermal models. The resulting temperature-dependent SEI aging representation will be incorporated into a thermal runaway model to evaluate its influence on heat generation, onset conditions, and predictive accuracy.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

### Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Simulating the Impact of Cell-to-Cell Heterogeneity on Asymmetric Aging and System-Level Battery Performance

### Description

#### Description

Large-scale battery systems—from EVs to grid storage—are fundamentally limited by their weakest cell. While individual cells are designed to be identical, real-world factors like manufacturing tolerances and uneven cooling create significant cell-to-cell (CTC) heterogeneity. These microscopic variations cause cells to degrade asymmetrically over time (e.g., uneven SEI layer growth), cascading into severe pack imbalance that drastically reduces the system's total capacity, safety, and lifespan.

Because traditional Equivalent Circuit Models (ECMs) cannot accurately predict these complex physical phenomena over long lifecycles, the industry requires robust, physics-based modeling. This thesis tackles that exact challenge. By simulating how underlying micro-level variations drive macro-level system failure, you will bridge the gap between cell behavior and pack performance, directly contributing to the digitalization and optimization of next-generation battery designs..

#### Objectives

- **Develop:** Build a physics-based cell model focused on temperature-driven aging.
- **Scale:** Create a module network that introduces real-world cell-to-cell variations.
- **Simulate:** Track how these micro-variations cause long-term pack imbalance.
- **Optimize:** Test strategies to mitigate uneven aging and extend pack life.

#### Methodology

The project will proceed through the following key steps:

- **Review:** Study existing literature on physics-based aging models and the physical drivers of battery pack imbalance.
- **Build:** Use standard platforms (MATLAB/Simulink, PyBaMM, or COMSOL) to construct the thermal-electrical degradation model.
- **Simulate & Validate:** Run multi-cycle simulations with introduced heterogeneity and validate the resulting degradation trends against existing lab data or literature.

#### Pre-requisites

The candidate is expected to have the following experience/skills:

- Basic knowledge of electrochemistry, lithium-ion battery fundamentals, and degradation mechanisms.
- Familiarity with simulation tools e.g., MATLAB/Simulink, PyBaMM, or COMSOL is an

added advantage.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

## Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Identifying Key Parameters in a Physics-Based Lithium-Ion Battery Model Using Sensitivity Analysis

### Description

#### Background & Motivation:

The Doyle–Fuller–Newman (DFN) model is a widely used physics-based model for lithium-ion batteries. It consists of a set of partial differential equations (PDEs) describing electrochemical and transport phenomena within the cell. The model includes parameters related to diffusion, conductivity, interfacial kinetics, and geometry. Some of these parameters significantly affect the model's output, such as voltage, state of charge, or current response, while others have minimal impact.

Sensitivity analysis helps quantify how variations in input parameters influence the model outputs. This is crucial for:

- Prioritizing parameters for accurate estimation or optimization.
- Reducing model complexity.
- Enhancing computational efficiency and robustness.

The goal of this thesis is to systematically classify parameters into high, medium, and low sensitivity groups, based on their influence on simulation outputs using an existing DFN model implemented in PyBaMM.

- PyBaMM (Python Battery Mathematical Modelling): Open-source Python-based tool with built-in DFN and other models.

o Website: <https://www.pybamm.org>

#### Objectives:

- Explore how lithium-ion battery models (DFN) work
- Run simulations and vary key parameters (e.g., diffusion, reaction rates)
- Analyze how these changes affect voltage and battery performance
- Identify which parameters are critical and which can be simplified

#### Expected Outcomes:

- A categorized list of parameters based on their sensitivity.
- Visual representations (e.g., bar plots, spider charts) of sensitivity levels.
- A documented and reproducible sensitivity analysis pipeline.
- A summary report that could serve as a guide for model simplification or robust design.

#### Student Profile:

#### Background (Education):

- Master's student in:
  - o Electromechanical Engineering
  - o Energy Systems
  - o Applied Mathematics

Technical Skills Required:

- Strong programming experience in Python
- Numerical methods and mathematical modeling
- Understanding of ODEs/PDEs
- Familiarity with lithium-ion battery principles is needed
- Experience with PyBaMM is a bonus but not required (training will be provided)

Soft Skills:

- Critical thinking and analytical mindset
- Good documentation and communication skills
- Ability to work independently and meet deadlines

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

## Supervision

Supervisor : Berecibar Maitane (Maitane.Berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Finite-Control-Set Model-Predictive Control for a Vehicle-To-Grid Bidirectional Inverter

### Description

Classical PI current controllers with PWM are the industry standard for grid-connected inverters, but finite-control-set model-predictive control (FCS-MPC) has emerged as an attractive alternative that eliminates the modulator and offers intuitive multi-objective tuning. This thesis will implement both control strategies in Simulink on the MicroLabBox II for the same two-level inverter and battery setup, and compare them experimentally in terms of current THD, dynamic response, and ease of tuning. The FCS-MPC implementation will use a single prediction step (horizon = 1) as a baseline, with extension to longer horizons left as an option for motivated students.

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

### Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## The Effects of Different Slurry Mixing Methods on the Performance of Water-Based Anodes for Lithium-Ion Batteries

### Description

Slurry mixing is one of the most critical steps that significantly impacts the final properties of lithium-ion batteries. In laboratory-scale processes, vacuum mixers, magnetic stirrers, ultrasonic homogenizers and ball milling are among the most commonly used methods. Moreover, the parameters set during the application of these methods are of crucial importance for the process. This study will investigate the relationship between different mixing methods applied in the laboratory setting, varying parameters, and different cell chemistries and electrode compositions. Electrochemical, X-ray diffraction and AFM analyses will be conducted to evaluate the performance and chemical structures of the produced batteries.

#### - Objectives of the Project

- Design and optimization of slurry mixing parameters
- Investigation of the impact of different mixing methods on the battery performance
- Analysis of the influence of the cell chemistry on mixing requirements

#### - Methodology

A standard slurry formulation will be prepared for different cell chemistries such as graphite and silicon. These formulations will be processed using the different mixing methods under varying parameters (time, speed, ball amount, amplitude etc.). The effects of these mixing parameters on slurry homogeneity, particle distribution, and the final electrode properties will be investigated. Subsequently, electrodes produced from the slurries will be assembled into batteries and subjected to electrochemical performance tests, where performance metrics will be evaluated. Furthermore, the impact of each mixing method on different cell chemistries will be compared and analyzed, with the results being statistically assessed. Throughout this process, analytical techniques such as EIS, AFM, and XRD will be employed to thoroughly examine the relationship between material structure and performance.

#### - Prerequisites needed

- Fundamental knowledge of mixing methods
- Basic laboratory experience

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

## Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Real-Time State-of-Charge-Aware Vehicle-To-Grid Power Scheduling with Grid Frequency Support

### Description

Effective vehicle-to-grid (V2G) participation requires the inverter controller to be aware of the battery's state of charge and to respond to grid frequency deviations in a coordinated way. This thesis will develop a supervisory layer combining a real-time SoC estimator (e.g. extended Kalman filter or adaptive observer) for the LiFePO<sub>4</sub> pack with a primary frequency droop response, dynamically modulating injected/absorbed power according to SoC constraints. The MicroLabBox II will run both the SoC estimator and the power reference generator in real time, enabling full closed-loop V2G frequency support experiments.

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

### Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Virtual-Synchronous-Machine Control of a Vehicle-To-Grid Bidirectional Inverter Using a LiFePO4 Battery Pack

### Description

Grid-forming control via Virtual Synchronous Machine (VSM) emulation is one of the most active research areas in power electronics, as inverter-dominated grids increasingly lack the natural inertia of synchronous generators. This Master thesis will build upon previous work and implement a VSM algorithm on the MicroLabBox II to make the battery-side inverter behave like a synchronous generator, providing synthetic inertia and voltage support. The student will tune the virtual inertia and damping coefficients and validate the frequency response experimentally.

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

### Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.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.

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

## Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

## Arrhenius-Based Aging equation Development for Lithium-Ion Batteries Using Accelerated Degradation method.

### Description

Lithium-ion batteries degrade through temperature-dependent chemical and structural changes that can be accelerated and quantified through controlled aging tests. This thesis focuses on developing an Arrhenius equation that captures the relationship between temperature, aging rate, and capacity fade using data from accelerated calendar tests. The student will extract activation energies, identify dominant degradation pathways, and construct a temperature-dependent aging law suitable for system-level simulations. The resulting equation will be evaluated for its applicability to safety-critical scenarios and prepared for integration into a thermal runaway prediction framework.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	No
<b>Masters concernés</b>	M-IRELE, M-IREMR-O
<b>Nombre de sujets</b>	1

### Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Optimized topologies of an actuator and arm for a humanoid robot

### Description

Humanoid robots could revolutionize many sectors, but their progress is limited by the challenge of designing compact, efficient, and powerful joint actuators.

This project aims to develop an optimized humanoid arm and actuator topology that improves performance, range of motion, and weight efficiency.

It involves comparing existing designs and creating a CAD model of an improved solution, ideal for students interested in mechanical design and robotics.

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

### Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@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>

<b>Langue</b>	EN (english)
<b>Ouvert à d’autres masters</b>	No
<b>Masters concernés</b>	M-IRIFS, M-IRELE, M-IREMR-M
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Expansion of gearbox test bench for NVH testing

### Description

Human-centered robots like humanoids and cobots require not only efficient actuators but also low noise and vibration for user comfort and acceptance.

This project expands a VUB gearbox test bench, in collaboration with AILOS, to include Noise, Vibration, and Harshness (NVH) analysis using specialized sensors and data processing methods.

The goal is to evaluate and compare gearbox performance and acoustic behavior, ensuring quieter and smoother operation for robotic applications.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-A, M-IREMR-E
<b>Nombre de sujets</b>	2

### Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Commissioning of a robotics actuator for a humanoid robot

### Description

Humanoid robots can transform sectors like healthcare and manufacturing, but their deployment is limited by the challenge of designing compact, powerful, and safe joint actuators.

This project focuses on integrating and testing an actuator for a humanoid arm using existing components, with evaluation based on torque, efficiency, and controllability under realistic conditions.

The goal is to build a functional, well-characterized actuator, suited for students interested in robotics, control systems, and mechanical design.

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

### Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Adaptive robotic grippers for fruit harvesting

### Description

#### 1) Objectives of the project

Soft robotic grippers have shown strong potential in agricultural harvesting due to their inherent adaptability and gentle interaction with delicate objects. A common approach is the use of suction cups to pick fruits directly from branches. However, conventional suction-based grippers require precise alignment and orientation to form a proper seal, which limits their robustness in unstructured environments.

To address this limitation, we have developed self-closing suction cups and universal vacuum grippers that can conformably grasp objects with varying shapes, sizes, and quantities, without requiring precise alignment. These technologies introduce embodied intelligence at the hardware level, enabling more robust and versatile grasping.

The main challenge in applying these systems to fruit harvesting lies in the limited actuation force of current vacuum-driven bending actuators, which is often insufficient to reliably detach fruits from branches.

This project aims to develop high-force, flexible vacuum actuators and integrate them with self-closing suction cups to create adaptive robotic grippers for fruit harvesting. By combining vacuum actuation with cable-driven mechanisms, the gripper will achieve stronger and more controllable bending. The final goal is to develop an efficient, adaptable gripper capable of handling a wide variety of fruits in realistic harvesting scenarios.

#### 2) Methodology

This project focuses on enhancing actuation force and integrating multiple actuation principles into a single gripper system. The main steps include:

- i) Literature study on vacuum actuators and cable-driven soft actuators.
- ii) Design and numerical analysis of high-force vacuum bending actuators, including pleated or structured geometries to increase effective pressure area.

- iii) Integration of cable-driven mechanisms with vacuum actuation to enhance force output and controllability.
- iv) Fabrication of prototypes using molding or additive manufacturing, such as FFF and SLA 3D printing.
- v) Experimental characterization and demonstration of fruit gripping and detachment performance.

To support this project, we already have working prototypes of vacuum actuators and self-closing suction cups that can be further developed. The student will benefit from a research team with strong expertise in soft robotics, as well as collaboration with the FYSC group at VUB for materials and fabrication.

3) the prerequisites needed to succeed in this project

We are looking for students with interests in:

- i) CAD design and mechanical design
- ii) 3D printing and prototyping
- iii) Basic electronics and Arduino
- iv) Hands-on experimentation and robotics

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	No
<b>Masters concernés</b>	M-IRCNE, M-IRELE
<b>Nombre de sujets</b>	1

## Supervision

Supervisor : Wang Zhanwei (Zhanwei.Wang@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/>)

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

## Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Practical demonstration of a bidirectional converter topology for a hybrid energy storage system in mobile robotics

### Description

#### Context:

Mobile robots are subject to highly dynamic load conditions, with repeated peak power demands during acceleration and opportunities for energy recovery during braking. A Hybrid Energy Storage System (HESS) can improve performance by combining storage units with different characteristics and interfacing them to a common DC bus through bidirectional power converters.

#### Objective:

The objective of this thesis is to identify, implement, and evaluate the most suitable bidirectional converter topology for connecting multiple battery modules to a common DC bus that feeds a robot power profile emulator.

This includes the development of a control and energy management strategy for stable bus operation, controlled power sharing, and handling of dynamic robotic load profiles.

The thesis will address the following questions:

1. Which bidirectional converter topology is the most suitable for interfacing multiple battery modules with different voltage or state-of-charge levels to a common DC bus in a mobile robotic application?
2. Can a control and energy management strategy maintain stable DC bus voltage and appropriate power sharing under representative robot load cycles, including peak power events?

#### Methodology:

The student will first perform a short literature review on Hybrid Energy Storage Systems (HESS) and bidirectional converter topologies for mobile robotic applications. Based on this review, a small number of candidate topologies will be selected and compared in terms of efficiency, controllability, complexity, and suitability for representative robotic load profiles. The selected topologies will then be modelled and simulated using a robot power profile emulator as the load. In parallel, the student will design a control and energy management strategy for DC bus regulation and coordinated power flow between the connected storage elements. Finally, a simple demonstrator will be built using the converter and battery-related modules provided by the group, and the simulation results will be compared with experimental observations in order to identify and recommend the most suitable topology.

Requirements:

Preferred student qualifications include experience in power electronics, electrical systems, and their simulation tools such as MATLAB/Simulink. Interest in battery integration, control, and robotic applications is expected.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-E
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : VANDERBORGHT Bram (Bram.Vanderborght@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.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : Falcone Paolo (paolo.falcone@ulb.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

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE, M-IREMR-M
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : munteanu adrian (adrian.munteanu@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics  
constructions - M-IREMR-M

## Universal vacuum gripper with self-closing suction cups for handling thin elastic films

### Description

#### 1) The objectives of the project

Vacuum grippers are widely used in manufacturing and logistics due to their compactness, reliability, and high gripping force. In many industrial applications, arrays of suction cups are used to handle objects of varying sizes and shapes. However, when some suction cups are not sealed, vacuum leakage occurs, reducing gripping efficiency and increasing energy consumption.

To address this challenge, our group has developed an advanced self-closing suction cup technology. These suction cups can automatically close when they are not in contact with an object, preventing air leakage and maintaining stable vacuum pressure. This technology introduces embodied intelligence into the hardware level, reducing the need for complex control systems. Based on this concept, we have developed universal vacuum grippers that can handle objects with different shapes and sizes, and these systems have already been tested in industrial environments.

A new challenge arises in the handling of thin elastic film objects, such as plastic bags, packaging films, and flexible sheets. These materials are widely used in logistics, food packaging, recycling, and pharmaceutical industries. However, thin films are difficult to grasp because they deform easily, wrinkle, and may allow air leakage between the suction cup and the surface. Conventional suction cups often fail to reliably pick up such flexible materials.

In this project, we will further adapt our self-closing suction cup and universal gripper technologies to handle thin elastic film objects. The goal is to design and develop a specialized vacuum gripper capable of reliably picking and placing thin film materials commonly found in industrial and logistics applications.

#### 2) Methodology

This project focuses on adapting suction cup multi-material structures, airflow, and self-closing conditions to improve the gripping reliability of thin elastic films. To achieve these goals, the project will include:

- (i) A literature study on vacuum gripping of flexible materials and thin films.
- (ii) Design optimization of self-closing suction cups and gripper configurations for handling thin elastic films.
- (iii) Manufacturing of prototypes using molding or additive manufacturing methods such as FFF 3D printing.
- (iv) Experimental evaluation of gripping reliability, deformation behavior of thin films, and performance comparison with conventional suction cups.

To support this project, we already have working prototypes of self-closing suction cups and universal vacuum grippers. The student will build upon these existing technologies and benefit from the experience of our research team working on soft robotics, vacuum systems, and industrial grippers.

### 3) 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 prototyping
- (iii) Basic knowledge of mechanics
- (iv) Experimental testing and hands-on engineering
- (v) Robotics, automation, or industrial applications

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRCNE, M-IRELE, M-IRPH
<b>Nombre de sujets</b>	1

### Supervision

Supervisor : Wang Zhanwei (Zhanwei.Wang@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Design and Fabrication of an Aerial Manipulation Platform

### Description

This project is part of a larger effort to enable aerial-ground cooperative manipulation where drones and ground robots work together to transport objects. The drone platform, a X650 quadrotor (Figure 1, left), currently lacks a suitable grasping mechanism for transporting items with handles, such as kettlebells or beams. In prior work, a lightweight passive gripper was designed (Figure 1, right), capable of mechanically intelligent grasping without active actuation. The next step is to mount this gripper on the drone via a 2-DoF joint, allowing it to orient the gripper during flight for successful object handling.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-A
<b>Nombre de sujets</b>	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

## Design of new didactic devices for teaching control engineering

### Description

Many of the pilot processes used in the SAAS department to teach control theory were developed through master's theses. This is the case for the rotary inverted pendulum, the ring positioner, the ball in the tube process, ...

The aim of this master thesis is to develop new pilot processes that are modular, evolving, and open-source to provide a better and more practical learning experience to the students.

Here are a few examples of processes that SAAS would like to develop (non-exhaustive list):

- Ball in hoop or Flying ball in hoop
  - o <https://www.youtube.com/watch?v=8FaNk6C2ckM>
  - o <https://www.youtube.com/watch?v=484GN4KBQnc>
  - o <https://github.com/aa4cc/flying-ball-in-hoop>
  - o <https://aa4cc.github.io/flying-ball-in-hoop/>
- Cubli - robot that can jump up and balance on its corner
  - o <https://www.wevolver.com/specs/cubli>
- ...

Key objectives:

- o selection of the sensors/actuators
- o design of the signal conditioning / acquisition stages
- o design of the experimental setup (SolidWorks, 3D printer ...)
- o design of the power supply & cable management
- o modeling of the process
- o implementation of a control strategy (Arduino/C programming or Matlab/data-acquisition board or Raspberry PI)
- o setup of some didactic experiments & their related teaching materials

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E
<b>Nombre de sujets</b>	2

## Supervision

Supervisor : Garone Emanuele ([emanuele.garone@ulb.be](mailto:emanuele.garone@ulb.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

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE
<b>Nombre de sujets</b>	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

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE

<b>Nombre de sujets</b>	2
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## Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@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

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	No
<b>Masters concernés</b>	M-IRCNE, M-IRIFS, M-IRELE
<b>Nombre de sujets</b>	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

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE, M-IREMR-M
<b>Nombre de sujets</b>	2

### Supervision

Supervisor : Munteanu Adrian (adrian.munteanu@vub.be)



Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Study of a high-transmission ratio compliant actuator for robotics

### Description

The project aims to improve a high-efficiency Wolfrom gearbox for robotics by adding compliance to enhance safety in human-centered applications.

You will model the gearbox in Simscape, design a compliant element, and determine its optimal placement, followed by experimental validation.

It requires motivation and hands-on skills in CAD design, manufacturing (3D printing/molding), and mechanical assembly

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRELE, M-IREMR-A, M-IREMR-E
<b>Nombre de sujets</b>	2

### Supervision

Supervisor : LOPEZ GARCIA PABLO (pablo@ailos-robotics.com)

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

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	No
<b>Masters concernés</b>	M-IRMAE, M-IRIFS, M-IRELE
<b>Nombre de sujets</b>	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](mailto:yuri.durodie@vub.be) for more details.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	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
<b>Nombre de sujets</b>	5

### Supervision

Supervisor : Vanderborght Bram ([Bram.Vanderborght@vub.be](mailto: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.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE
<b>Nombre de sujets</b>	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)

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE, M-IREMR-M
<b>Nombre de sujets</b>	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.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRCNE, M-IRIFS, M-IRELE
<b>Nombre de sujets</b>	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.

<b>Langue</b>	EN (english)
<b>Ouvert à d'autres masters</b>	Yes
<b>Masters concernés</b>	M-IRIFS, M-IRELE, M-IREMR-E
<b>Nombre de sujets</b>	2

### Supervision

Supervisor : VANDERBORGHT Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

## Dual-motor drive for e-bikes

### Description

Dual-motor actuators use two motors to improve control, torque distribution, and efficiency in applications like robotics and e-bikes, enhancing performance and user experience.

This project supports the characterization of the OWURU drivetrain by E2Drives, used in Decathlon BTWIN bikes, leveraging R&MM expertise.

It includes performance testing (torque, speed, efficiency, inertia) and development of a new dual-motor actuator concept.

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

### Supervision

Supervisor : LOPEZ GARCIA PABLO (pablo@ailos-robotics.com)

Master's program offering the topic: EM - Sustainable transport and automotive M-IREMR-O

## Electrical motors for EV traction, design and control --- internships and Master theses, at/in collaboration with Punch Powertrain (Sint-Truiden)

### Description

Internship subjects (see also the document with Dropbox link):

- 1) In-house Multi-disciplinary emotor design toolchain maintenance
- 2) Torque ripple requirements definition in electric machine pre-design
- 3) Harmonics limits definition in electric machine pre-design
- 4) Emotor design towards short circuit protection

Master thesis subject (and more coming):

Title: DC and AC Harmonics reductions techniques in electric machine design

Promoter: Dr. Ilja Siera

Contact person: [ilja.siera@punchpowertrain.com](mailto:ilja.siera@punchpowertrain.com)

Description:

A critical design challenge in electric machines for the automotive market is the presence of electromagnetic harmonics, which can lead to undesirable effects such as torque ripple, increased losses, noise, vibration, reduced efficiency or inverter over-currents. In the current multi-disciplinary design methods applied at Punch powertrain, the potential issues often lay hidden until the latter stages of the design process.

This thesis proposes to investigate and implement advanced methods to reduce harmonic distortion early during the optimisation process of electric machines. The goal is to develop a multi-objective optimisation framework that explicitly includes harmonic reduction as a design target.

The current optimisation approach for electric machines focusses on objectives such as torque density, efficiency, and thermal performance. While torque ripple is considered, Current harmonic mitigation is only considered as a constraint, and then treated in the post design. This research aims to integrate harmonic reduction directly into the optimisation loop, allowing for a more balanced and robust design process.

The goals are to:

- (a) Review harmonic generation mechanisms in electric machines (with a focus on

slot/pole combinations, winding distribution, and magnetic saturation).

(b) Evaluate methods for harmonic analysis, including Fast Fourier Transform (FFT), Space Vector analysis, and Total Harmonic Distortion (THD) metrics.

(c) Evaluating methods for detecting the presence or vulnerability of a design to harmonics (e.g. through flux map analysis).

(d) Implement harmonic minimisation techniques in the design optimisation loop

(e) Evaluate performance and the trade-offs in a design optimisation study.

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

## Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Topics offered to students by other  
master's programs

**TARGET PROGRAM**

**Electrical Engineering**

# Electromagnetic Shielding Properties of Standard and Custom Materials from 100 MHz to 10 GHz

*Program : EM - Aeronautics - M-IREMR-A*

## **Description**

This thesis aims to develop and validate a practical experimental methodology for comparing the electromagnetic shielding performance of standard and custom materials in the 100 MHz–10 GHz frequency range. Electromagnetic shielding is increasingly important in aerospace systems, electronics, telecommunications, biomedical devices, sensor platforms, and space instrumentation, where sensitive components must be protected from external electromagnetic interference while limiting unwanted emissions. Classical metallic shielding solutions can be highly effective, but they are often heavy, rigid, or difficult to integrate into multifunctional structures.

The work will explore alternative shielding materials whose performance can be tuned through composition, thickness, porosity, rigidity, conductivity, magnetic response, or internal structure. Examples include conductive polymer composites, carbon-loaded elastomers, metallized textiles, porous conductive foams, graphene- or carbon-black-based films, magnetic particle composites, and multilayer hybrid materials. The laboratory has access to a vector network analyser and two probes covering approximately 100 MHz to 10 GHz, which will be used to establish a comparative testing platform.

The student will first review the principles of electromagnetic shielding, including reflection, absorption, multiple internal reflections, conductivity, magnetic permeability, skin depth, and frequency-dependent attenuation. The experimental work will then focus on defining a repeatable measurement protocol in which a material sample is placed between or near transmitting and receiving probes. Measurements with and without the sample will be used to estimate attenuation as a function of frequency, for example through relative changes in transmission parameters such as  $S_{21}$ . Particular attention will be paid to calibration, probe positioning, sample size, edge leakage, distance between probes, background noise, environmental reflections, and repeatability.

Reference materials such as aluminium foil, copper foil, stainless-steel mesh, conductive tape, metallized films, carbon-loaded sheets, ferrite-containing materials, or commercial EMI shielding fabrics will first be tested to establish baseline behaviour. Custom materials will then be fabricated or selected with controlled variations in composition, filler content, thickness, porosity, rigidity, and multilayer structure. The analysis will compare frequency-dependent attenuation curves and assess how material parameters influence shielding performance. Where possible, results may also be normalized by thickness or areal density to evaluate lightweight shielding efficiency.

The expected outcome is a validated laboratory-scale methodology for screening electromagnetic shielding materials. The thesis should identify promising material families, quantify the influence of composition and structure on attenuation, and clarify the limitations of the probe-based setup compared with standardized certification methods. It should also provide recommendations for

improving the platform, for example through a dedicated sample holder, shielding box, coaxial fixture, absorber-lined enclosure, or free-space measurement geometry.

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

## **Supervision**

### **Supervisor**

Axel Coussement (axel.coussement@ulb.be)

### **Co-supervisor**

Carlo Iorio (carlo.iorio@ulb.be)

# 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)

## 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).

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)