SUMMER RESEARCH OPPORTUNITY 2026 - 2027

UC Louvain, Belgium

We hope one of the interesting projects below will appeal, and provide you with an unusual and exciting reason to visit Belgium over the summer break! Please select the relevant tab below for your discipline.

Please feel welcome to contact me via the email address below with any questions.

Kind regards,
Beth
Global Student Experience Coordinator
engit-exchange@unimelb.edu.au

BIOMEDICAL ENGINEERING TOPICS				
DEPT	**Research Topic**	**Supervisors**	**Abstract**	**References**
BIOMED	Deep learning in computer vision : Detection of anatomical landmarks for the quantitative analysis of rat movement.	Christophe De Vleeschouwer	Researchers evaluate the therapeutic effectiveness of drugs for spinal cord contusions by analyzing the movement of injured rats using a multi-camera vision system. Anatomical keypoints are detected in images from different views and reconstructed in 3D to estimate the rats' posture and assess motor function recovery. Because animal behavior is highly variable, a precise and reliable pose-estimation system is required, while large numbers of rats and longitudinal monitoring generate extensive video datasets. The current commercial software lacks sufficient accuracy, so the thesis aims to adapt the open-source deep-learning framework DeepLabCut to the specific needs of the Louvain Drug Research Institute team. The project will explore recent advances in computer vision, including foundation models, self-supervised learning, and vision-language models, to reduce the amount of manual image annotation needed while maintaining robust and accurate rat pose estimation.	[1] https://www.tse-systems.com/products/motorater/ [2] https://www.mackenziemathislab.org/deeplabcut [3] A.Mathis et al., DeepLabCut: markerless pose estimation of user-defined body parts with deep learning, Nature Neuroscience 2018. https://arxiv.org/abs/1804.03142v1 [4] https://www.epfl.ch/labs/vita/research/perception/pifpaf/ ; https://cmu-perceptual-computing-lab.github.io/openpose/web/html/doc/index.html [5] UCLouvain : Seyed Abolfazl Ghasemzadeh et al., DeepSportLab: a Unified Framework for Ball Detection, Player Instance Segmentation and Pose Estimation in Team Sports Scenes, BMVC 2021. [6] UCLouvain : Seyed Abolfazl Ghasemzadeh et al., RUMPL: Ray-Based Transformers for Universal Multi-View 2D to 3D Human Pose Lifting, submitted to IEEE Transactions on Image Processing, https://arxiv.org/pdf/2512.15488. [7] A. Radford, Learning Transferable Visual Models From Natural Language Supervision, ICML 2021. [8] M. Caron et al., Emerging Properties in Self-Supervised Vision Transformers, ICCV 2021. [9] DINOv3, https://ai.meta.com/research/dinov3/ [10] R. Balestriero and Y. LeCun, LeJEPA: Provable and Scalable Self-Supervised Learning Without the Heuristics, https://arxiv.org/abs/2511.08544 [11] UCLouvain: M. Zanella, et al., Realistic Test-Time Adaptation of Vision-Language Models, IEEE CVPR 2025, https://openaccess.thecvf.com/content/CVPR2025/papers/Zanella_Realistic_Test-Time_Adaptation_of_Vision-Language_Models_CVPR_2025_paper.pdf [12] UCLouvain: M. Zanella, et al., Vocabulary-free few-shot learning for Vision-Language Models, IEEE CVPRW 2025. https://openaccess.thecvf.com/content/CVPR2025W/MULA2025/papers/Zanella_Vocabulary-free_few-shot_learning_for_vision-language_models_CVPRW_2025_paper.pdf
BIOMED	Spatio-temporal strain patterns of fingertip in response to scanned macro-shapes	Benoit Delhaye	The sense of touch allows us to manipulate objects with exquisite dexterity. Tactile receptors in the skin acquire crucial information about the mechanical interactions between the fingertip and objects during manipulation by transducing local skin deformations. This tactile information is essential for fine-tuning prehension forces. However, the specific information conveyed to the brain through nerves during manipulation and how the brain uses this information to coordinate finger forces remains unclear. Previous study in our lab has shown that distinct strain patterns of skin are generated when non-flat surfaces, such as bumps or holes, slide over the fingertip. Buiding on this background, this thesis aims to further characterize these strain patterns over a cohort of participants (e.g. 5~10) and explore the unchanged variable in these patterns across participants. A custom-made robotic platform will be used to control the mechanical stimuli, including the variation of sliding speeds, normal forces, and shape profiles. High-resolution cameras will be placed on the side and the bottom of the fingertip to record the high spatio-temporal deformations, which will be further extracted to strains data. The finding will provide insights into essential low-dimensional features that are transmitted to the peripheral nerves and the central nervous system. a. The setup to acquire fingertip images and control the mechanical stimuli using a servomotor and robotic platform. b. A typical image of a fingertip captured. c. typical strain patterns observed when a finger is contacting a bump and a hole.	
BIOMED	The impact of non-isotropic clinical target map definition on probabilistic optimization in proton therapy	John Lee	This thesis focuses on improving radiotherapy treatment planning by replacing traditional isotropic tumor margin expansion with a more realistic anisotropic probabilistic tumor model. Current methods assign tumor presence probabilities using simple Gaussian expansions that ignore anatomical structures such as tissue barriers and cavities. The project will integrate recent anisotropic tumor growth models into probabilistic optimization algorithms to generate anatomically informed Clinical Target Maps (CTMs). This approach aims to better balance tumor control and protection of organs at risk, potentially improving treatment outcomes. The work will be implemented in the OpenTPS platform and validated using real clinical data from head-and-neck and brain cancer patients. Contacts Prof. John A. Lee (john.lee@uclouvain.be), Eliot Peeters (eliot.peeters@uclouvain.be).	[1] S. Campbell et al., "Evaluation of Microscopic Disease in Oral Tongue Cancer Using Whole-Mount Histopathologic Techniques: Implications for the Management of Head-and-Neck Cancers," International Journal of Radiation Oncology*Biology*Physics, vol. 82, no. 2, pp. 574–581, Feb. 2012, doi: 10.1016/j.ijrobp.2010.09.038. [2] "The International Commission on Radiation Units and Measurements," Journal of the ICRU, vol. 10, no. 1, p. NP.2-NP, Apr. 2010, doi: 10.1093/jicru/ndq001. [3] N. Shusharina, D. Craft, Y.-L. Chen, H. Shih, and T. Bortfeld, "The clinical target distribution: a probabilistic alternative to the clinical target volume," Phys. Med. Biol., vol. 63, no. 15, p. 155001, Jul. 2018, doi: 10.1088/1361-

BIOMEDICAL ENGINEERING TOPICS				
DEPT	**Research Topic**	**Supervisors**	**Abstract**	**References**
BIOMED	Incorporating material compositions directly in CT/CBCT reconstruction for improved proton stopping power estimation	John Lee Edmond Sterpin	This Master's thesis aims to improve proton therapy treatment planning by making CT image reconstruction directly consistent with the material properties used for proton dose calculations. Current workflows convert CT images into tissue densities and compositions through a separate calibration step, which can introduce inaccuracies and increase treatment margins. The project will develop methods that explicitly incorporate material composition and density information into the CT reconstruction process, using techniques such as simulation and automatic differentiation. This could lead to more accurate estimates of proton range within the body, reducing uncertainty in dose delivery. Ultimately, the approach may allow smaller safety margins, better tumor targeting, and reduced damage to healthy tissues. The student will be part of the MIRO laboratory of the UCLouvain, based in Brussels, under the supervision of Dr. Andreas Smolders, Prof. John Lee and Prof. Edmond Sterpin. Required skills: ● Strong motivation and willingness to learn ● Solid background in Python In case of questions, feel free to reach out to andreas.smolders@uclouvain.be	
Biomedical	Role of local fingertip deformation on motor control	Benoit Delhaye Philippe Lefèvre	Humans gather environmental information through skin-object interaction during touch. Among other senses, tactile information plays a key role in planning and executing hand and finger movements. It has been shown that during object manipulation, finger force control is affected by local deformation at the periphery of the finger-object contact area [1]. To causally investigate this role, a tactile display is used (Fig. 1), which enables the delivery of artificial skin deformation and vibration. Combining the Latero device and force sensors in a single setup facilitates the design of behavioral experiments, providing insights into the isolated effect of tactile stimuli on sensorimotor coordination. One such experiment involves amplifying or reducing skin deformation while isometric force is being applied to the interface. The goal of this project is to develop and conduct a new behavioral experiment to causally test the role of fingertip skin deformation on finger force production.	
Biomedical	Study of the thermodynamics of the fingertip skin.	Benoit Delhaye Philippe Lefèvre	The human somatosensory system allows us to perceive and interact with the world through sensations such as touch and temperature. Mechanoreception corresponds to the detection of mechanical stimuli acting on the skin, while thermoception refers to the perception of temperature changes through specialized thermoreceptors. These sensory modalities are essential for everyday interactions with objects, helping us manipulate them, recognize materials, and protect ourselves from harmful stimuli. Understanding how these signals are generated is also important for biomedical applications, such as the development of prosthetic devices capable of restoring realistic tactile and thermal feedback. Despite significant progress in somatosensory research, the physical processes that generate thermal signals in the skin remain to be better understood; In particular, the thermal properties of the skin (such as thermal conductivity and heat capacity) that determine how temperature changes propagate toward thermoreceptors. In natural situations, thermal stimuli rarely occur alone: they usually happen when we touch an object. The resulting deformation of the skin can strongly influence heat transfer at the contact interface, potentially modifying the temperature signals reaching the receptors. During this master's thesis, the student will design and conduct experiments to study the interaction between mechanical deformation of the skin and thermal stimulation. The project will involve developing an experimental protocol using existing laboratory setups (robotized platforms to control forces on the skin, thermodes, thermal cameras,…), collecting data from human participants, and analyzing the results. Depending on the student's interests, the project may also include analytical or numerical modeling of heat transfer and skin mechanics. The exact research question can be discussed and adapted to the student's background and interests.	
Biomedical	Coupling between structural and functional connectivity at rest	Benoît Macq	This master's project aims to explore how meditation influences the coupling between structural (SC) and functional (FC) brain connectivity at rest. Using existing matrices of structural connectivity (derived from gray matter regions dilated into the white matter) and functional connectivity (between these non-dilated regions during resting-state fMRI), the objective is to provide an original quantification of SC–FC coupling in relation to meditation. The study also seeks to determine whether SC–FC coupling differs according to meditation experience and to quantify the potential impact of meditation on the organization of brain networks. The student will analyze a large data set that has already been acquired in over more than 100 participants. Ref: Collins, et al. Mapping the structure-function relationship along macroscale gradients in the human brain. Nat Commun 15, 7063 (2024). https://doi.org/10.1038/s41467-024-51395-6	

ELECTRICAL ENGINEERING TOPICS				
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Electrical	Spatio-temporal strain patterns of fingertip in response to scanned macro-shapes	Benoit Delhaye	The sense of touch allows us to manipulate objects with exquisite dexterity. Tactile receptors in the skin acquire crucial information about the mechanical interactions between the fingertip and objects during manipulation by transducing local skin deformations. This tactile information is essential for fine-tuning prehension forces. However, the specific information conveyed to the brain through nerves during manipulation and how the brain uses this information to coordinate finger forces remains unclear. Previous study in our lab has shown that distinct strain patterns of skin are generated when non-flat surfaces, such as bumps or holes, slide over the fingertip. Buiding on this background, this thesis aims to further characterize these strain patterns over a cohort of participants (e.g. 5~10) and explore the unchanged variable in these patterns across participants. A custom-made robotic platform will be used to control the mechanical stimuli, including the variation of sliding speeds, normal forces, and shape profiles. High-resolution cameras will be placed on the side and the bottom of the fingertip to record the high spatio-temporal deformations, which will be further extracted to strains data. The finding will provide insights into essential low-dimensional features that are transmitted to the peripheral nerves and the central nervous system. a. The setup to acquire fingertip images and control the mechanical stimuli using a servomotor and robotic platform. b. A typical image of a fingertip captured. c. typical strain patterns observed when a finger is contacting a bump and a hole.	
Electrical	Batch Active Learning for Efficient Materials Discovery	Benoît Legat	Imagine designing a material with superior thermal conductivity for next-generation electronics or a catalyst with unprecedented efficiency for green energy applications. Achieving such breakthroughs requires a strategic approach to experimentation, as testing every possible material is impossible. Machine learning offers guidance for experimentalists as it can be used to suggest the next experiments to perform. This should be done efficiently by selecting the experiments that balance the exploration of the possible space and the exploitation of the model to reach optimal performances with a minimum of wasted experiments. This thesis focuses on developing a methodology to efficiently select batches of experiments to identify materials that optimize a target property or the experimental conditions to grow such material that will lead to the best performances. The research introduces a framework that leverages information theory to manage uncertainty while prioritizing materials with high predicted performance. By addressing the critical exploration-exploitation trade-off, this work advances the state-of-the-art in batch active learning. Conducted in collaboration with Matgenix, a Belgian SME active in research and development in materials science, this thesis combines theoretical developments with practical applications, contributing to faster and more efficient materials discovery.	

ELECTRICAL ENGINEERING TOPICS				
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Electrical	Incorporating material compositions directly in CT/CBCT reconstruction for improved proton stopping power estimation	John Lee Edmond Sterpin	This Master's thesis aims to improve proton therapy treatment planning by making CT image reconstruction directly consistent with the material properties used for proton dose calculations. Current workflows convert CT images into tissue densities and compositions through a separate calibration step, which can introduce inaccuracies and increase treatment margins. The project will develop methods that explicitly incorporate material composition and density information into the CT reconstruction process, using techniques such as simulation and automatic differentiation. This could lead to more accurate estimates of proton range within the body, reducing uncertainty in dose delivery. Ultimately, the approach may allow smaller safety margins, better tumor targeting, and reduced damage to healthy tissues. The student will be part of the MIRO laboratory of the UCLouvain, based in Brussels, under the supervision of Dr. Andreas Smolders, Prof. John Lee and Prof. Edmond Sterpin. Required skills: ● Strong motivation and willingness to learn ● Solid background in Python In case of questions, feel free to reach out to andreas.smolders@uclouvain.be	

ELECTRICAL ENGINEERING TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
Electrical	Deep learning in computer vision : Modèles vision-langage et modèles auto-supervisés pour la reconnaissance de caractéristiques végétales.	Christophe De Vleeschouwer Sébastien Jodogne	This Master's thesis aims to develop an AI-based system for automatically validating plant characteristics in photos submitted by students on the QuoVidi educational platform. Unlike traditional plant recognition, the challenge is to identify specific, non-exclusive traits that may or may not be present in a given plant. The project will leverage recent advances in vision-language models (VLMs), foundation models, and self-supervised learning to recognize plant features from textual descriptions and images. The research will also explore how generic foundation models can be adapted to perform specialized visual classification tasks more effectively. Using a dataset of over 30,000 annotated images, the project will contribute both to reducing teachers' grading workload and to advancing AI methods for visual understanding. An article describing the pedagogical approach : https://onlinelibrary.wiley.com/doi/10.1002/ece3.7130 Project Github (a bit outdated): https://github.com/QuoVidi/quovidi_public Contacts QuoVidi : Guillaume Lobet <guillaume.lobet@uclouvain.be> and Jean-François Rees <jf.rees@uclouvain.be>.	[1] A. Radford, Learning Transferable Visual Models From Natural Language Supervision, ICML 2021. [2] M. Caron et al., Emerging Properties in Self-Supervised Vision Transformers, ICCV 2021. [3] DINOv3, https://ai.meta.com/research/dinov3/ [4] R. Balestriero and Y. LeCun, LeJEPA: Provable and Scalable Self-Supervised Learning Without the Heuristics, https://arxiv.org/abs/2511.08544 [5] M. Zanella et al., Realistic Test-Time Adaptation of Vision-Language Models, IEEE CVPR 2025, https://openaccess.thecvf.com/content/CVPR2025/papers/Zanella_Realistic_Test-Time_Adaptation_of_Vision-Language_Models_CVPR_2025_paper.pdf [6] M. Zanella et al., Vocabulary-free few-shot learning for Vision-Language Models, IEEE CVPRW 2025. https://openaccess.thecvf.com/content/CVPR2025W/MULA2025/papers/Zanella_Vocabulary-free_few-shot_learning_for_vision-language_models_CVPRW_2025_paper.pdf [7] K. El Khoury et al. , Enhancing Remote Sensing Vision-Language Models for Zero-Shot Scene Classification, IEEE ICASSP 2025. https://arxiv.org/abs/2409.00698 [8] T. Godelaine et al., Conditional Random Fields for Interactive Refinement of Histopathological Predictions, IEEE ICASSP 2026, https://arxiv.org/pdf/2601.12082 . [9] K. El Khoury et al., Leveraging Prediction Entropy for Automatic Prompt Weighting in Zero-Shot Audio-Language Classification, IEEE ICASSP 2026, https://arxiv.org/pdf/2601.05011 .
Electrical	Characterization of highly strained vanadium dioxide devices on polyimide	Denis Flandre	Pressure and strain sensors are used in a large number of monitoring applications: velocity and pressure fields study for aerodynamic characterization, environment control, on-board monitoring for vehicles, biomedical applications, microphones, etc. The signals can go from very low pressures to ultrasounds with higher frequency contents, depending on the application. Embedding ultra-thin pressure or strain sensors and IC in flexible foils or substrate allows to consider conform monitoring of non-planar surfaces. A good example is the current typical setup for aerodynamic measurements on non-planar surfaces: individual highly sensitive pressure sensors with rigid substrate are mounted inside the piece, each in a small hole, and then wired one per one to the measurement system. The goal would be to replace the rigid substrates with a thin flexible foil that can directly be applied on the surface to monitor. Conventional pressure or strain sensors rely either on the geometrical or material dependent piezoresistive effect. For instance, the deformation of aluminum traces induces resistance variation with a gage factor of around 1 to 2 (only attributed to geometrical change of the material cross section) while silicon exhibits a gage factor ranging from -102 to 135 depending on the crystal orientation (attributed to material effect). In this master thesis, the use of vanadium dioxide as the active strain sensing element will be discussed. This well-known phase change material promises to reach unprecedented gage factor in the range of 300-350 for polycrystalline vanadium dioxide film but also to allow the encoding of strain in a spike train exploiting the IMT (insulator – metal – transition). Previously developed processes allowed us to integrate VO2 memristors on thin (2.5 µm-thick) polyimide thin films. In this master thesis, the samples are to be attached to dog-bone like sample carriers for mechanical testing up to 1% of tensile deformation. Depending on the candidate aspirations and likings, different experiments could be designed including numerical modeling of the strain-field, measurement of the non-linear variation of the VO2 electrical resistance, characterization of the spiking behavior of strained VO2, … All of this under different temperatures, humidity or illuminating conditions. In a nutshell, the work will focus on the Multiphysics characterization of the material. The work will involve both theoretical and experimental aspects and will make use of the Winfab and Welcome fabrication and characterization labs of UCLouvain.	

ELECTRICAL ENGINEERING TOPICS				
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Electrical	The self-organizing maps reloaded	John Lee	Self-organizing maps (SOMs, Teuvo Kohonen, 1982) are a very efficient and light-weight visualization tools for numerical data. These maps deploy an articulated/flexible grid in the data space, that gets attracted by data points while ensuring the topological consistency between the low-dimensional definition of the grid (typ. 2D) and its embedding into the HD data space. In contrast to other techniques of dimensionality reduction, like t-SNE, which produce scatter plots, the SOMs produce rectangular displays and also performs vector quantization: the number of grid nodes is lower than the data set size. The SOMS have, however, show a few weaknesses: * The rectangular display does not reflect the shape of the data distribution as well as scatterplot-based embeddings. * The size of the grid has to be fixed in advance by the user. * The original algorithm by Teuvo Kohonen is a heuristic update rule of the grid positions without a known energy or cost function. This work addresses the third limitation and proposes the investigation of a slightly modified update rule that would actually correspond to the gradient of a cost function. This function would include a data fidelity term, closely related to the vector quantization error of K-means, plus a topological consistency term inspired from Laplacian eigenmaps (Belkin&Niyogi 2003). The deliverable of the project would be scalable implementation of this reformulation of the SOMs, with both a 'batch' version (gradient descent) and an 'online' one (stochastic gradient descent). The experimental work would compare the original heuristic SOMs versus the proposed one, on a number of benchmarks (COIL-20, COIL-100, MNIST, Fashion MNIST, etc.). Monitoring of the cost function as well as quality assessment with independent figures of merit would complete the experimental campaign.	
Electrical	Role of local fingertip deformation on motor control	Benoit Delhaye Philippe Lefèvre	Humans gather environmental information through skin-object interaction during touch. Among other senses, tactile information plays a key role in planning and executing hand and finger movements. It has been shown that during object manipulation, finger force control is affected by local deformation at the periphery of the finger-object contact area [1]. To causally investigate this role, a tactile display is used (Fig. 1), which enables the delivery of artificial skin deformation and vibration. Combining the Latero device and force sensors in a single setup facilitates the design of behavioral experiments, providing insights into the isolated effect of tactile stimuli on sensorimotor coordination. One such experiment involves amplifying or reducing skin deformation while isometric force is being applied to the interface. The goal of this project is to develop and conduct a new behavioral experiment to causally test the role of fingertip skin deformation on finger force production.	
Electrical	Study of the thermodynamics of the fingertip skin.	Benoit Delhaye Philippe Lefèvre	The human somatosensory system allows us to perceive and interact with the world through sensations such as touch and temperature. Mechanoreception corresponds to the detection of mechanical stimuli acting on the skin, while thermoception refers to the perception of temperature changes through specialized thermoreceptors. These sensory modalities are essential for everyday interactions with objects, helping us manipulate them, recognize materials, and protect ourselves from harmful stimuli. Understanding how these signals are generated is also important for biomedical applications, such as the development of prosthetic devices capable of restoring realistic tactile and thermal feedback. Despite significant progress in somatosensory research, the physical processes that generate thermal signals in the skin remain to be better understood; In particular, the thermal properties of the skin (such as thermal conductivity and heat capacity) that determine how temperature changes propagate toward thermoreceptors. In natural situations, thermal stimuli rarely occur alone: they usually happen when we touch an object. The resulting deformation of the skin can strongly influence heat transfer at the contact interface, potentially modifying the temperature signals reaching the receptors. During this master's thesis, the student will design and conduct experiments to study the interaction between mechanical deformation of the skin and thermal stimulation. The project will involve developing an experimental protocol using existing laboratory setups (robotized platforms to control forces on the skin, thermodes, thermal cameras,…), collecting data from human participants, and analyzing the results. Depending on the student's interests, the project may also include analytical or numerical modeling of heat transfer and skin mechanics. The exact research question can be discussed and adapted to the student's background and interests.	
Electrical	Gesture Recognition from Fingertip Deformation on Transparent Surfaces	Benoit Delhaye Jean Vanderdonckt Philippe Lefèvre	Gesture-based interaction has been widely explored in free-space and on opaque touchscreens. In comparison, interaction on transparent surfaces offers access to rich and underused information about fingertip deformation, shear motion, and contact-area dynamics, as demonstrated in recent biomechanics studies on transparent glass. These detailed signals offer new opportunities for recognising gestures in compact interfaces such as transparent tactile screens or small embedded sensors. This thesis investigates whether contact-deformation features can support effective recognition of static and dynamic gestures performed on transparent surfaces. Instead of relying mainly on finger-trajectory tracking, the project examines how the geometry and evolution of the fingertip–surface contact patch can reveal the user's intended gesture earlier or more robustly. The student will collect a new dataset using high-speed imaging and analyse cross-participant regularities in deformation behaviour. The work will combine computer vision with biomechanics-inspired modelling to identify informative features and evaluate their suitability for gesture classification. The outcome will be a feasibility study and proof-of-concept pipeline, providing insights for the design of future transparent and compact gesture-input devices.	

COMPUTING AND INFORMATION SYSTEMS TOPICS				
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CIS	Deep learning in computer vision : Detection of anatomical landmarks for the quantitative analysis of rat movement.	Christophe De Vleeschouwer	Researchers evaluate the therapeutic effectiveness of drugs for spinal cord contusions by analyzing the movement of injured rats using a multi-camera vision system. Anatomical keypoints are detected in images from different views and reconstructed in 3D to estimate the rats' posture and assess motor function recovery. Because animal behavior is highly variable, a precise and reliable pose-estimation system is required, while large numbers of rats and longitudinal monitoring generate extensive video datasets. The current commercial software lacks sufficient accuracy, so the thesis aims to adapt the open-source deep-learning framework DeepLabCut to the specific needs of the Louvain Drug Research Institute team. The project will explore recent advances in computer vision, including foundation models, self-supervised learning, and vision-language models, to reduce the amount of manual image annotation needed while maintaining robust and accurate rat pose estimation.	[1] https://www.tse-systems.com/products/motorater/ [2] https://www.mackenziemathislab.org/deeplabcut [3] A.Mathis et al., DeepLabCut: markerless pose estimation of user-defined body parts with deep learning, Nature Neuroscience 2018. https://arxiv.org/abs/1804.03142v1 [4] https://www.epfl.ch/labs/vita/research/perception/pifpaf/ ; https://cmu-perceptual-computing-lab.github.io/openpose/web/html/doc/index.html [5] UCLouvain : Seyed Abolfazl Ghasemzadeh et al., DeepSportLab: a Unified Framework for Ball Detection, Player Instance Segmentation and Pose Estimation in Team Sports Scenes, BMVC 2021. [6] UCLouvain : Seyed Abolfazl Ghasemzadeh et al., RUMPL: Ray-Based Transformers for Universal Multi-View 2D to 3D Human Pose Lifting, submitted to IEEE Transactions on Image Processing, https://arxiv.org/pdf/2512.15488. [7] A. Radford, Learning Transferable Visual Models From Natural Language Supervision, ICML 2021. [8] M. Caron et al., Emerging Properties in Self-Supervised Vision Transformers, ICCV 2021. [9] DINOv3, https://ai.meta.com/research/dinov3/ [10] R. Balestriero and Y. LeCun, LeJEPA: Provable and Scalable Self-Supervised Learning Without the Heuristics, https://arxiv.org/abs/2511.08544 [11] UCLouvain: M. Zanella, et al., Realistic Test-Time Adaptation of Vision-Language Models, IEEE CVPR 2025, https://openaccess.thecvf.com/content/CVPR2025/papers/Zanella_Realistic_Test-Time_Adaptation_of_Vision-Language_Models_CVPR_2025_paper.pdf [12] UCLouvain: M. Zanella, et al., Vocabulary-free few-shot learning for Vision-Language Models, IEEE CVPRW 2025. https://openaccess.thecvf.com/content/CVPR2025W/MULA2025/papers/Zanella_Vocabulary-free_few-shot_learning_for_vision-language_models_CVPRW_2025_paper.pdf
CIS	Solving the Mystery of Pente Grammai: AI Experiments on an Ancient Roman Board Game	Eric Piette	This project aims to reconstruct and evaluate possible rules of the ancient Roman board game Pente Grammai, whose complete gameplay remains unknown despite significant archaeological evidence. Building on recent successes of AI in analyzing ancient games, the research will develop a flexible software platform to model and test different rule hypotheses proposed by historians and archaeologists. The system will allow experimentation with alternative game rules and use AI techniques, such as search algorithms and simulations, to automatically play and analyze the game. Human-like AI approaches may also be explored to better reflect how ancient players might have made decisions. The final outcome of the project will be a software platform for computational experimentation with Pente Grammai, together with a comparative analysis of the different rule hypotheses and their gameplay properties. Such a tool could provide valuable support for historians and archaeologists by offering a systematic way to explore and evaluate competing interpretations of this ancient game. For more information on this topic, please contact: Prof. Eric Piette (eric.piette@uclouvain.be).	
CIS	Spatio-temporal strain patterns of fingertip in response to scanned macro-shapes	Benoit Delhaye	The sense of touch allows us to manipulate objects with exquisite dexterity. Tactile receptors in the skin acquire crucial information about the mechanical interactions between the fingertip and objects during manipulation by transducing local skin deformations. This tactile information is essential for fine-tuning prehension forces. However, the specific information conveyed to the brain through nerves during manipulation and how the brain uses this information to coordinate finger forces remains unclear. Previous study in our lab has shown that distinct strain patterns of skin are generated when non-flat surfaces, such as bumps or holes, slide over the fingertip. Buiding on this background, this thesis aims to further characterize these strain patterns over a cohort of participants (e.g. 5~10) and explore the unchanged variable in these patterns across participants. A custom-made robotic platform will be used to control the mechanical stimuli, including the variation of sliding speeds, normal forces, and shape profiles. High-resolution cameras will be placed on the side and the bottom of the fingertip to record the high spatio-temporal deformations, which will be further extracted to strains data. The finding will provide insights into essential low-dimensional features that are transmitted to the peripheral nerves and the central nervous system. a. The setup to acquire fingertip images and control the mechanical stimuli using a servomotor and robotic platform. b. A typical image of a fingertip captured. c. typical strain patterns observed when a finger is contacting a bump and a hole.	

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	The impact of non-isotropic clinical target map definition on probabilistic optimization in proton therapy	John Lee	This thesis focuses on improving radiotherapy treatment planning by replacing traditional isotropic tumor margin expansion with a more realistic anisotropic probabilistic tumor model. Current methods assign tumor presence probabilities using simple Gaussian expansions that ignore anatomical structures such as tissue barriers and cavities. The project will integrate recent anisotropic tumor growth models into probabilistic optimization algorithms to generate anatomically informed Clinical Target Maps (CTMs). This approach aims to better balance tumor control and protection of organs at risk, potentially improving treatment outcomes. The work will be implemented in the OpenTPS platform and validated using real clinical data from head-and-neck and brain cancer patients. Contacts Prof. John A. Lee (john.lee@uclouvain.be), Eliot Peeters (eliot.peeters@uclouvain.be).	[1] S. Campbell et al., "Evaluation of Microscopic Disease in Oral Tongue Cancer Using Whole-Mount Histopathologic Techniques: Implications for the Management of Head-and-Neck Cancers," International Journal of Radiation Oncology*Biology*Physics, vol. 82, no. 2, pp. 574–581, Feb. 2012, doi: 10.1016/j.ijrobp.2010.09.038. [2] "The International Commission on Radiation Units and Measurements," Journal of the ICRU, vol. 10, no. 1, p. NP.2-NP, Apr. 2010, doi: 10.1093/jicru/ndq001. [3] N. Shusharina, D. Craft, Y.-L. Chen, H. Shih, and T. Bortfeld, "The clinical target distribution: a probabilistic alternative to the clinical target volume," Phys. Med. Biol., vol. 63, no. 15, p. 155001, Jul. 2018, doi: 10.1088/1361-6560/aacfb4. [4] G. Buti, N. Shusharina, A. Ajdari, E. Sterpin, and T. Bortfeld, "Exploring trade-offs in treatment planning for brain tumor cases with a probabilistic definition of the clinical target volume," Medical Physics, vol. 50, no. 1, pp. 410–423, Jan. 2023, doi: 10.1002/mp.16097. [5] E. Peeters and R. Schyns, "Exploring the Computational and Clinical Added-value of Probabilistic Optimization in Proton Therapy," Master Thesis, UCLouvain, 2023_2024. [6] T. Bortfeld and G. Buti, "Modeling the propagation of tumor fronts with shortest path and diffusion models—implications for the definition of the clinical target volume," Phys. Med. Biol., vol. 67, no. 15, p. 155014, Aug. 2022, doi: 10.1088/1361-6560/ac8043. [7] S. Wuyckens et al., "OpenTPS -- Open-source treatment planning system for research in proton therapy," Mar. 01, 2023, arXiv: arXiv:2303.00365. Accessed: Jul. 20, 2024. [Online]. Available: http://arxiv.org/abs/2303.00365
CIS	Meditation, the Gut Microbiome, and Brain Health	Benoît Macq	This Master's project investigates how meditation may improve health through interactions between the brain, immune system, and gut microbiome. While meditation is known to enhance psychological well-being and brain plasticity, its biological mechanisms remain poorly understood. The study will examine whether differences in diet, gut microbiota composition, and systemic inflammation contribute to the positive effects of meditation on mental health and brain function. By combining approaches from neuroscience, immunology, and microbiome research, the project aims to identify biological pathways linking meditation to health outcomes. This interdisciplinary research offers valuable insight into mind–body interactions and the role of the gut–brain–immune axis in well-being.	Ref: Dutcher JM, et al., Smartphone mindfulness meditation training reduces Pro-inflammatory gene expression in stressed adults: A randomized controlled trial. Brain Behav Immun. 2022 Jul;103:171-177. doi: 10.1016/j.bbi.2022.04.003.
CIS	AI-Assisted Development of Interactive JavaScript Animations for Introductory Physics Education	Vincent Legat	https://perso.uclouvain.be/vincent.legat/documents/memo2990/master_thesis_proposal_intro_physics_animations_ai.html	
CIS	Efficiently Updatable Neural Networks for Game Playing: Extending NNUE Beyond Chess and Shogi	Eric Piette	Heuristics based on neural networks trained through self-play have become the state of the art in high-performance game-playing agents [1]. However, the strongest engines in games such as Chess [2], Shogi [3], and Renju [4] do not rely on large, GPU-intensive deep neural networks. Instead, they employ Efficiently Updatable Neural Networks (NNUE) [5], which are specifically designed for fast evaluation on CPUs. Unlike conventional deep learning architectures, NNUE models are typically shallow, featuring large input layers followed by rapidly decreasing layer sizes. Their key advantage lies in exploiting incrementally changing input features, allowing partial recomputation of the network during inference. As a result, NNUE models can efficiently update evaluations by recomputing only affected portions of the network, significantly improving performance in search-based systems. This thesis investigates whether the core principles underlying NNUE can be extended to other neural network architectures, including Convolutional Neural Networks (CNNs) [6], Graph Neural Networks (GNNs) [7], and potentially Recurrent Neural Networks (RNNs) [8]. A central question is whether NNUE-style efficiency gains can be achieved in more complex domains, such as Go and Hex, where current state-of-the-art approaches rely heavily on deep neural networks. Accordingly, this thesis aims to address the following research question: To what extent can the principles of efficiently updatable neural networks be generalized to other neural network architectures and applied to more complex problem domains? Expected Outcomes: A comprehensive review of NNUE architectures, including the current state of the art and key challenges. The development of efficiently updatable variants of Graph Neural Networks (GNNs) and Convolutional Neural Networks (CNNs). An assessment of the applicability of NNUE-based approaches across a broader range of problem domains. For more information on this topic, please contact Prof. Eric Piette (eric.piette@uclouvain.be) and Alois Rautureau (alois.rautureau@ens-rennes.fr).	[1] Silver, D., Schrittwieser, J., Simonyan, K., Antonoglou, I., Huang, A., Guez, A., Hubert, T., Baker, L., Lai, M., Bolton, A., et al. (2017). Mastering the game of Go without human knowledge. Nature, 550(7676), 354–359. [2] Romstad, T., Costalba, M., Kiiski, J., & Linscott, G. (2026). Stockfish (Version 18) [Software]. https://github.com/official-stockfish/Stockfish [3] Nasu, Y. (2025). YaneuraOu (Version 9.10) [Software]. https://github.com/yaneurao/YaneuraOu [4] Jin, Z., Duan, H., & Hang, Z. (2025). Rapfi: Distilling efficient neural network for the game of Gomoku. arXiv:2503.13178. https://arxiv.org/abs/2503.13178 [5] Nasu, Y. (2018). Efficiently updatable neural-network-based evaluation functions for computer shogi. The 28th World Computer Shogi Championship Appeal Document, 185. [6] O'Shea, K., & Nash, R. (2015). An introduction to convolutional neural networks. arXiv:1511.08458. https://arxiv.org/abs/1511.08458 [7] Khemani, B., Patil, S., Kotecha, K., & Tanwar, S. (2024). A review of graph neural networks: Concepts, architectures, techniques, challenges, datasets, applications, and future directions. Journal of Big Data, 11(1), 18. [8] Hochreiter, S., & Schmidhuber, J. (1997). Long short-term memory. Neural Computation, 9(8), 1735–1780.

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	Batch Active Learning for Efficient Materials Discovery	Benoît Legat	Imagine designing a material with superior thermal conductivity for next-generation electronics or a catalyst with unprecedented efficiency for green energy applications. Achieving such breakthroughs requires a strategic approach to experimentation, as testing every possible material is impossible. Machine learning offers guidance for experimentalists as it can be used to suggest the next experiments to perform. This should be done efficiently by selecting the experiments that balance the exploration of the possible space and the exploitation of the model to reach optimal performances with a minimum of wasted experiments. This thesis focuses on developing a methodology to efficiently select batches of experiments to identify materials that optimize a target property or the experimental conditions to grow such material that will lead to the best performances. The research introduces a framework that leverages information theory to manage uncertainty while prioritizing materials with high predicted performance. By addressing the critical exploration-exploitation trade-off, this work advances the state-of-the-art in batch active learning. Conducted in collaboration with Matgenix, a Belgian SME active in research and development in materials science, this thesis combines theoretical developments with practical applications, contributing to faster and more efficient materials discovery.	
CIS	Support for Kernel-Bypass in QUICHE, a QUIC implementation	Tom Barbette	QUIC is a modern transport protocol designed for low-latency and secure communications, widely adopted in web and real-time applications. Cloudflare's QUICHE is a popular QUIC implementation written in Rust, known for its efficiency and security guarantees. However, traditional network stacks introduce performance bottlenecks due to kernel overhead in packet processing. Kernel-bypass networking, enabled by technologies like DPDK and AF_XDP offers a solution by allowing user-space applications to directly interact with network interfaces, reducing context-switching latency and improving throughput. This thesis explores the integration of kernel-bypass networking in QUICHE to enhance its performance in high-throughput scenarios. The research involves analyzing existing kernel-bypass techniques, designing a compatible architecture for QUICHE, implementing support for a selected kernel-bypass framework, and evaluating the performance gains in terms of latency, throughput, and CPU utilization. The findings provide insights into optimizing QUIC implementations for high-performance networking applications.	
CIS	Support for AF_XDP in FastClick, a high-speed dataplane	Tom Barbette	FastClick is an extended version of the Click modular router designed for high-performance packet processing, widely used in software-defined networking (SDN) and network function virtualization (NFV). To maximize packet processing efficiency, FastClick already integrates support for DPDK, a user-space networking framework that bypasses the kernel to achieve low-latency, high-throughput networking. However, AF_XDP, a recent addition to the Linux eXpress Data Path (XDP) framework, offers an alternative kernel-bypass mechanism with a lightweight, zero-copy socket interface while maintaining tighter kernel integration than DPDK. The goal of this thesis is to investigate the integration of AF_XDP into FastClick and conduct a comparative analysis against DPDK. You will have to implement AF_XDP support in FastClick, evaluate its performance in terms of packet processing rate, latency, and CPU efficiency, and analyze trade-offs between AF_XDP and DPDK. The findings aim to determine whether AF_XDP can provide a viable, lower-overhead alternative to DPDK in FastClick-based high-performance networking applications.	
CIS	Incorporating material compositions directly in CT/CBCT reconstruction for improved proton stopping power estimation	John Lee Edmond Sterpin	This Master's thesis aims to improve proton therapy treatment planning by making CT image reconstruction directly consistent with the material properties used for proton dose calculations. Current workflows convert CT images into tissue densities and compositions through a separate calibration step, which can introduce inaccuracies and increase treatment margins. The project will develop methods that explicitly incorporate material composition and density information into the CT reconstruction process, using techniques such as simulation and automatic differentiation. This could lead to more accurate estimates of proton range within the body, reducing uncertainty in dose delivery. Ultimately, the approach may allow smaller safety margins, better tumor targeting, and reduced damage to healthy tissues. The student will be part of the MIRO laboratory of the UCLouvain, based in Brussels, under the supervision of Dr. Andreas Smolders, Prof. John Lee and Prof. Edmond Sterpin. Required skills: ● Strong motivation and willingness to learn ● Solid background in Python In case of questions, feel free to reach out to andreas.smolders@uclouvain.be	

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	Deep learning in computer vision : Modèles vision-langage et modèles auto-supervisés pour la reconnaissance de caractéristiques végétales.	Christophe De Vleeschouwer Sébastien Jodogne	This Master's thesis aims to develop an AI-based system for automatically validating plant characteristics in photos submitted by students on the QuoVidi educational platform. Unlike traditional plant recognition, the challenge is to identify specific, non-exclusive traits that may or may not be present in a given plant. The project will leverage recent advances in vision-language models (VLMs), foundation models, and self-supervised learning to recognize plant features from textual descriptions and images. The research will also explore how generic foundation models can be adapted to perform specialized visual classification tasks more effectively. Using a dataset of over 30,000 annotated images, the project will contribute both to reducing teachers' grading workload and to advancing AI methods for visual understanding. An article describing the pedagogical approach : https://onlinelibrary.wiley.com/doi/10.1002/ece3.7130 Project Github (a bit outdated): https://github.com/QuoVidi/quovidi_public Contacts QuoVidi : Guillaume Lobet <guillaume.lobet@uclouvain.be> and Jean-François Rees <jf.rees@uclouvain.be>.	[1] A. Radford, Learning Transferable Visual Models From Natural Language Supervision, ICML 2021. [2] M. Caron et al., Emerging Properties in Self-Supervised Vision Transformers, ICCV 2021. [3] DINOv3, https://ai.meta.com/research/dinov3/ [4] R. Balestriero and Y. LeCun, LeJEPA: Provable and Scalable Self-Supervised Learning Without the Heuristics, https://arxiv.org/abs/2511.08544 [5] M. Zanella et al., Realistic Test-Time Adaptation of Vision-Language Models, IEEE CVPR 2025, https://openaccess.thecvf.com/content/CVPR2025/papers/Zanella_Realistic_Test-Time_Adaptation_of_Vision-Language_Models_CVPR_2025_paper.pdf [6] M. Zanella et al., Vocabulary-free few-shot learning for Vision-Language Models, IEEE CVPRW 2025. https://openaccess.thecvf.com/content/CVPR2025W/MULA2025/papers/Zanella_Vocabulary-free_few-shot_learning_for_vision-language_models_CVPRW_2025_paper.pdf [7] K. El Khoury et al. , Enhancing Remote Sensing Vision-Language Models for Zero-Shot Scene Classification, IEEE ICASSP 2025. https://arxiv.org/abs/2409.00698 [8] T. Godelaine et al., Conditional Random Fields for Interactive Refinement of Histopathological Predictions, IEEE ICASSP 2026, https://arxiv.org/pdf/2601.12082 . [9] K. El Khoury et al., Leveraging Prediction Entropy for Automatic Prompt Weighting in Zero-Shot Audio-Language Classification, IEEE ICASSP 2026, https://arxiv.org/pdf/2601.05011 .
CIS	(2026-2027) Strategy-Aware Highlighting of Mismatches in Student Programs	Kim Mens	In our lab, we have developed a prototype of an automated assessment system that can classify student programs by their underlying solution strategy. Indeed, for a given programming exercice there may be multiple "good" solution strategies to solve it, for example an iterative or a recursive ones. The system classifies student programs by transforming them into a generalized abstract syntax tree and then calculating the tree edit distance between that tree and the corresponding tree of an ideal solution representative of that solution strategy. While this approach can label which strategy a student's program corresponds to, it does not explain yet *how* the student's program deviates from the ideal representative of that strategy. The goal of this master thesis is to give more feedback on the student on how his solution deviates so that he or she can fix his program to get closer to that ideal solution. Given the student's program, a canonical instructor-written representative of the intended solution strategy, and the abstract-syntax tree edit-distance computation between both, the goal of this master thesis will be to create a tool that automatically highlights and annotates the structural mismatches in the student's program. These annotations should help the student understand *what* to change, without prescribing exact code. The suggested approach towards would be to reuse the existing abstract syntax tree abstraction and edit-distance algorithms from the existing prototype system. Edit operations on the syntax tree should be mapped back to specific source-level constructs. An appropriate annotation strategy should then be explored: inline highlights, code colouring, margin comments, visual overlays, ... Finally the tool can be evaluated on a set of real student submissions. The expected outcomes are a prototype tool that takes a student program and produces annotated source code showing structural mismatches; a taxonomy of useful annotation types for strategy-level feedback; an empirical evaluation (small-scale) of clarity and usefulness of this type of annotations for learners.	
CIS	(2026-2027) Teaching Small Language Models to Speak Code: Grammar-Constrained Generation	Kim Mens	Recent advances in generative language models have significantly improved the ability of machines to produce natural language and source code. Systems such as ChatGPT and GitHub Copilot demonstrate strong capabilities in assisting developers with tasks such as code generation, documentation writing, and debugging. However, despite their impressive capabilities, language models frequently produce syntactically incorrect or structurally inconsistent code. This issue becomes particularly pronounced when using small language models, which often lack the capacity to implicitly learn the full grammar of programming languages. One promising approach to address this limitation is to explicitly enforce programming language grammar during text generation. Instead of relying solely on the model to learn syntactic correctness, generation can be constrained using formal grammars or structured decoding strategies. This Master's thesis aims to investigate methods for imposing programming grammar constraints on the outputs of small language models, with the objective of improving the syntactic correctness and structural reliability of generated code. The expected outcome is a better understanding of how formal grammars can compensate for limited model capacity, enabling smaller AI models to generate more reliable and usable code.	

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	The self-organizing maps reloaded	John Lee	Self-organizing maps (SOMs, Teuvo Kohonen, 1982) are a very efficient and light-weight visualization tools for numerical data. These maps deploy an articulated/flexible grid in the data space, that gets attracted by data points while ensuring the topological consistency between the low-dimensional definition of the grid (typ. 2D) and its embedding into the HD data space. In contrast to other techniques of dimensionality reduction, like t-SNE, which produce scatter plots, the SOMs produce rectangular displays and also performs vector quantization: the number of grid nodes is lower than the data set size. The SOMS have, however, show a few weaknesses: * The rectangular display does not reflect the shape of the data distribution as well as scatterplot-based embeddings. * The size of the grid has to be fixed in advance by the user. * The original algorithm by Teuvo Kohonen is a heuristic update rule of the grid positions without a known energy or cost function. This work addresses the third limitation and proposes the investigation of a slightly modified update rule that would actually correspond to the gradient of a cost function. This function would include a data fidelity term, closely related to the vector quantization error of K-means, plus a topological consistency term inspired from Laplacian eigenmaps (Belkin&Niyogi 2003). The deliverable of the project would be scalable implementation of this reformulation of the SOMs, with both a 'batch' version (gradient descent) and an 'online' one (stochastic gradient descent). The experimental work would compare the original heuristic SOMs versus the proposed one, on a number of benchmarks (COIL-20, COIL-100, MNIST, Fashion MNIST, etc.). Monitoring of the cost function as well as quality assessment with independent figures of merit would complete the experimental campaign.	
CIS	Benchmarking Imperfect-Information Card Games through OpenSpiel	Eric Piette	Imperfect-information games represent one of the most challenging and practically relevant domains in artificial intelligence research. Unlike perfect-information games such as Chess or Go, these games require agents to reason under uncertainty, model hidden information, and balance exploration with exploitation, skills that are directly transferable to real-world decision-making problems. Card games are a natural domain for studying imperfect information, as they inherently combine hidden hands, stochastic draws, and rich strategic interactions. However, AI algorithms for imperfect-information games are typically evaluated on individual games in isolation, making it difficult to assess the robustness and generalizability of any given approach across diverse game structures. To address this, our research group has introduced Valet [1], a standardized testbed of 21 traditional imperfect-information card games. These games were carefully selected to span a wide range of genres, cultures, player counts, deck structures, mechanics, winning conditions, and methods of hiding and revealing information. The rules of each game are encoded in RECYCLE, a card game description language, providing a first layer of standardization. However, to fully leverage the algorithmic tools of modern game AI research, these games need to also be available in OpenSpiel [2], an open-source framework developed by DeepMind that provides a unified collection of games and algorithms, including Counterfactual Regret Minimization (CFR), Monte Carlo Tree Search (MCTS), and deep reinforcement learning approaches, widely used by the academic community. The primary goal of this thesis is to implement the Valet games into OpenSpiel, and to use this unified platform to validate and deepen the characterization of the dataset's diversity. The student will first familiarize themselves with OpenSpiel's architecture and game API, then implement the 21 card games, ensuring correctness and compliance with the framework's standards. Building on this foundation, the student will conduct a systematic analysis combining structural metrics, such as branching factor, information set size, and chance node frequency, with agent-based metrics derived from running OpenSpiel's suite of algorithms across all games. The central research question is whether these metrics collectively confirm that Valet's games exhibit sufficiently varied strategic and computational properties to serve as a fair and comprehensive benchmark for comparing AI agents, and potentially to cluster games by their algorithmic difficulty or structural profile. For more information on this topic, please contact Achille Morenville (achille.morenville@uclouvain.be).	[1] Goadrich, M., Morenville, A., & Piette, É. (2026). Valet: A Standardized Testbed of Traditional Imperfect-Information Card Games. arXiv preprint arXiv:2603.03252. [2] Lanctot, M., et al. (2019). OpenSpiel: A framework for reinforcement learning in games. arXiv preprint arXiv:1908.09453.
CIS	Role of local fingertip deformation on motor control	Benoit Delhaye Philippe Lefèvre	Humans gather environmental information through skin-object interaction during touch. Among other senses, tactile information plays a key role in planning and executing hand and finger movements. It has been shown that during object manipulation, finger force control is affected by local deformation at the periphery of the finger-object contact area [1]. To causally investigate this role, a tactile display is used (Fig. 1), which enables the delivery of artificial skin deformation and vibration. Combining the Latero device and force sensors in a single setup facilitates the design of behavioral experiments, providing insights into the isolated effect of tactile stimuli on sensorimotor coordination. One such experiment involves amplifying or reducing skin deformation while isometric force is being applied to the interface. The goal of this project is to develop and conduct a new behavioral experiment to causally test the role of fingertip skin deformation on finger force production.	

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Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	Study of the thermodynamics of the fingertip skin.	Benoit Delhaye Philippe Lefèvre	The human somatosensory system allows us to perceive and interact with the world through sensations such as touch and temperature. Mechanoreception corresponds to the detection of mechanical stimuli acting on the skin, while thermoception refers to the perception of temperature changes through specialized thermoreceptors. These sensory modalities are essential for everyday interactions with objects, helping us manipulate them, recognize materials, and protect ourselves from harmful stimuli. Understanding how these signals are generated is also important for biomedical applications, such as the development of prosthetic devices capable of restoring realistic tactile and thermal feedback. Despite significant progress in somatosensory research, the physical processes that generate thermal signals in the skin remain to be better understood; In particular, the thermal properties of the skin (such as thermal conductivity and heat capacity) that determine how temperature changes propagate toward thermoreceptors. In natural situations, thermal stimuli rarely occur alone: they usually happen when we touch an object. The resulting deformation of the skin can strongly influence heat transfer at the contact interface, potentially modifying the temperature signals reaching the receptors. During this master's thesis, the student will design and conduct experiments to study the interaction between mechanical deformation of the skin and thermal stimulation. The project will involve developing an experimental protocol using existing laboratory setups (robotized platforms to control forces on the skin, thermodes, thermal cameras,…), collecting data from human participants, and analyzing the results. Depending on the student's interests, the project may also include analytical or numerical modeling of heat transfer and skin mechanics. The exact research question can be discussed and adapted to the student's background and interests.	
CIS	Coupling between structural and functional connectivity at rest	Benoît Macq	This master's project aims to explore how meditation influences the coupling between structural (SC) and functional (FC) brain connectivity at rest. Using existing matrices of structural connectivity (derived from gray matter regions dilated into the white matter) and functional connectivity (between these non-dilated regions during resting-state fMRI), the objective is to provide an original quantification of SC–FC coupling in relation to meditation. The study also seeks to determine whether SC–FC coupling differs according to meditation experience and to quantify the potential impact of meditation on the organization of brain networks. The student will analyze a large data set that has already been acquired in over more than 100 participants. Ref: Collins, et al. Mapping the structure-function relationship along macroscale gradients in the human brain. Nat Commun 15, 7063 (2024). https://doi.org/10.1038/s41467-024-51395-6	
CIS	Advanced topics in hybrid finite-element modelling with HybriDFEM	João Saraiva Esteves Pacheco De Almeida	The Hybrid Discrete-Finite Element Method (HybriDFEM), developed at UCLouvain these past years, has shown potential to model unreinforced masonry (URM) and reinforced concrete (RC) structures. The method models a structure as an assembly of rigid blocks that are in contact with each other through zero-length contact pairs. All the deformations are concentrated at the contact pairs, which are modelled as series of linear or non-linear springs in the normal and shear direction. One of the main advantages of the method is the fact that it combines a discrete formulation, well-suited for representing strong discontinuities, with classical finite element formulations. The project will improve the simulation of structural behavior under seismic and dynamic loads, building on recent successful validations against experimental and numerical benchmarks. Possible research directions include enhanced energy dissipation models, large-sliding contact formulations, mass-scaling techniques for computational efficiency, probabilistic modeling of masonry, and applications to reinforced concrete or geotechnical systems. The work involves developing and implementing new algorithms in the Python-based HybriDFEM code. The expected outcome is a more accurate and versatile tool for assessing the safety and performance of civil engineering structures under complex loading conditions. This MSc thesis focuses on the numerical analysis of structures and the development of numerical methods in an object-oriented framework. Strong notions of Python and programming in general are necessary. Preferably, the student should have attended the courses of Stabilité des Constructions, Numerical Analysis of Structures, and Dynamics of Structures. An important skill the student(s) will develop during the MSc thesis is their ability to communicate and explain mathematical and programmatical concepts in a synthetic way.	Please contact us for further information and discussion before selecting this topic (igor.bouckaert@uclouvain.be, michele.godio@ri.se, joao.almeida@uclouvain.be).
CIS	Numerical investigation of Physics-Informed Neural Networks (PINNs) with hard constraints	Geovani Nunes Grapiglia	Context: Physics-Informed Neural Networks (PINNs) solve differential equations by embedding physical laws into neural network training [1,2,3].More specifically, the thesis involves numerical comparison of nonlinear programming solvers in terms of convergence, accuracy, and computational cost. The study aims to provide practical insights for solving equality-constrained PINN problems efficiently. Objective: This thesis investigates an alternative equality-constrained formulation where boundary and initial conditions are treated as hard constraints:	References: [1] Raissi, M., Perdikaris, P., Karniadakis, G.E.: Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. Journal of Computational Physics 378 (2019) [2] Baty, H.: A hands-on introduction to Physics-Informed Neural Networks for solving partial differential equations with benchmark tests taken from astrophysics and plasma physics. ArXiv 2024. [3] https://www.youtube.com/watch?v=-zrY7P2dVC4

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	Structural Parametric Identification using Vibration Data	João Saraiva Esteves Pacheco De Almeida	Content / Motivation Estimating structural parameters from vibration data is an important problem in structural dynamics and structural health monitoring. Parameters such as stiffness, damping, and nonlinear properties determine the dynamic behavior of structures and strongly influence the accuracy of predictive models. This project focuses on parametric identification of structural systems using experimental vibration data from a reinforced concrete frame structure subjected to earthquake excitations. These rather unique tests (see figure), which are currently taking place (in April and June 2026), will output a large dataset from a wide range of instrumentation systems, namely from a dense grid of motion capture markers distributed throughout the structure, as well as other conventional instrumentation (strain gauges, LVDTs, accelerometers, etc). These experimental measurements provide a valuable opportunity to estimate structural parameters and understand how they evolve as nonlinear behavior develops. Students will investigate methods for identifying unknown parameters from measured structural responses. Possible approaches include model updating, time-domain or frequency-domain identification techniques, filtering approaches, and data-driven or physics-informed machine learning methods. Tasks • Analyze experimental vibration data from the shake-table tests. • Develop numerical models of the structural system. • Apply parameter identification techniques using measured responses. • Evaluate how identified parameters change with increasing earthquake intensity. • Compare different identification approaches. Suggested Skills: • Programming in Python or MATLAB • Basic knowledge of structural dynamics • Interest in system identification and data analysis Contact Students interested in this topic are encouraged to contact the supervisor joao.almeida@uclouvain.be before selecting the project so that we can briefly discuss the project scope and ensure a good match of interests.	
CIS	Reduced-Order Modeling for Structural Dynamic Systems	João Saraiva Esteves Pacheco De Almeida	Content / Motivation Structural dynamic simulations of buildings and infrastructures can become computationally expensive when large models or repeated simulations are required. Reduced-order modeling aims to approximate complex structural systems with simplified models that retain the essential dynamic behavior while significantly reducing computational cost. This project focuses on developing reduced-order models for structural dynamic systems using experimental data from the shake-table tests from a reinforced concrete frame structure subjected to earthquake excitations. These rather unique tests (see figure), which are currently taking place (in April and June 2026), will output a large dataset from a wide range of instrumentation systems, namely from a dense grid of motion capture markers distributed throughout the structure, as well as other conventional instrumentation (strain gauges, LVDTs, accelerometers, etc). The dataset provides a challenging benchmark because the structure exhibits nonlinear behavior as earthquake intensity increases. Students will investigate how reduced-order models can efficiently represent the structural response observed in the experiments. Possible approaches include modal reduction, Proper Orthogonal Decomposition (POD), substructuring techniques, or data-driven reduced-order modeling methods. Tasks • Develop numerical models of the structural system. • Implement reduced-order modeling techniques. • Use experimental data to validate the reduced models. • Evaluate model accuracy and computational efficiency. • Compare reduced-order and full numerical simulations. Suggested Skills: • Programming in Python or MATLAB • Basic knowledge of structural dynamics • Interest in data analysis and computational modeling Contact Students interested in this topic are encouraged to contact the supervisor (joao.almeida@uclouvain.be) before selecting the project so that we can briefly discuss the project scope and ensure a good match of interests.	

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	Uncertainty Quantification in Structural Dynamic Systems	João Saraiva Esteves Pacheco De Almeida	Content Structural models often contain uncertainties due to unknown parameters, measurement noise, and modeling simplifications. These uncertainties can significantly influence predicted structural responses and may lead to inaccurate predictions if not properly accounted for.Uncertainty quantification aims to evaluate how uncertainties in model parameters or external loads propagate into structural responses. This is particularly important in structural engineering where safety and reliability are key concerns. In this project, students will investigate uncertainty quantification in structural dynamic systems using numerical simulations and vibration data. Possible approaches include probabilistic simulations, Monte Carlo methods, Bayesian model updating, and data-driven techniques such as Bayesian neural networks or physics-informed machine learning models. Tasks • Develop numerical models of structural dynamic systems. • Introduce uncertainty in model parameters or loading conditions. • Apply uncertainty quantification methods. • Analyze how uncertainties affect structural responses. Suggested Skills: • Programming in Python or MATLAB • Basic knowledge of structural dynamics • Interest in data analysis and computational modeling Contact Students interested in this topic are encouraged to contact the supervisor before selecting the project so that we can briefly discuss the project scope and ensure a good match of interests.	
CIS	Compiling Network Functions to Hardware Match Action Tables	Tom Barbette	Network functions (firewalls, NATs, load balancers...) are traditionally implemented in software on general-purpose CPUs, which struggles to keep up with modern line rates (100 Gb/s and beyond). Modern programmable Network Interface Cards (NICs) can instead process packets entirely in hardware at line rate, through a simple match/action rule model: "if the destination IP is X and TCP port is Y, then forward to port Z and decrement TTL". The challenge is that programming these rules by hand is tedious and error prone. Furthermore, often the only way to know if the hardware is capable of offloading a given rule is to push it and see if it accepts it or not. [Alkali](https://github.com/utnslab/Alkali) is a compiler that takes network functions written in plain C and automatically generates low-level code for various hardware targets (FPGAs, SmartNICs). The goal of this thesis is to add a new backend to Alkali that targets commodity server NICs via the [DPDK RTE_FLOW API](https://doc.dpdk.org/guides/prog_guide/rte_flow.html), enabling a programmer to write a network function in C and have the compiler automatically offload it to NIC hardware with no knowledge of the underlying NIC API required. Prerequisites - Good grades in LINFO2241 - Systems programming in C / C++ - Basic understanding of computer networks (IP, TCP/UDP) - Interest in compilers and/or computer architecture	
CIS	Replicating a Privacy Attack on Network Data and Defending Against It with Differential Privacy	Tom Barbette	In many modern systems, sensitive data are shared with analysts or researchers through aggregate statistics, query answers, anonymized traces, or partially sanitized releases. Although such releases may appear harmless, a large body of work has shown that they can still leak private information. Classic examples include re-identification attacks on supposedly anonymized datasets, linkage attacks based on auxiliary information, and the uniqueness of mobility or behavioral traces [1,2,3,6]. In networked settings, similar risks arise through traffic analysis and fingerprinting attacks, where an adversary may infer sensitive information from patterns in observed traffic even without direct identifiers [4,5]. Differential privacy (DP) offers a solution to this problem. Rather than relying on heuristic anonymization, DP provides a formal guarantee that the presence or absence of a single individual in a dataset does not significantly affect the released output [7]. The goal of this thesis will be to study this privacy problem both empirically and theoretically. First, the student will replicate a concrete privacy attack from the literature on statistical or aggregate data releases. The attack will be implemented and evaluated in a non-private setting to measure how much private information can be extracted in practice. The second part of the project will consist of evaluating a differential privacy defense. The student will compare the attack's effectiveness before and after DP protection, and will analyze the trade-off between privacy and utility. This project will also investigate the theoretical amount of information that an adversary can learn from released outputs. This may be studied by modeling the adversary's prior and posterior knowledge, by quantifying inference gain, or by relating the attack's success to the formal leakage bounds provided by differential privacy [8]. For more information, contact Alessandro Maggi (alessandro.maggi@uclouvain.be)	References: [1] Arvind Narayanan and Vitaly Shmatikov. 2007. How To Break Anonymity of the Netflix Prize Dataset. [2] Marie Douriez, Harish Doraiswamy, Juliana Freire, and Claudio T. Silva. 2016. Anonymizing NYC Taxi Data: Does It Matter? In 2016 IEEE International Conference on Data Science and Advanced Analytics (DSAA), 140–148. [3] Yves-Alexandre de Montjoye, César A. Hidalgo, Michel Verleysen, and Vincent D. Blondel. 2013. Unique in the Crowd: The Privacy Bounds of Human Mobility. Scientific Reports, 3, 1376. [4] Giovanni Cherubin, Rob Jansen, and Carmela Troncoso. 2022. Online Website Fingerprinting: Evaluating Website Fingerprinting Attacks on Tor in the Real World. In 31st USENIX Security Symposium (USENIX Security 22), 753–770. [5] Andriy Panchenko, Fabian Lanze, Andreas Zinnen, Martin Henze, Jan Pennekamp, Klaus Wehrle, and Thomas Engel. 2016. Website Fingerprinting at Internet Scale. In Proceedings of the Network and Distributed System Security Symposium (NDSS 2016). [6] Paul Ohm. 2010. Broken Promises of Privacy: Responding to the Surprising Failure of Anonymization. UCLA Law Review, 57, 1701–1777. [7] Cynthia Dwork. 2006. Differential Privacy. In Proceedings of the 33rd International Colloquium on Automata, Languages and Programming (ICALP), 1–12. [8] Cynthia Dwork, Adam Smith, Thomas Steinke, and Jonathan Ullman. 2017. Exposed! A Survey of Attacks on Private Data. Annual Review of Statistics and Its Application, 4, 61–84

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	Gesture Recognition from Fingertip Deformation on Transparent Surfaces	Benoit Delhaye Jean Vanderdonckt Philippe Lefèvre	Gesture-based interaction has been widely explored in free-space and on opaque touchscreens. In comparison, interaction on transparent surfaces offers access to rich and underused information about fingertip deformation, shear motion, and contact-area dynamics, as demonstrated in recent biomechanics studies on transparent glass. These detailed signals offer new opportunities for recognising gestures in compact interfaces such as transparent tactile screens or small embedded sensors. This thesis investigates whether contact-deformation features can support effective recognition of static and dynamic gestures performed on transparent surfaces. Instead of relying mainly on finger-trajectory tracking, the project examines how the geometry and evolution of the fingertip–surface contact patch can reveal the user's intended gesture earlier or more robustly. The student will collect a new dataset using high-speed imaging and analyse cross-participant regularities in deformation behaviour. The work will combine computer vision with biomechanics-inspired modelling to identify informative features and evaluate their suitability for gesture classification. The outcome will be a feasibility study and proof-of-concept pipeline, providing insights for the design of future transparent and compact gesture-input devices.	
CIS	[Numerical Linear Algebra, Neural Networks, Dynamical Systems] Applying the power method on neural representations of the Koopman operator	Raphaël Jungers	Recently, we have proposed a neural approach to the computation of the Koopman operator of an arbitrary nonlinear dynamical system. The algorithm implements the celebrated power method from numerical linear algebra, in an implicit way, via learning the weights of a neural network. The student will implement the algorithm and apply it in different context. Motivated students could further develop the theory by proposing more advanced techniques for eigenvalues computation than the power method, and/or proving performance of the approach by applying tools from statistical machine learning.	
CIS	Multi-GPU Lagrangian particle tracking for online coupling with the multi-scale ocean model SLIM	Emmanuel Hanert Jonathan Lambrechts	Lagrangian particle tracking (LPT) is widely used in coastal ocean modeling to simulate the dispersal of sediments, pollutants, coral larvae, and other passive or active tracers transported by ocean currents, wind, and waves. In the SLIM modeling framework, an LPT module has recently been rewritten to run entirely on GPU, yielding substantial performance improvements over traditional CPU-based implementations. However, the current single-GPU design becomes a bottleneck for very large simulations where the hydrodynamic model SLIM runs in parallel across multiple GPUs using MPI domain decomposition. In such configurations, the ocean velocity fields can become too large to store on disk for subsequent offline particle tracking, making online coupling — where particles are advected simultaneously with the hydrodynamic computation — the only viable strategy. The objective of this project is to extend the existing GPU-based LPT module to a multi-GPU architecture using MPI, so that particles can be tracked online alongside SLIM's hydrodynamic solver using the same mesh partitioning. The main challenges include managing particle migration between subdomains as they cross partition boundaries, maintaining load balance when particles cluster in specific regions of the domain, and ensuring efficient GPU-to-GPU communication with minimal overhead. The student would design and implement the inter-GPU particle exchange protocol, benchmark the scaling performance on the LUMI supercomputer, and validate the results against the existing single-GPU offline implementation. The approach would be demonstrated on a large-scale application such as coral larval dispersal over the Great Barrier Reef, where the combination of high mesh resolution and large numbers of particles makes online coupling essential.	
CIS	High-speed network packet processing using Stream-Processing-like SQL queries	Etienne Riviere Tom Barbette	Network functions and stream processing are two areas of computer science in which operations are applied in sequence onto small data units. In stream processing, queries are usually expressed as SQL statements and then compiled into a graph of operators using Apache Calcite [1]. A stream processing engine, like Apache Flink [2], will then execute the graph. On the other hand, for network functions, you usually have to define the graph yourself manually. For example, FastClick [3] is a modular router implemented in software targeting high-speed network processing. It allows you to declare a pipeline of network elements using a predefined syntax. While this allows for modularity, as it is easy to modify your pipeline, it still requires knowledge of the specific tool you use (here, the FastClick configuration language). In this thesis, you will take inspiration from the generality of query expression in stream processing, and apply it to network function processing. The idea is to create support for mapping a declarative query (e.g., a SQL query) describing operations on network packets, to the actual FastClick pipeline. You will need to write Java and C++ code. The project might lead to a scientific publication in a workshop. Contact : For more info, you can contact Maxime Vanliefde, PhD student in the CLSC and ENSG groups: maxime.vanliefde@uclouvain.be	References [1] https://calcite.apache.org/ [2] https://flink.apache.org/ [3] https://github.com/tbarbette/fastclick or Barbette, T., Soldani, C., & Mathy, L. (2015, May). Fast userspace packet processing. In 2015 ACM/IEEE Symposium on Architectures for Networking and Communications Systems (ANCS) (pp. 5-16). IEEE. https://doi.org/10.1109/ANCS.2015.7110116

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	A provably correct compiler for Jasmin	Charles Pecheur	Formal verification of software is a powerful technique to ensure that a piece of code is correct. In this thesis, you will work with the Rocq programming language and proof assistant to implement parts of a compiler. You will also prove that the compiler is correct (which means that it preserves the functionality of the code it compiles). In more detail, the object of this thesis is the compilation of Jasmin [1]. Jasmin is a programming language used for writing code under very strict performance, correctness and security requirements. Excellent performance and security is achieved by providing very low-level control to the programmer, allowing to fully select the CPU instructions and data location when necessary. The correctness of Jasmin programs can be verified by tools. In particular, Jasmin code can be translated to the language of the easycrypt theorem prover, which can then be used to prove that the code satisfies a high-level specification. The Jasmin compiler (from Jasmin to assembly) is formally verified. However, the extraction from Jasmin to easycrypt is not, which leaves a gap in the correctness proofs of Jasmin programs (and it is a source of bugs), see Figure 1 of [2]. In this thesis, you will extend the Jasmin compiler to re-implement in Rocq and verify the correctness of key transformations in the path from Jasmin to easycrypt.	[1] https://github.com/jasmin-lang/jasmin/ [2] https://eprint.iacr.org/2023/215
CIS	(no longer available) Towards Adaptive Game-Playing Agents: Opponent Modelling in Perfect-Information Games	Eric Piette	Game-playing agents are typically designed under the assumption that their evaluation of positions is accurate and that their opponent behaves as a perfectly rational agent, i.e., one that plays optimally using similar goals, heuristics, and search procedures. In practice, however, these assumptions rarely hold. Opponents may differ in playstyle, skill level, or objectives, leading to suboptimal or unpredictable behavior. Opponent modelling (OM) encompasses a set of techniques aimed at inferring characteristics of an opponent from observed gameplay and leveraging this information to guide decision-making. Opponent modelling has been extensively studied in imperfect-information games such as Texas Hold'em and in multi-agent settings [1][2], where uncertainty about hidden state naturally motivates such approaches. In contrast, it has received less attention in perfect-information games, where all relevant state information is fully observable. One argument is that, in these settings, there is no hidden information to infer. However, empirical evidence from human play suggests otherwise: players routinely account for their opponent's tendencies, plans, and strategic preferences, whether by preparing through analysis of past games or by adapting dynamically during play. In this context, opponent modelling focuses not on hidden state, but on modelling the opponent's decision-making process and behavioral patterns. Existing work in this area includes the PhD thesis of Peter Jansen [3], the M* algorithm [4], and Probabilistic Opponent-Model Search [5]. While these approaches demonstrate the potential of opponent modelling in perfect-information games, they typically rely on static or predefined opponent models and are therefore limited in their ability to capture the diversity and adaptability of real-world playstyles This thesis aims to investigate how opponent modelling can complement modern advances in perfect-information game-playing agents from two perspectives: offline, by learning opponent models from large datasets without time constraints, and online, by adapting to an opponent during gameplay based solely on observed actions and under strict time limits. Accordingly, this work explores both offline and online learning paradigms within a unified framework. The central research question is whether efficient algorithms for online opponent modelling can be developed, and whether integrating such models into game tree search leads to measurable performance improvements against both human and artificial opponents.	References: [1] Jing, Y., Liu, B., Li, K., Zang, Y., Fu, H., Fu, Q., Xing, J., & Cheng, J. (2024). Opponent modeling with in-context search. In Advances in Neural Information Processing Systems (Vol. 37, pp. 61549–61591). Curran Associates, Inc. https://doi.org/10.52202/079017-1967 [2] Yu, X., Jiang, J., & Lu, Z. (2024). Opponent modeling based on subgoal inference. In Advances in Neural Information Processing Systems (Vol. 37, pp. 60531–60555). Curran Associates, Inc. https://doi.org/10.52202/079017-1936 [3] Jansen, P. J. (1992). Using knowledge about the opponent in game-tree search [Technical report]. [4] Carmel, D., & Markovitch, S. (1996). Incorporating opponent models into adversary search. In AAAI/IAAI (Vol. 1, pp. 120–125). [5] Donkers, H. H. L. M., Uiterwijk, J. W. H. M., & van den Herik, H. J. (2001). Probabilistic opponent-model search. Information Sciences, 135(3–4), 123–149.
CIS	Adaptive stochastic optimization for the calibration of bottom friction parameters in SLIM for tidal prediction	Emmanuel Hanert Jonathan Lambrechts	Accurate tidal prediction is a key challenge in coastal and estuarine hydrodynamic modelling, with important applications in flood risk assessment, coastal management, and environmental studies. One of the main factors influencing model accuracy is the representation of bottom friction, which strongly affects tidal amplitude, phase, and energy dissipation. The objective of this thesis is to develop an automatic calibration approach for friction parameters in the in order to improve tidal predictions against observational data. The work will be based on the adaptive stochastic optimization method proposed by Spall (2000), using the Simultaneous Perturbation Stochastic Approximation (SPSA) approach. This method is particularly well suited to numerical models such as SLIM because it enables efficient parameter calibration with a limited number of model simulations. The student will implement and test an optimization framework coupling this method with SLIM, define an objective function based on discrepancies between simulations and tidal observations, and evaluate the improvement in predictive skill. The thesis will include a validation study on a realistic coastal or estuarine test case and an assessment of the method's robustness and computational efficiency.	References: J. C. Spall, "Adaptive stochastic approximation by the simultaneous perturbation method," in IEEE Transactions on Automatic Control, vol. 45, no. 10, pp. 1839-1853, Oct. 2000, doi: 10.1109/TAC.2000.880982. https://www.slim-ocean.be

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	Development of a two-dimensional horizontal non-hydrostatic extension of SLIM based on hyperbolic Boussinesq-type models	Emmanuel Hanert Jonathan Lambrechts	Accurate simulation of coastal waves, dispersive wave propagation, and tsunami dynamics often requires going beyond the hydrostatic shallow-water approximation. Recent developments in hyperbolic Boussinesq-type and Serre-Green-Naghdi models provide an efficient framework for representing non-hydrostatic and dispersive effects while maintaining a computationally tractable system of equations. The objective of this thesis is to investigate the extension of SLIM toward a two-dimensional horizontal non-hydrostatic model inspired by the framework proposed in the paper cited below. The work will focus on the formulation and implementation of a depth-averaged non-hydrostatic extension suitable for horizontal 2D coastal and ocean applications. Particular attention will be given to preserving the hyperbolic structure of the equations in order to retain computational efficiency and scalability on parallel architectures. The student will study the mathematical formulation of the model, derive a suitable numerical discretization within the SLIM framework, and validate the implementation on benchmark wave propagation test cases such as dispersive coastal waves, solitary waves, or tsunami propagation.	References: G.L. Richard, An extension of the Boussinesq-type models to weakly compressible flows, European Journal of Mechanics - B/Fluids, Volume 89, 2021 https://doi.org/10.1016/j.euromechflu.2021.05.011. https://www.slim-ocean.be

COMPUTING AND INFORMATION SYSTEMS TOPICS				
Department	**Research Topic**	**Supervisors**	**Abstract**	**References**
CIS	(2026-2027) Synthesizing Pyttern patterns using Large Language Models	Kim Mens	Pyttern [1] is an expressive pattern-matching language for Python programs developed in our lab. It allows users to define structural patterns over Python code using a concise Python-like syntax with additional wildcards, enabling the detection of programming idioms, design patterns, and common coding flaws ("code smells"). Currently, Pyttern patterns must be written manually by instructors or experts. This requires both a deep understanding of program structures and familiarity with the Pyttern language, which may limit its adoption and scalability. At the same time, Large Language Models (LLMs) have shown promising capabilities in code understanding and generation. In particular, they can translate high-level, natural language descriptions of programming concepts into executable code. The goal of this thesis is to explore whether LLMs can assist in the automatic synthesis (i.e., code generation) of correct and useful Pyttern patterns from higher-level specifications of programming patterns, idioms and flaws. More concretely, the student will investigate how to generate Pyttern expressions from: - natural language descriptions of programming patterns (e.g., “a function that returns early inside a loop”); - well-documented design patterns or code smells, such as those available on platforms like https://refactoring.guru/; - example code snippets illustrating a given programming idiom or anti-pattern. The project will investigate prompting and fine-tuning strategies to produce patterns that are both syntactically valid and semantically meaningful, while respecting language-specific constraints. Different methods for evaluating pattern quality will be studied, focusing on accuracy, generalization, and the avoidance of false positives and false negatives. The research will also examine iterative and interactive approaches, such as self-refinement, human-in-the-loop feedback, and example-based prompt improvement. Finally, it will explore combining information from textual descriptions, code examples, and structured pattern repositories to improve automatic pattern synthesis. The expected outcome is a working prototype that takes high-level descriptions or examples as input and produces candidate Pyttern patterns, along with an evaluation of their correctness and usefulness in realistic educational or code analysis scenarios. This thesis lies at the intersection of program analysis, programming languages, and AI-assisted software engineering. A key challenge will be to ensure that generated patterns are not only syntactically valid, but also precise abstractions of the intended concept, avoiding both overfitting to examples and overly broad matches.	[1] Julien Liénard, Kim Mens, and Siegfried Nijssen. Pyttern: a python-based program query language. In Belgium-Netherlands Software Evolution Workshop (BENEVOL), 2024.