MICS EA4037

LABORATOIRE MATHÉMATIQUES ET INFORMATIQUE POUR LA COMPLEXITÉ ET LES SYSTÈMES

Mathematics in Interaction with Computer Science (MICS)

Founded in the early 2000's, MICS (formerly MAS) is the research laboratory in Mathematics and Computer Science at CentraleSupélec. Research at MICS is concerned with the analysis and modelling of complex systems and data, whether they come from the industry, life or social sciences, financial markets, information technology or networks.

Research Axes

- **Biomathematics**: Data-driven and Knowledge-based Mathematical Modelling, Statistical Inference and Computational to help solve major challenges in life sciences and health. Methods for Biological Systems and Data. Applications to precision medicine, neurosciences, molecular biology, genetics, plant science, epidemiology, decision-aided diagnosis.
- **Quantitative Finance:** Microstructure, high-frequency massive data: auctions, manipulation, market making, reinforcement learning; Covariance matrix filtering and investment; Agent models: cognitive biases and investor behaviour, money markets; Robust transport, mean-field games.
- **Fundamental Mathematics**: Harmonic analysis and geometric measure theory; Analysis of partial differential equations; Harmonic analysis and geometric measure theory; Numerical analysis; Stochastic analysis (rough paths, Fokker-Planck equation); Probabilistic Modelling and Statistics of Stochastic Processes: Regularity of stochastic processes (fractional processes).
- **Scientific Computing**: Massively parallel computing; GPU computing; Algorithmic interface between parallel computing and the numerical analysis of partial differential equations and algebraic differential equations.
- **Computer Science**: formalisms and methods based on logic, probabilities, graphs, category theory, mathematical morphology for software-based systems.
- **Artificial Intelligence and Decision Modelling**: Deep learning; Representation learning; Few shot and continual learning; Explainable artificial intelligence; AI for computer vision; AI for NLP; Multicriteria decision making, preference learning, knowledge representation and reasoning, explaining decisions, multi-objective optimization, collective decisions.

Application Domains

- Industrial systems (aerospace, construction, energy, transportation);
- Environment (plants, hydrology, landscapes, acoustics);
- Information technology and networks (Internet, multimedia, knowledge management);
- Life sciences (medicine, molecular biology, genetics, epidemiology);
- Markets and companies (finance, capital markets, business intelligence).

HIGHLIGHTS 2022

HDR DEFENSE

Wassila Ouerdane has defended her HDR on the topic: "From Preference Elicitation to Explaining Decisions: a Dialectical Perspective".

Alexandre Richard has defended his HDR on the topic: "Construction and approximation of some irregular stochastic models: hitting times, fractional noises, singular drifts and interactions".

PAPER AWARDS

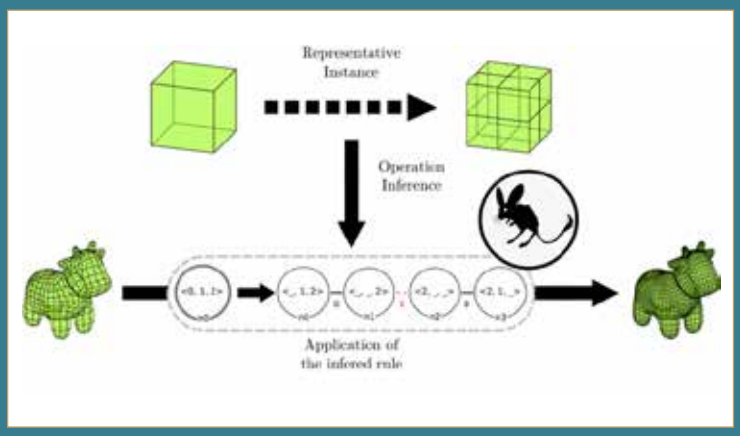
N. Belloir, an intern under the supervision of W. Ouerdane in the context of a collaboration with IRISA and CREC received the Best Forum Paper / Poster Award for the paper "A Conceptual Characterization of Fake News: A Positioning Paper" at RCIS 2022.

M. Lerouge, a PhD student under the supervision of Prof V. Mousseau, W. Ouerdane and C. Gicquel from LISN received the Best Paper Award Honorable for the paper "Counterfactual Explanations for Workforce Scheduling and Routing Problems" at ICORES 2023.

RESEARCH PROJECTS

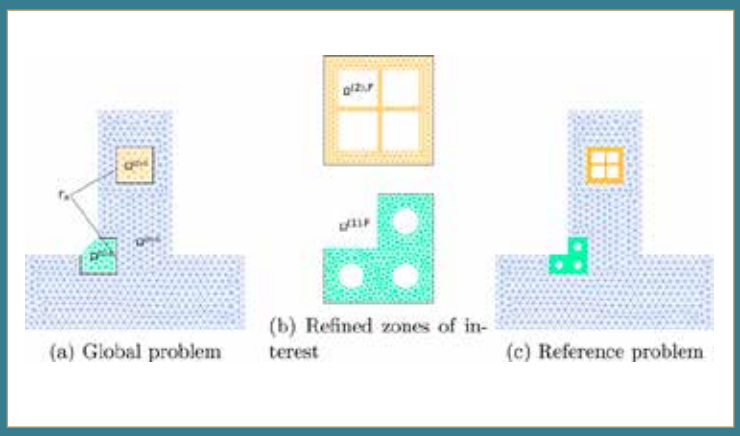
Anaëlle Wilczynski was granted by the ANR in the call "Jeunes Chercheurs" for her projet Apple Pie: AdaPting and explaining fairness for Preference-based assignment.

The MICS Lab is part of the **Research Chair** with **Transvalor,** Artificial Intelligence Research Chair for the simulation of material forming processes.



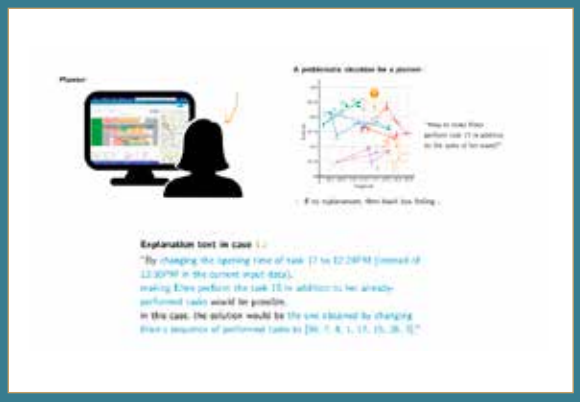
Inference of graph transformation rules for the design of geometric modelling operations: (Pascual et al, 2022).

The design of correct topological modeling operations is known to be a time-consuming and challenging task. However, these operations are intuitively understood via simple drawings of a representative object before and after modifcation. We propose to infer topological modeling operations from an application example. Our algorithm exploits a compact and expressive graph-based language. In this framework, topological modeling operations on generalized maps are represented as rules from the theory of graph transformations (Collaboration with H. Belhaouari and A. Arnoult, XLIM). To learn more: Romain Pascual, Hakim Belhaouari, Agnès Arnould, Pascale Le Gall. Inferring topological operations on generalized maps: application to subdivision schemes. Graphics and Visual Computing, 2022 (10.1016/j.gvc.2022.200049. hal-03491856v2).



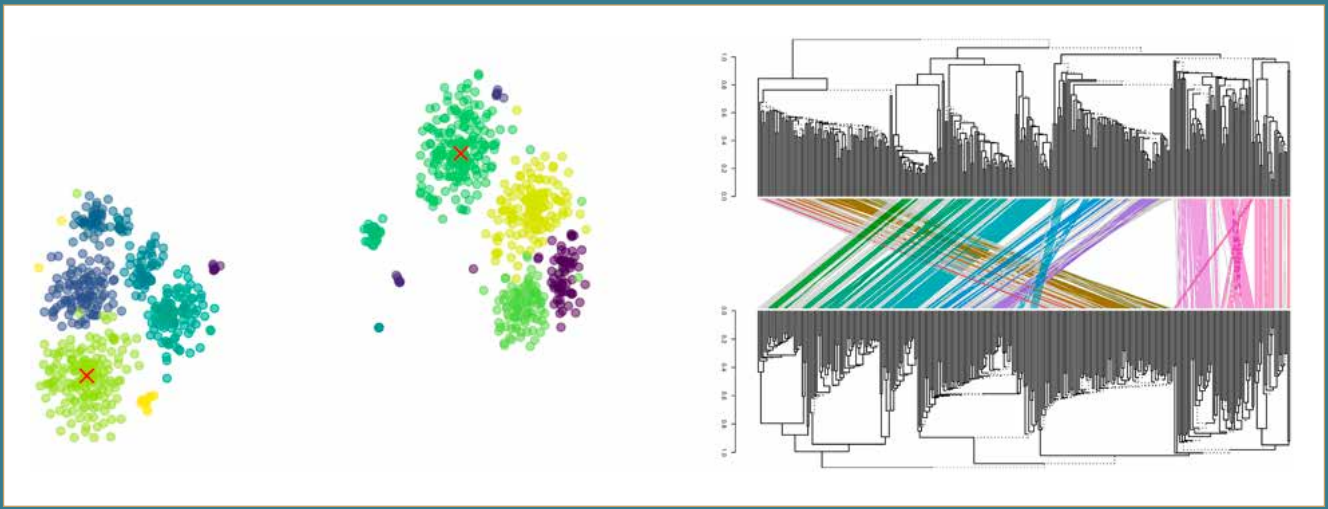
Non-invasive global-local coupling (El Kerim, 2022)

The Global-Local non-invasive coupling is an improvement of the submodeling technique, which permits to locally enhance structure computations by introducing patches with refned models and to take into accounts all the interactions. In order to circumvent its inherently limited computational performance, we propose and implement an asynchronous version of the method. The asynchronous coupling reduces the dependency on communications, failures, and load imbalance. To learn more: Ahmed El Kerim, Pierre Gosselet, Frederic Magoules. Asynchronous global-local non-invasive coupling for linear elliptic problems. Computer Methods in Applied Mechanics and Engineering, 2023, 406 (115910), (10.1016/j.cma.2023.115910. hal-03855733v2).



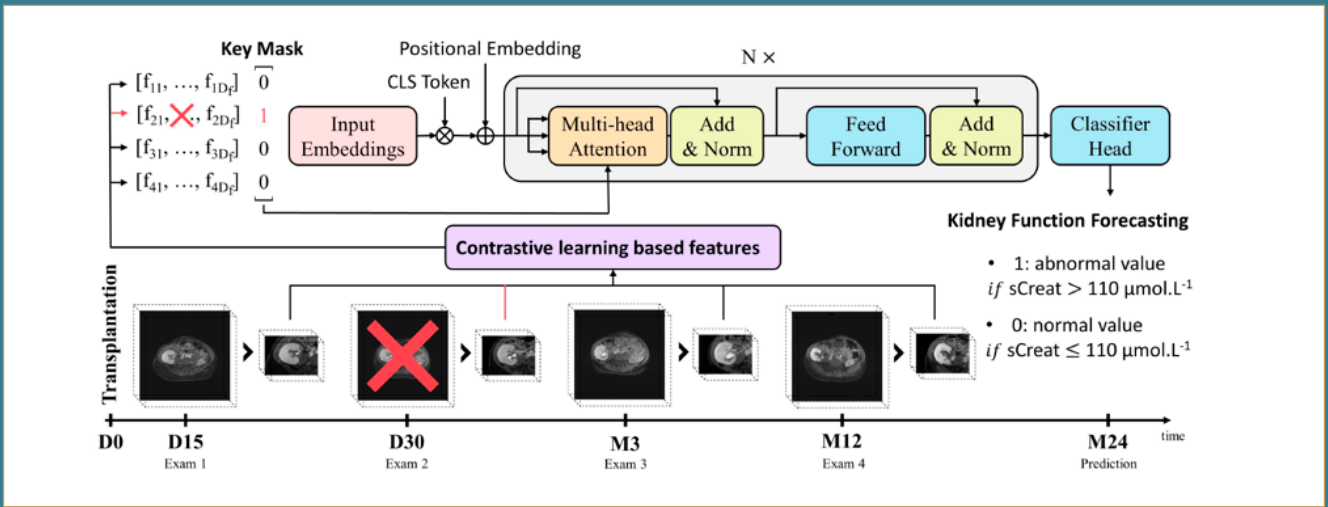
Generating explanations of various types for end-users of optimization systems

Lerouge et al. (ICORES 2023) introduce a new mathematical programming-based approach to compute counterfactual explanations in response to end-users' questions. Such explanations emphasize the few changes that may be operated on the instance data for obtaining solutions corresponding to the end-users' expectations. (Collaboration with LISN, C. Gicquel).
To learn more: Mathieu Lerouge, Céline Gicquel, Vincent Mousseau, Wassila Ouerdane. Counterfactual - Explanations for Workforce Scheduling and Routing Problems. 12th International Conference on Operations Research and Enterprise Systems, Feb 2023, Lisbon, Portugal. pp.50-61, (10.5220/0011639900003396. hal-04016553)



Covariance matrix filtering with bootstrapped hierarchies (Bongiorno et al, 2022)

Cleaning covariance matrices is a highly non-trivial problem, yet of central importance in the statistical inference of dependence between objects. We propose here a probabilistic hierarchical clustering method, named Bootstrapped Average Hierarchical Clustering (BAHC), that is particularly effective in the high-dimensional case, i.e., when there are more objects than features. To learn more : Bongiorno C, Challet D (2021) Covariance matrix filtering with bootstrapped hierarchies. PLoS ONE 16(1): e0245092. https://doi.org/10.1371/journal.pone.0245092.



Medical Imaging : Contrastive Masked Transformers for Forecasting Renal Transplant Function (Milecki et al, 2022)

We propose a sequential architecture based on transformer encoders to predict the renal function 2-years post-transplantation. Our method uses features generated from Dynamic Contrast-Enhanced Magnetic Resonance Imaging from 4 follow-ups during the first year after the transplant surgery. To deal with missing data, a key mask tensor exploiting the dot product attention mechanism of the transformers is used. Moreover, different contrastive schemes based on cosine similarity distance are proposed to handle the limited amount of available data. To learn more : Leo Milecki, Vicky Kalogeiton, Sylvain Bodard, Dany Anglicheau, Jean-Michel Correas, et al.. Contrastive Masked Transformers for Forecasting Renal Transplant Function. MICCAI 2022 - 25th International Confernce on Medical Image Computing and Computer Assisted Intervention, Sep 2022, Singapore, Singapore. pp 244-254. (hal-03738395).

Industrial Partners

- AIR LIQUIDE HEALTHCARE
- BNP PARIBAS
- CYBELETECH
- DASSAULT AVIATION
- DASSAULT SYSTEMS
- EDF
- GE HEALTHCARE
- IBM
- ICON CFD
- ILLUIN TECHNOLOGIES
- INCEPTO MEDICAL
- RANDSTAD
- SAINT-GOBAIN
- SCIENTA LABS
- SERVIER
- SICARA
- SNCF
- SUN ZU LAB
- THALES
- THERAPANACEA,
- TRANSVALOR
- VITADX.

Academic Partners

Institut Gustave Roussy, CEA, INRA, INRIA, INSERM, AgroParisTech, Cambridge, Oxford, Georg-August-Universität Göttingen, Sapienza University of Rome, Polytechnic University of Turin, RUDN University, Bar Ilan, TU München, University of Tokyo, Doshisha University (Japan), Beihang University, (China), Providence University (Taiwan), University of Washington, University of Michigan, Temple University, Berkeley Lab (USA).

Key figures

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