UNIVERSITÀ DI TRENTO

Università di Verona

Borsa di studio/Scholarship

A	Large views of small phenomena: decompositions, localizations and representation type (LAVIE)

Project Code: FIS00001706

CUP: B53C23007630001

Topic: Representation theory of algebras

Project Manager: Lidia Angeleri (UniVr)

Contact: lidia.angeleri@univr.it

Synthetic description of the activity and expected research outcome
Three scholarships are available in the research group in Representation Theory of Algebras at the University of Verona. The research work will focus on one of the themes of the project LAVIE.
The project LAVIE is prompted by some open problems around the notion of representation type, a measure for the complexity of the category of modules over an algebra. These problems concern small, that is, finite dimensional modules. But they are controlled by large, that is, possibly infinite dimensional modules. We propose a novel approach that takes into account the interplay between small and large objects and is based on recent advances on infinite dimensional modules achieved e.g. in silting theory and localization theory. This leads us to consider three important invariants of an algebra A: the lattice of torsion classes in the category modA of small A-modules, the lattice of ring epimorphisms with domain A, and the Ziegler spectrum of A. One of our main goals is to exploit the information encoded by these invariants and to understand their interrelation. Another significant aspect of the project is to develop concrete case studies aiming at classification results over specific classes of algebras.
Possible topics for a PhD-thesis include
- triangular matrix rings
- gentle algebras
- rank functions, character theory
- silting theory
- stability theory
- geometric representation theory
- spectra and localization theory

Individual research work will be complemented by team activities such as reading groups, internal workshops and seminars. Part of the research work can further be carried out at partner universities abroad.
For more details on the project LAVIE please see the link below.

References: http://profs.scienze.univr.it/~angeleri/LAVIE

Ideal candidate (skills and competencies)
The ideal candidates have a MSc in Mathematics and some background in one of the areas representation theory of algebras, homological algebra, or commutative algebra.

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Borsa di studio/Scholarship

B	**Development of novel Advanced Structure Preserving Lagrangian methods for the solution of Hyperbolic equations**
Project Code: ERC-STG AlcHyMiA, Grant Agreement nr. 101114995	
CUP: B33C23001120006	
Topic: Numerical Analysis, Scientific Computing, High order numerical methods for Hyperbolic equations	
Project Manager: Elena Gaburro (UniVr)	
Contacts: elena.gaburro@univr.it	

Synthetic description of the activity and expected research outcome

The research activity funded by this scholarship will be carried out in the context of the ERC Starting Grant ALcHyMiA: "Advanced Structure Preserving Lagrangian schemes for novel first order Hyperbolic Models: toward General Relativistic Astrophysics" (GA 101114995).

The PhD student will work on the development and validation of novel numerical methods, of Finite Volume and Discontinuous Galerkin type, of high order of accuracy, for solving systems of nonlinear hyperbolic equations with an improved efficiency and robustness.

These methods will be developed on polygonal and polyhedral meshes moving together with the fluid flow in the context of cutting-edge *Arbitrary-Lagrangian-Eulerian* techniques, that involve a novel challenging integration over space-time 3d and 4d control volumes (which can be also degenerate).

The following topics could be also object of study: i) algorithms for grid generation and optimization, ii) the parallelization of the developed codes, iii) introduction of *structure preserving* techniques to increase accuracy and robustness, iv) adaptive mesh refinement and local time-stepping, v) use of novel quadrature rules and basis functions, vi) the developments of routines for visualization.

The resulting methods will be applied in the field of computational fluid dynamics (e.g. Euler equations, multiphase models ...) and/or computational astrophysics (Euler-Einstein equations).

References

Professor's website: https://www.elenagaburro.it/index.html .

Project's website: https://www.elenagaburro.it/ALcHyMiA.html .

A simple paper: *High-order Arbitrary-Lagrangian-Eulerian schemes on crazy moving Voronoi meshes*, Springer 2023, link: https://arxiv.org/pdf/2208.02092.

Ideal candidate (skills and competencies)

The ideal candidate has a master's degree in Mathematics, Engineering or Informatics and some experience with the analysis, development and implementation of numerical methods for the discretization of partial differential equations (Finite Elements and/or Finite Volume methods, mesh generation and optimization, characteristic of hyperbolic equations…). Good programing skills will be also appreciated.

These experiences should be highlighted in the application citing also a few examples (courses, projects …).

The ideal candidate is also expected to have a very good capability of writing scientific original and interesting text in English (the submitted statement of purpose and research project will be used to attest this skill).

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Dipartimento di Matematica – Università di Trento
Fondazione Bruno Kessler – FBK

Borsa di studio/Scholarship

C	**Statistical Analysis and Temporal Graph Neural Networks for the Mathematical Modeling of Disinformation Propagation**

Topic: Mathematical Modeling, Temporal Graph Neural Networks, Disinformation, Temporal Point Processes, Stochastic Processes for Networks, Mathematical Statistics

Project Manager: Riccardo Gallotti, Claudio Agostinelli

Contacts: rgallotti@fbk.eu, claudio.agostinelli@unitn.it

Synthetic description of the activity and expected research outcome

This project aims to develop a comprehensive mathematical framework for modeling disinformation propagation in networked environments through the integration of statistical analysis and temporal graph neural networks (TGNNs). The research will conceptualize information diffusion as a dynamic process on evolving graphs, enhancing traditional epidemic-style diffusion models with the more flexible temporal point process framework to better capture the stochastic nature of information transmission across diverse network topologies.

The candidate will investigate how temporal point processes can effectively model the sporadic and bursty nature of content sharing, enabling precise mathematical formulation of cascade effects in both centralized and decentralized social structures. Adaptations of clustering techniques will be explored to identify emergent patterns in user behavior, and novel mathematical metrics will be developed to quantify the influence potential of network nodes.

Temporal graph neural network architectures will be incorporated to learn time-varying node embeddings that capture the evolutionary dynamics of information spread. The research will establish theoretical bounds on disinformation propagation rates and develop predictive models that quantify uncertainty through rigorous statistical inference.

References

[1] Song, Chenguang, Kai Shu, and Bin Wu. "Temporally evolving graph neural network for fake news detection." Information Processing & Management 58.6 (2021).

[2] Trivedi, Rakshit, et al. "Dyrep: Learning representations over dynamic graphs." International conference on learning representations. (2019).

[3] Longa, Antonio, et al. "Graph Neural Networks for Temporal Graphs: State of the Art, Open Challenges, and Opportunities." Transactions on Machine Learning Research. (2024)

Ideal candidate (skills and competencies)

The ideal candidate must have strong mathematical background with particular emphasis on probability, stochastic processes and mathematical statistics. Proficiency in machine learning, deep learning, data handling and statistical analysis would be considered a plus.

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Fondazione Bruno Kessler – FBK

Borsa di studio/Scholarship

D	**Quantum-safe applied cryptography for the Cloud-Edge Continuum**

Topic: Applied cryptography, post-quantum cryptography, cloud service cybersecurity

Project Manager: Silvio Ranise, Alessandro Tomasi

Contacts: silvio.ranise@unitn.it, altomasi@fbk.eu

Synthetic description of the activity and expected research outcome

Cloud and edge service providers enable outsourcing of services such as large data storage and computation while allowing for meeting more stringent quality of service constraints by strategically distributing workloads. They also require key building blocks to deliver services with authentication and confidentiality of data at rest, in transit, at the application layer, and in use. Specific regulatory and security requirements also place a burden on service providers to maximise the privacy of users, minimise the impact of any data breaches, and actively contribute to the resilience of complex infrastructures and digital ecosystems.

Applications of current research interest include privacy-preserving federated learning [XBZAL_19] through, e.g., functional encryption [MSV_21], model training on encrypted data [SFBMKCM_23] through fully homomorphic encryption [MSMBFA_22], and e-voting [dPLNS_17]. Additionally, NIST recommendations to deprecate by 2030 and then forbid by 2035 certain widely used cryptographic primitives (such as RSA) because of the emerging quantum computing threats, put additional pressure on organisations worldwide to plan for the adoption of Post Quantum Cryptography, i.e. cryptographic primitives that are Quantum resistant. Indeed, to satisfy the requirements of different use case scenarios demands the adoption of primitives with different features. In particular, the choice for each application depends not only on the security of each scheme but also on its trust assumptions, its performance at each stage, its complexity for implementers and its usability for end-users.

The candidate's research may focus on several of the above aspects: improving the most appropriate cryptosystem for a scenario; applying cryptanalysis to improve trustworthiness and validate parameter choices; benchmarking libraries for performance comparisons, and contributing to open source code; and improving the efficiency of operations, e.g., number-theoretic transforms or tighter error bounds for more efficient parameters; or creating tools to make cryptosystems more accessible and transparent to developers as well as end-users. Of interest will also be the development of approaches to assist organizations in the process of adopting Post Quantum Cryptography in the context of the selected use case scenarios.

References

[XBZAL_19] HybridAlpha: An Efficient Approach for Privacy-Preserving Federated Learning. R Xu, N Baracaldo, Y Zhou, A Anwar, H Ludwig. AISec'19. https://doi.org/10.1145/3338501.3357371

[dPLNS_17] Practical Quantum-Safe Voting from Lattices. R del Pino, V Lyubashevsky, G Neven, G Seiler. CCS '17. https://doi.org/10.1145/3133956.3134101

[SFBMKCM_23] Deep Neural Networks for Encrypted Inference with TFHE. Stoian, A., Frery, J., Bredehoft, R., Montero, L., Kherfallah, C., Chevallier-Mames, B. (2023). In: Dolev, S., Gudes, E., Paillier, P. (eds) Cyber Security, Cryptology, and Machine Learning. CSCML 2023. LNCS 13914. https://doi.org/10.1007/978-3-031-34671-2_34

[MSMBFA_22] Survey on Fully Homomorphic Encryption, Theory, and Applications. Marcolla, Sucasas, Manzano, Bassoli, Fitzek, Aaraj https://eprint.iacr.org/2022/1602

[MSV_21] A survey on functional encryption. C Mascia, M Sala, I Villa. AMC 2023, 17(5): 1251-1289. https://doi.org/10.3934/amc.2021049

Ideal candidate (skills and competencies)

MSc in Mathematics or Computer Science with a focus on Cryptography
Software development skills, preferably in Rust or Python
Good knowledge and proficiency of the English language
Expertise on one or more of the scientific topics in the call description above

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Fondazione The Microsoft Research - University of Trento Centre for Computational and Systems Biology (COSBI)

Borsa di studio/Scholarship

E	**Hybrid approaches for multiscale mathematical modeling integrated with Machine Learning in Quantitative Systems Pharmacology**

Topic: Hybrid approaches for mathematical modeling of biological dynamics

Project Manager: Stefano Giampiccolo (Fondazione COSBI), Prof. Luca Marchetti (Universitá di Trento)

Contacts: giampiccolo@cosbi.eu, luca.marchetti@unitn.it

Synthetic description of the activity and expected research outcome

Mathematical modeling plays a central role in supporting the understanding of complex diseases and the development of novel therapeutic strategies. In particular, Quantitative Systems Pharmacology (QSP) relies on the integration of mechanistic models, often based on systems of ordinary differential equations, to describe biological processes involved in drug action and disease progression. However, as models grow in complexity to reflect the multifaceted nature of human biology, issues of incomplete mechanistic knowledge of biological systems, parameter estimation, and computational cost become major challenges. Recent advances in machine learning (ML) offer powerful tools to overcome these limitations by enabling hybrid modeling strategies and surrogate approaches that preserve, at least partially, the model interpretability while improving flexibility and efficiency [1].

This PhD project offers the candidate the opportunity to contribute to this emerging field at the intersection of applied mathematics, computational biology, and artificial intelligence. The candidate will first extend and analyze hybrid models that combine ODE-based components with neural networks (e.g., Neural ODEs), particularly in contexts where some biological mechanisms are unknown or only partially characterized, using as a basis previous literature developed by the group [2]. A key focus will be on the rigorous treatment of parameter identifiability, uncertainty quantification, and model generalization, central topics in the mathematical modeling of biological systems.

In parallel, the candidate will explore surrogate modeling techniques, including bottleneck Neural Networks [3] and Physics-Informed Neural Networks [4], to approximate the solutions of systems of ordinary differential equations. These techniques will play a pivotal role in enabling efficient generation of virtual populations (VP) and support precision medicine approaches based on QSP modeling [5,6]. VP generation involves optimization, high-dimensional approximation, and probabilistic reasoning, offering a rich environment for mathematical exploration and innovation.

Through this work, the PhD student will develop a strong methodological foundation in both the mathematical theory and numerical implementation of traditional and hybrid modeling approaches, while also gaining hands-on experience in tackling real-world problems at the intersection of mathematics, pharmacology, and data science. The project will be carried out in strict collaboration with Fondazione The Microsoft Research - University of Trento Centre for Computational and Systems Biology (COSBI). The resulting methodologies will be applied to test cases related to the several international collaborations that Fondazione COSBI has in place in the pharma world.

References

[1] ZHANG, Tongli, et al. Two heads are better than one: current landscape of integrating QSP and machine learning: an ISoP QSP SIG white paper by the working group on the integration of quantitative systems pharmacology and machine learning. Journal of Pharmacokinetics and Pharmacodynamics, 2022, 49.1: 5-18.

[2] GIAMPICCOLO, Stefano, et al. Robust parameter estimation and identifiability analysis with hybrid neural ordinary differential equations in computational biology. NPJ Systems Biology and Applications, 2024, 10.1: 139.

[3] ANTAL, Botond B., et al. Achieving Occam's razor: Deep learning for optimal model reduction. PLOS Computational Biology, 2024, 20.7: e1012283.

[4] RAISSI, Maziar; PERDIKARIS, Paris; KARNIADAKIS, George E. Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. Journal of Computational physics, 2019, 378: 686-707.

[5] PAWŁOWSKI, Tomasz, et al. Emulation of Quantitative Systems Pharmacology models to accelerate virtual population inference in immuno-oncology. Methods, 2024, 223: 118-126.

[6] MYERS, Renée C., et al. Using machine learning surrogate modeling for faster QSP VP cohort generation. CPT: Pharmacometrics & Systems Pharmacology, 2023, 12.8: 1047-1059.

Ideal candidate (skills and competencies)

The ideal candidate will be a highly motivated student with an MSc in Mathematics, Quantitative Computational Biology, Bioinformatics, Computational Science, or related disciplines, with a solid background in differential equations, numerical methods, and optimization. Experience with machine learning, and knowledge of the concepts of parameter identifiability and uncertainty quantification of model predictions will be highly appreciated, as well as familiarity with Python or Julia programming and relevant scientific computing libraries. The candidate should be enthusiastic about applying mathematical theory and computational tools to real-world problems in pharmacology and systems biology. A genuine interest in interdisciplinary research at the interface of mathematics, biology, and artificial intelligence is essential. The student will work in a multidisciplinary environment and interact closely with researchers at COSBI and the University of Trento. The project will require both independent problem-solving skills and a collaborative attitude to contribute to the development of new methodologies supporting the Quantitative Systems Pharmacology community.