

HIGH-ORDER METHODS IN SCIENTIFIC MACHINE LEARNING: CHALLENGES, SYNERGIES AND PERSPECTIVES

CATERINA MILLEVOI[†], STEFANO PAGANI[†], FRANCESCO
REGAZZONI[†] AND GIOVANNI ZIARELLI[†]

[†]MOX, Department of Mathematics, Politecnico di Milano
Piazza Leonardo da Vinci 32, Milano (Italy)
caterina.millevoi@polimi.it, stefano.pagani@polimi.it,
francesco.regazzoni@polimi.it, giovanni.ziarelli@polimi.it

ABSTRACT

Recent years have witnessed the emergence of Scientific Machine Learning (SciML) as a new paradigm for the numerical treatment of differential equations. Complementing traditional discretization techniques, SciML leverages machine learning algorithms to address forward and inverse PDE problems, construct surrogate models, learn solution operators, and accelerate traditional numerical methods.

Despite the remarkable success across a broad range of applications, many fundamental questions remain open regarding the mathematical foundations, convergence properties, computational efficiency, and generalization of these methods. Addressing these challenges naturally calls for concepts and techniques from high-order numerical methods. Variational formulations, accurate quadrature, approximation theory, adaptive sampling, high-order discretization schemes and rigorous error analysis offer powerful tools for improving both the theoretical understanding and practical performance of SciML algorithms.

This minisymposium aims to bring together researchers working at the intersection of Scientific Machine Learning and Numerical Analysis to highlight open challenges, explore emerging synergies, and stimulate new research directions at the interface of these fields. We welcome contributions spanning theoretical analysis, algorithmic developments, and computational applications.

SPEAKERS

1. Stefano Berrone (Politecnico di Torino, Turin, Italy): *A posteriori Error Estimates, Adaptive Refinement and Robustness for VPINN solvers.*
2. Edoardo Centofanti (Università di Pavia, Pavia, Italy): *High-Order Operator Learning for Forward and Inverse Problems in Cardiac Electrophysiology.*
3. Fabio Di Fonzo (Università LUM “Giuseppe Degennaro”, Bari, Italy): *Predictor-Corrector Physics-Informed Neural Networks with Data Augmentation Training Techniques.*
4. Emmanuel Franck (INRIA Nancy Grand-Est, Strasbourg, France): *Learnable solver: Improve high-order methods with differentiable programming.*
5. Nicola Rares Franco (Politecnico di Milano, Milan, Italy): *Boundaries matter! Integrating Sobolev encodings in Neural Operators.*
6. Avi Gupta (Simon Fraser University, Burnaby, Canada): *Deep learning is an optimal, universal recovery algorithm for anisotropic high-dimensional functions.*
7. Carlo Marcati (Institut Camille Jordan of the Université Claude Bernard Lyon 1, Lyon, France): *Neural operators for PDEs: approximation theory and architectures.*
8. Fabio Marcuzzi (Università di Padova, Padua, Italy): *Conservation principles and constitutive laws in neural operators.*
9. Francesco Mezzadri (Università degli studi di Modena e Reggio Emilia, Reggio Emilia, Italy): *Physics-informed neural networks for parameterized PDEs in shape optimization.*
10. Rachel Morris (Concordia University, Montreal, Quebec, Canada): *Performance guarantees for deep Koopman autoencoders.*
11. Giovanni Pagano (Università Federico II di Napoli, Naples, Italy): *Parameter Estimation in Vegetation Models via Numerical Optimization and Convolutional Neural Networks.*
12. Federico Pichi (Scuola Internazionale Superiore di Studi Avanzati, Trieste, Italy): *Graph-based and meshless latent dynamics models.*
13. Lorenzo Rosasco (Università di Genova, Genoa, Italy): *PIKS: Physics informed kernel methods.*

14. Silvia Villa (Università di Genova, Genoa, Italy): *Zeroth order optimization algorithms through smoothing: from finite differences to zeroth order prox.*
15. Nilo Schwenke (ENS Lyon, Lyon, France): *Beyond PINNs: From Natural-Gradient Geometry to Hybrid Galerkin Methods.*
16. Constantinos Siettos (Università Federico II di Napoli, Naples, Italy): *Enabling Local Neural Operators to perform Numerical Analysis Tasks for PDEs.*
17. Andrea Zanoni (Scuola Normale Superiore, Pisa, Italy): *Enhancing uncertainty quantification through neural active manifolds.*