POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 39th cycle

PNRR 118 PNRR Research Field: COMPUTATIONAL MODELING OF THE HUMAN BRAIN: FROM PHYSIOLOGY TO NEURODEGENERATIVE DISEASES

Monthly net income of PhDscholarship (max 36 months)
€ 1325.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Computational modeling has become increasingly popular and has contributed to the understanding of the central nervous system (i.e. the brain and the spinal cord) in health and disease. This project aims at developing new mathematical models and simulation methods to gain insights into the brain's physiological function and into the mechanisms underlying the progression of neurodegenerative diseases. Neurodegenerative diseases are complex disorders leading to progressive deterioration and loss of neurological function over time. As the global population ages, the prevalence of neurodegenerative disorders is predicted to rise dramatically with the aging population, posing a significant threat to global healthcare systems. Understanding the mechanisms underlying neurodegenerative diseases and identifying patient-specific models of neurodegeneration require sophisticated mathematical models capable of representing the evolution of physical quantities of interest, such as the accumulation of disease-specific misfolded aggregated prionic proteins or the ionic imbalances generating abnormal electrical activity. At the organ scale, these models can be described by means of (multiscale and multiphysics) systems of Partial Differential Equations (PDEs). The project's final objective is the exploitation of the

	translational potential of computational models, coupled with machine learning techniques, to model the nervous system, addressing both brain's physiological function and neurodegeneration mechanisms. The results of the proposed research can be relevant to the study of neurodegeneration and contribute to advances in brain modelling towards a "digital twins" approach in brain medicine. Furter information can be found at https://antonietti.faculty.polimi.it/BraiNum/ The present research fits into the PNNR thematic areas - Digitalization and innovation; - Health. The proposed research topic can lead a significant development of knowledge in the above mentioned areas of interest of the PNRR. Moreover, the proposed research promotes interdisciplinarity approaches, membership of international networks and inter-sectoral collaborations.
Methods and techniques that will be developed and used to carry out the research	The goal of the research project is to develop mathematically sound numerical methods for the modeling of the nervous system, addressing both the fundamental brain tissue electro-mechanics and the neurodegeneration mechanisms. Within the project we will develop innovative adaptive polyhedral Finite Element methods to tame the inherited complexity. The proposed computational methods will account for the complex (patient-specific) geometries, the coupling effects, the multi-physics nature of the phenomena, and the relevant time scales. Scientific machine learning methods will be employed to enhance computational efficiency and enable the clinical translation of these solvers towards patient-specific models. Existing collaborations with Istituto Neurologico Carlo Besta in Milano will be fundamental to validate and improve the proposed computational models. The successful candidate will spend 6 months at the University of Oslo and at the Simula Research Laboratory (Oslo) working in the group of Professor Kent-Andre Mardal (https://kent-and.github.io). Professor Kent-Andre Mardal is a world-wide recognized expert in the field of

	mathematical modeling of the human brain.
Educational objectives	This research focuses on innovative mathematical methods that embrace the complementary perspectives of Numerical Methods for PDEs, Machine Learning and Neuroscience, to face translational and interdisciplinary challenges in the context of brain modeling. Furter information can be found at https://antonietti.faculty.polimi.it/BraiNum/
Job opportunities	The research activity addresses innovative topics at the frontier of Computational Mathematics and Neuroscience. The PhD candidate will develop mathematical and translational skills that will open to both industrial and academic research opportunities.
Composition of the research group	1 Full Professors 1 Associated Professors 3 Assistant Professors 2 PhD Students
Name of the research directors	Prof. Paola F. Antonietti, Dr. Stefano Pagani

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	662.5 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	
By number of months at the company	0
Institution or company where the candidate will spend the period abroad (name and brief description)	University of Oslo and/or at the Simula Research Laboratory Oslo
By number of months abroad	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
All the research results/data/software will be made available to the scientific community according to the "Open science" and "FAIR Data" principles. Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per year: 1st year: max 1.800,47 euros 2nd year: max 1.800,47 euros 3rd year: max 1.800,47 euros The PhD students are encouraged to take part in activities related to teaching, within the limits allowed by the regulations.1 individual PC per student +several shared PC. Access to one cluster with 32 processors and 384 GB RAM, and to several multi-processor servers.