POLITECNICO DI MILANO

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

THEMATIC Research Field: MATHEMATICAL AND NUMERICAL MODELS FOR COMPUTATIONAL MEDICINE OF THE HEART

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 cardiovascular medicine stands a new frontier in patient care that aims to support clinicians in decision-making and therapy planning with computational tools based on numerical simulations of mathematical models. These are typically systems of coupled differential equations that describe the complex pathophysiological processes of heart function at different spatial and temporal scales. Model personalization (achieved with the integration of clinical data within models) is pivotal for handling pathological scenarios and capturing the patient-specific interplay of feedback and interactions between the different physics. Still, several challenges remain open: 1. the design of efficient and accurate high-performance numerical solvers that control the coupling instabilities and the nonlinearity of the underlying equations; 2. the development of data-assimilation routines that exploit scientific machine learning leveraging both physics and clinical data; 3. the reliable numerical prediction scenarios to guide the selection and optimization of pharmacological and/or interventional therapies; 4. the long-term prediction of pathophysiology progression, as well as feedbacks to the changes in the patient's condition. The project objective is to perform clinical translation of models of heart function to improve the diagnosis, treatment, and monitoring of some cardiovascular diseases. The candidate will

	contribute to the development of innovative mathematical models, coupling all the relevant physics (electrophysiology, mechanics, fluid-dynamics, perfusion and the metabolism), numerical methods, and translational approaches, such as methods in scientific machine learning.
Methods and techniques that will be developed and used to carry out the research	The research activity will contribute to the development and implementation of suitable numerical methods for multiscale and multiphysics differential problems and for their coupling, with particular emphasis on the aspects of numerical stability for portioned-staggered algorithms and high performance computing (HPC). The project will foster the development of a comprehensive mathematical model accounting for the multiscale in-time features of the interaction between cardiac perfusion and electromechanics, embedding the metabolic activities which act on a slower time scale. In this context, to tackle the multiscale in time features of the perfusion-contraction coupling, Scientific Machine Learning algorithms will be designed by learning one temporal scale through a neural-network based algorithm to be then surrogated in the coupling with the other temporal scale. On-going clinical collaborations with hospitals will support the validation of the models and methods and the effective translation into the clinical routine.
Educational objectives	This project develops topics that require interdisciplinary and collaborative research, fostering the development of critical thinking and problem-solving. The research activity will foster the candidate's knowledge of advanced mathematical and computational models and methods: the student will contribute to the development of new algorithms in Scientific Computing and Machine Learning for differential problems; processing clinical data; building digital twins; and performing patient-specific simulations through new paradigms in AI and HPC.
Job opportunities	The research addresses timely, innovative and advanced topics in Applied Mathematics, Scientific Computing, Computational Medicine, and Machine Learning. The translational knowledge and competences developed will

	allow the candidate to pursue several career opportunities in academia, research hospitals, industry (Industry 4.0), especially biotech industry.
Composition of the research group	2 Full Professors 1 Associated Professors 2 Assistant Professors 3 PhD Students
Name of the research directors	Luca Dedè

Contacts
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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

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
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.