POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 40th cycle

PNRR 630 Research Field: DISCONTINUOUS GALERKIN METHODS FOR MULTIPHASE FLOW AND THEIR EFFICIENT IMPLEMENTATION ON GPUS

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 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	In recent years, discontinuous Galerkin (DG) methods have become very popular in a variety of fields, including aeronautical, oil and gas, and chemical, among others. DG methods are high-order finite element discretizations based on the variational formulation of the governing equations that combine features from Finite Volume (FV) and Finite Element (FE) methods, offering several advantages, including high accuracy, geometric flexibility, and suitability for handling discontinuous solutions. At the same time, Graphics Processing Units (GPUs) have emerged as powerful computational platforms capable of performing massively parallel computations. With thousands of cores optimized for data-parallel tasks, GPUs offer significant potential for accelerating scientific simulations. Leveraging GPUs for numerical simulations can lead to substantial speedups compared to traditional CPU-based implementations, thereby enabling the efficient exploration of complex physical phenomena. In recent years, discontinuous Galerkin (DG) methods have become very popular in a variety of fields, including aeronautical, oil and gas, and chemical, among others. DG methods are high-order finite element discretizations based on the variational formulation of the governing equations that combine features from Finite Volume (FV) and Finite Element (FE) methods, offering several advantages, including high accuracy, geometric flexibility,

	and suitability for handling discontinuous solutions. At the same time, Graphics Processing Units (GPUs) have emerged as powerful computational platforms capable of performing massively parallel computations. With thousands of cores optimized for data-parallel tasks, GPUs offer significant potential for accelerating scientific simulations. Leveraging GPUs for numerical simulations can lead to substantial speedups compared to traditional CPU-based implementations, thereby enabling the efficient exploration of complex physical phenomena. Multiphase flows are a quintessential example of such phenomena, characterized by the simultaneous presence of multiple fluid phases, each exhibiting distinct properties and intricate interactions. Given their complex dynamics and intricate interfacial phenomena, the accurate simulation of multiphase flows poses different modeling and computational challenges, motivating the exploration of advanced techniques like DG methods. The proposed PhD project aims to develop, assess, and implement a state-of-the-art computational tool for simulating multiphase flows with accuracy and efficiency. By harnessing the computational power of GPUs and the versatility of high-order DG methods, the developed code will enable the student to tackle a wide range of multiphase flow problems confidently.
Methods and techniques that will be developed and used to carry out the research	Research Objectives: 1. Develop a high-order DG framework tailored for GPU architectures, focusing on efficient memory management and data-parallel algorithms. 2. Implement algorithms for solving the governing equations of multiphase flows within the DG framework. 3. Optimize the computational performance of the DG code on GPUs through advanced parallelization strategies and hardware-aware optimizations. 4. Validate the developed code against benchmark test cases and real-world multiphase flow problems to assess its accuracy, scalability, and applicability. The student will have at disposal the supercomputing capabilities that enable the testing and validation of the proposed methodologies and algorithms.

Educational objectives	The student will follow the courses offered by the PhD school of Politecnico di Milanio https://www.dottorato.polimi.it/ and by the PhD Program M3I (https://www.mate.polimi.it/dottorato/). The research project involves deepening the knowledge of numerical methods for partial differential equations and advanced programming techniques. The student will be integrated in the Laboratory of Modelling and Scientific Computing of the Department of Mathematics, and in particular the research area of Geosciences and protection of land and water resources.The internship in the Eni Company will allow the student to get in contact with an industrial environment and advanced computing architectures, increasing her competences and skills.
Job opportunities	Industries of the manifacturing and Energy sectors High performance computing centers IT Industries Research Centers.
Composition of the research group	5 Full Professors 11 Associated Professors 6 Assistant Professors 25 PhD Students
Name of the research directors	Carlo de Falco, Luca Formaggia, Paola Antonietti

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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	750.0 €
By number of months	6

National Operational Program for Research and Innovation	
Company where the candidate will attend the stage (name and brief description)	ENI spa
By number of months at the company	6
Institution or company where the candidate will spend the period abroad (name and brief description)	
By number of months abroad	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 2.038,16 euros
2nd year: max 2.038,16 euros
3rd year: max 2.038,16 euros

The PhD student is encouraged to take part in activities related to teaching, within the limits allowed by the regulations.
The student will be provided with an individual PC and access to the high performance facilities of the Mathematics Department, including a cluster with 40 CPU nodes and a dedicated node with 2x AMD EPYC 7313 16-Core Processors, 512 Gbytes of Ram and 3 GPU AMD MI210 con 64Gb di RAM.