POLITECNICO DI MILANO

PhD in MODELLI E METODI MATEMATICI PER L'INGEGNERIA / MATHEMATICAL MODELS AND METHODS IN ENGINEERING - 41st cycle

THEMATIC Research Field: DEVELOPMENT OF MATERIAL POINT METHODS (MPM) FOR FLUID-STRUCTURE INTERACTION PROBLEMS

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	Recent evolutions of software and hardware technologies is leading to a renewed computational interest in Particle-In-Cell (PIC) methods such as the Material Point Method (MPM). Indeed, provided some critical aspects are properly handled, PIC methods can be cast in formulations suitable for the requirements of data locality and fine-grained parallelism of modern hardware accelerators such as Graphics Processing Units (GPUs). The capabilities of MPM on a wide range of continuum mechanics problems have been well assessed. While the use of the method in compressible fluid dynamics had received less attention, Baioni et al. (2024) presented a portable, highly parallel, GPU based MPM solver for compressible gas dynamics, that showed the feasibility of reaching a good compromise between portability and efficiency in solving strongly compressible gas flow problems. The intent of the present proposed work is to build on the previous experience towards the development of a monolithic MPM solver for Fluid–Structure Interaction (FSI) problems at all Mach numbers up to the supersonic regime.
Methods and techniques that will be developed and used to carry out the research	The starting point is the work of Baioni et al. (2024) that explored the feasibility of a portable and efficient implementation of the MPM for compressible fluids in the transonic and supersonic regime. To extend the latter

	ideas to a more realistic setting including viscous stresses, more advanced time stepping approaches and models will be explored, to achieve stability while maintaining the explicit structure of the algorithm. In order to address the well-known issues of cell-crossing instability and excessive energy dissipation that affect MPM methods in FSI scenarios, stabilizations based on the use of regular B-Spline basis functions and advanced mapping schemes based on the Affine Particle In Cell (APIC) transfer will be adopted (see Cheng et al. (2026)) References: Baioni et al. (2024): Baioni, Paolo Joseph, et al. "Portable, massively parallel implementation of a material point method for compressible flows." *Computational Particle Mechanics* (2024): 1-23. Cheng et al. (2026): Cheng, Zhang, et al. "Stabilized explicit material point method for fluid flow and fluid-structure interaction simulations using dual high-order B-spline volume averaging." *Computer Methods in Applied Mechanics and Engineering* 448 (2026): 118428.
Educational objectives	The researcher will acquire a unique and highly sought-after set of transversal skills in advanced mathematical, numerical and physical modeling, and high performance computing as well as the ability to collaborate with academic and industrial researchers.
Job opportunities	Positions in leading national and international research centers—both in academia and in industry. Consultancy firms or regulatory bodies.
Composition of the research group	0 Full Professors 1 Associated Professors 0 Assistant Professors 1 PhD Students
Name of the research directors	Prof. C. De Falco, Dott. F. Petri e P.J. Baioni

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
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 2.038,16 euros 2nd year: max 2.038,16 euros 3rd year: max 2.038,16 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 will be granted to the Department cluster which features 40 CPU nodes and one GPU node. Each CPU node is powered by two 24-core CPUs with 512 GB RAM. The GPU node includes two 16-core CPUs with 512 GB RAM, and three GPUs, each possessing 64 GB of memory.Access will be granted to the davinci-1 cluster https://top500.org/system/179877/ of Leonardo s.p.a. which features 38,400 total cores. Each node is powered by 2 AMD EPYC 7402 24-core CPUs running at 2.8 GHz, with interconnection via Mellanox HDR Infiniband. The system includes NVIDIA A100 GPUs and achieves a measured performance of 3.45 PFlop/s, with a peak theoretical performance of 6.41 PFlop/s.