POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 40th cycle

THEMATIC Research Field: DEEP LEARNING ALGORITHMS AND HIGH-FIDELITY NUMERICAL SIMULATIONS FOR HEALTH AND USAGE MONITORING SYSTEMS

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	Monitoring engineering systems (aerospace, civil, energy, mechanical, structural, etc.) is essential for tracking degradation and guiding maintenance actions to prevent failures. Traditional maintenance strategies rely on scheduled inspections to assess structural health. While effective for safety, this approach incurs high costs and avoidable downtimes, as inspections often find the structure in good condition without requiring maintenance.Recent research has introduced more advanced strategies, notably the integration of sensors on structures to collect diagnostic signals, which are then processed through specialized algorithms for damage detection, localization, or quantification. Among these methods, machine learning has shown particularly strong performance. However, training these algorithms requires extensive datasets, often generated from experimental or numerical data, which is both costly and challenging to produce. When numerical simulations are used, they must achieve high fidelity to capture the impact of damage on diagnostic signals accurately, making simulation development and execution resource-intensive.In this context, the Ph.D. candidate will focus on creating surrogate models of numerical simulations to produce larger, high-quality datasets, enabling more cost-effective and scalable data-driven approaches suitable for industrial applications. These surrogate models must maintain the accuracy of the original simulations while minimizing computational demands. The research will

	explore and combine two primary methods for developing damage diagnosis algorithms: **1. Deep learning algorithms** as surrogate models for numerical simulations. **2. Physics-informed neural networks (PINNs)** coupled with numerical simulations to leverage physical laws and constraints, allowing for accurate modeling of structural behavior under varying environmental and operational conditions, including damage scenarios. **3. Other possible advanced AI algorithms.**
Methods and techniques that will be developed and used to carry out the research	To conduct his/her research, the Ph.D. candidate will need to develop digital twin-oriented high-fidelity models of engineering systems. These models will enable the candidate to numerically investigate the behavior of real systems through validated simulations, accounting for various environmental and operational conditions affecting the system. These high-fidelity models may involve modeling multiple physical phenomena, using a series of high-resolution sub-models, and will simulate diagnostic signals through virtual sensor networks. The Ph.D. candidate will analyze these signals, alongside experimental data, to identify damage-sensitive features critical for structural health monitoring.Additionally, the Ph.D. candidate will acquire knowledge in advanced, modern deep learning techniques, e.g., PINNs and graph neural networks, as well as multi-physics modeling approaches. These advanced tools, capable of integrating physical constraints within neural networks, will allow for accurate simulation of engineering systems under different scenarios. By coupling deep learning approaches with high-fidelity numerical models, the candidate will be able to acquire diagnostic signals that are sufficiently accurate for damage diagnosis and can be used effectively for monitoring purposes.Finally, the research will require the candidate to study deep learning algorithms for structural health monitoring. These algorithms will function as (i) surrogate models for complex simulations and (ii) diagnostic/prognostics tools. To ensure that the machine learning algorithms are

	explainable and interpretable, the candidate will implement explainability techniques, such as layer-wise relevance propagation, which will help in understanding the model's decision-making processes and enhancing the reliability of structural health assessments.
Educational objectives	We provide doctoral candidates with high-level scientific training, fostering and refining research and problem-solving capabilities. At the end of the PhD cycle the candidate will be able to plan and carry out original research by working in a team or leading a research group active in the field of health monitoring of complex engineering systems. The candidate will strongly enhance both theoretical and experimental skills acquired during master studies.Opportunities will be offered for spending visiting periods hosted by project partners for scientific cooperation.The candidate will acquire knowledge in the disciplines of: • Advanced machine learning algorithms (deep learning, transfer learning, explainability methods, etc.) • Algorithms for damage diagnosis: damage detection, localization and quantification • Performance assessment • Sensor installation, acquisition and data processing • Surrogate modeling
Job opportunities	Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared Master of Science holders in the same field. A recent survey showed that PhD candidates are 100% employed after one year, in national and international companies and academic and non-academic research institutions, engaged in innovation, research and technical development. On average the survey showed that people earning our PhD title obtain 35% higher salary than the corresponding employers with a Master of Science degree. Specifically, the skills and know-how developed during the PhD will allow to cover positions for design, maintenance and integrity assessment of advanced systems and components in aerospace,

	automotive and mechanical companies.
Composition of the research group	2 Full Professors 2 Associated Professors 2 Assistant Professors 10 PhD Students
Name of the research directors	Proff. Francesco Cadini, Marco Giglio

Contacts
Prof. Francesco Cadini Ph +39 022399 8213 francesco.cadini@polimi.it Prof. Marco Giglio Ph +39 022399 8234 marco.giglio@polimi.it phd-dmec@polimi.it

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

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 6.114,50. Our candidates are strongly encouraged to spend a research period abroad, joining high-level research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 750 euro/month - net amount). Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.