POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 38th cycle

Research Area n. 1 - Advanced Materials and Smart Structures

INTERDISCIPLINARY Research Field: REAL-TIME OPTIMAL CONTROL AND MONITORING OF MECHANICAL STRUCTURES BY PDE CONSTRAINED OPTIMIZATION AND REDUCED ORDER MODELING

Monthly net income of PhDscholarship (max 36 months)
€ 1325.0
In case of a change of the welfare rates or of changes of the scholarship minimum amount from the Ministry of University and Reasearch, during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	Interdisciplinary PhD Grant The PhD research will be carried out in collaboration with research groups of the PhD programme in **"MATHEMATICAL MODELS AND METHODS IN ENGINEERING"**. See https://www.dottorato.polimi.it/?id=422&L=1 for further information. Being able to solve optimal control and optimal design problems in real-time, for several virtual scenarios, requires rapid and reliable numerical methods that cannot rely on traditional high-fidelity, full order models (FOMs) such as the ones based on the finite element method. Two instances of relevant problems in this class are, for instance, the structural health monitoring (SHM) of vehicles/components by ultrasonic inspection to detect cracks in an early stage, and the design of (e.g., acoustic) cloaking devices. In the former case, the goal would be to design e.g. the geometry of the axles to maximize the performance of ultrasonic testing systems, ultimately identifying the presence of damage. In the latter, we rather aim at determining space-varying fields of material properties that nullify the scattered wave, after identifying

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	the incident field from distributed measurements. In both cases, a double inverse problem has to be solved, in which a suitable cost functional that encodes the desired objective has to be minimized, subject to a set of physical constraints related to wave propagation, by acting on a control. This latter can be either the shape of the structure, as in the case of the SHM of the vehicle axles, or a space modulated density and bulk modulus in the cloaking region. This yields the solution of nonlinear optimal control problems governed by partial differential equations (PDEs). Moreover, to take into account different scenarios related to, e.g., loading conditions, vehicle motion, or material properties, a suitably parametrized version of the OCPs must be considered.The goal of the project is to analyse and numerically approximate nonlinear optimal control problems arising from the aforementioned applications, then performing experimental validation on mock-up structures. Algorithms for large-scale constrained optimization problems and reduced order modelling relying, e.g., on the reduced basis method for parametrized PDEs will be considered to enhance the numerical approximation of the physical models and solve the optimal control (or design) problems in almost real-time, for any new virtual scenario of interest.
Methods and techniques that will be developed and used to carry out the research	The project will combine techniques such as: PDE-constrained optimization and optimal control, reduced order modeling to replace high-fidelity FOMs for the efficient numerical approximation of parametrized differential problems and system identification. PhD candidates with a strong background in mathematical and numerical methods for engineering are therefore ideally positioned to carry out this project.
Educational objectives	The research aims at developing mathematical methods for the real-time optimal control and monitoring of mechanical structures exploiting PDE-constrained optimization and reduced order modelling.This research

	will tackle this task by advancing on four correlated objectives: 1. well-posedness analysis of nonlinear optimal control and shape optimization problems related with wave phenomena, and setting of a system of optimality conditions; 2. setting, analysis and implementation of rapid and reliable ROMs for the sake of computational efficiency, also paying attention to the definition of suitable shape parametrization in the case of optimal design, and the setting of material properties, aiming at finding the optimal implementable solution; 3. numerical approximation of double inverse problems, related with the identification of structural damages (for SHM problems) or the estimation of the incident field (for acoustic cloaking); 4. experimental validation on structural mock-ups of the structural designs obtained through numerical optimization.
Job opportunities	The primary job opportunity will be in the optimal control field, that is today required by almost any company that aims at minimizing costs and maximizing performance.Besides this, job opportunities will be with national and international academic and non-academic institutions and organizations, engaged in innovation, research, and technical development. Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field.
Composition of the research group	1 Full Professors 2 Associated Professors 4 Assistant Professors 0 PhD Students
Name of the research directors	Prof. Francesco Braghin, Prof. Andrea Manzoni ,

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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
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 5401,42 euro.   Accommodation in Politecnico's Residences (http://www.residenze.polimi.it) is available for PhD candidates; special rates will be applied to selected out-of-town candidates (detailed info in the call for application). 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. 550 euro/month- net amount). Teaching assistantship: availability of funding in recognition of supporting teaching activitiesby the PhD candidate. There are various forms of financial aid for activities of support to theteaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.