POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 40th cycle

THEMATIC Research Field: META-MEMS-BASED NEURAL NETWORKS

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	Taking advantage of the advancements in both the fields of Micro Electro-Mechanical Systems (MEMS) and deep learning algorithms, this PhD aims to develop a novel MEMS device that can process mechanical signals using mechanical components, i.e. to simulate the behavior of an artificial neural network (ANN) without the traditional digital operations, offering a new approach to signal processing within MEMS devices. The advantage of exploring mechanical artificial neural networks (ANNs) over their software-based counterparts has some key advantages: •efficiency: mechanical ANNs eliminate the need for digital operations by using physical systems, resulting in more energy-efficient processing and reducing the energy consumption associated with running complex algorithms in software; •parallel processing: compared to software ANNs that typically rely on sequential data processing, mechanical ANNs can process signals in parallel thus leading to faster and simultaneous processing of multiple inputs; •robustness: by employing robust physical elements in the form of interconnected mechanical resonators, mechanical ANNs may offer increased resilience to noise, interference, and other external environmental factors.

	The objective of this PhD is, therefore, to integrate deep learning algorithms and metamaterials to design novel MEMS devices that can perform complex signal processing tasks solely through mechanical components, mimicking the functionality of an ANN and without the requirement for external computational resources.
Methods and techniques that will be developed and used to carry out the research	The candidate will formulate and develop mathematical models to study interconnected metamaterial architectures, understanding the principles behind their (eventuaYy nonlinear) dynamic behavior, and predicting their performance characteristics. This task will be carried out both analytically and numerically using computer simulations and computational tools to simulate different configurations, and validate theoretical predictions. Software tools, such as finite element analysis (FEA) or computational fluid dynamics (CFD), will be employed for this purpose.Relevant case studies are the implementation of transfer functions to achieve desired output responses from given input signals. Optimizing and fine-tuning the designed mechanical ANN is also a target of this PhD and will require dedicated algorithms.Once a solution for a dedicated mechanical ANN is found, experiments will be carried out to validate and calibrate the theoretical models and numerical simulations, testing the performance of the designed network in real-world conditions and comparing the results with the expected outcomes.
Educational objectives	This PhD will allow the candidate to gain deep knowledge and comprehension of metamaterial architectures, their properties, characteristics, and applications in advanced technology and signal processing. Moreover, the candidate will develop expertise in formulating and solving mathematical models that describe the behavior and interactions within interconnected metamaterial networks, enabling accurate predictions and informed design decisions. Additionally, the candidate will acquire skills in using computational tools and software for simulating the behavior of complex systems, verifying theoretical predictions, validating experimental results, and optimizing the performance of metamaterial structures

	through virtual experiments. Finally, the candidate will gain hands-on experience in designing and conducting experiments to validate theoretical models and numerical simulations, assess the functionality of metamaterial networks, and collect data for analysis and interpretation.
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. List of Universities, Companies, Agencies and/or National or International Institutions that are cooperating in the research include: STMicroelectronics; University of California San Diego; Delft Institute of Technology; ETH Zurich.
Composition of the research group	1 Full Professors 0 Associated Professors 2 Assistant Professors 2 PhD Students
Name of the research directors	Proff. F. Braghin, J. Marconi, E. Riva

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	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 6114,50. 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.