UNIVERSITÀ DEGLI STUDI
DI TRENTO
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Room A210 – Polo Ferrari 1

Physics-informed neural networks for computational physics: why neural networks must learn physics before guessing

Abstract:

There is a growing interest in developing deep learning (DL) and artificial intelligence (AI) algorithms for electromagnetic wave engineering, computational imaging, and metamaterials design. Rapidly emerging approaches include training artificial neural networks (ANNs) to solve inverse and parameter estimation problems in complex environments. However, traditional DL and AI methods remain essentially data-driven approaches that require time-consuming training steps and massive datasets. In order to improve on these methods, it is important to constrain and regularize them by leveraging the underlying physics of the investigated problems formulated in terms of high-dimensional partial or integro-differential models. In this talk, I will discuss our current approaches to build a robust framework that efficiently integrates powerful ANN architectures and physical laws in order to constrain wave scattering and parameter retrieval inverse-problems beyond the capabilities of direct homogenization and inverse scattering methods for applications to photonics, metamaterials design, thermal transport, and imaging problems. Specifically, I will focus on adaptive learning based on diffractive optical networks (a-DONs) and on physics-informed neural networks (a-PINNs) for complex electromagnetic scattering and radiative transfer problems. The a-DONs approach utilizes diffractive optical networks that naturally merge wave diffraction physics and deep learning capabilities to achieve inverse-design of functional
diffractive components. I will introduce and discuss multiscale PINNs architectures for the inverse solution of high-dimensional integro-differential transport problems of great relevance to the engineering of advanced optoelectronic devices and bio-imaging techniques. Using the a-PINN approach, we demonstrate inverse design capabilities combined with robust parameter estimation in coupled conductive-radiative systems of relevance to complex photonics and heat transfer problems in semiconductor devices.

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