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Title: Machine learning 2.0 for the disruptive design of metaoptics and nanophotonics

Machine learning (ML) methods have attracted a lot attention in the metaoptics and nanophotonics modeling areas, especially deep learning-based modeling methods. Different supervised machine learning, unsupervised machine learning and reinforcement learning techniques have been proposed in the literature for both forward and inverse modeling. Forward models describe an input-output relationship between the design parameters (input space) and the device response (output space). Inverse models describe the inverse relationship. All these recent developments pave the foundations towards novel disruptive design flows (e.g., design exploration, optimization and variability analysis) for complex systems in the metaoptics and nanophotonics domains. Applications of interest are very broad: metalenses, vortex beam generators, holographic plates, VR/AR components, biosensors, and Surface Enhanced Raman Scattering (SERS) substrates.

However, multiple fundamental challenges still need to be addressed. I cite some of them that are of interest in this project:

- Low-data regime for accurate model generation. Collecting a lot of data samples (Big-data scenario) using electromagnetic solvers can result very computationally expensive.
- Low-complexity (still highly accurate) and interpretable model architectures. Massive model architectures that cannot be interpreted are nowadays a serious limitation.
- Adaptive sampling and adaptive model architecture selection. This is fundamental to avoid very tedious trial and error approaches.
- Developing intrusive machine learning methods (no black-box) that can efficiently and accurately learn the electromagnetic equations behind light-matter interaction. This goes beyond black-box models that do not use a-priori knowledge.
- Developing tolerance-aware modeling techniques to include design tolerances (e.g., layout, material and alignment parameters) into account from the beginning of the design flow.
- Cross-fertilizing supervised ML, unsupervised ML and reinforcement learning techniques to establish a unique hybrid ML methodology with unprecedented results.

In this project, we focus on addressing these challenges (and other related aspects), which will lead to disruptive results in the design of metaoptical and nanophotonic devices. Computational electromagnetics and advanced machine learning techniques for design (design exploration, optimization and variability analysis) of complex systems will be the backbone of this groundbreaking multi-inter-disciplinary project. The fabrication of prototypes to validate the full modeling and design flow is possible and supported. This project is embedded into a multi-inter-disciplinary research environment at Brussels Photonics (B-PHOT) of the Vrije Universiteit Brussel (VUB).

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