Reaping The Full Potential of Artificial Intelligence for Programmable Metamaterials: The Example of Intelligent Computational Meta-Imaging

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I will discuss opportunities for synergizing programmable metamaterial hardware with emerging tools from artificial intelligence (AI), focusing in particular on applications to computational imaging.

The most common use of AI is in the realm of data interpretation and thus in the digital world. But programmable metamaterials offer the opportunity to shape wave-matter interactions in the physical world and thus the process of data acquisition. To date, most metamaterial research groups unnecessarily limit the role of AI to data interpretation.

Programmable meta-atoms can be interpreted as trainable physical weights. Therefore, hybrid analog-digital artificial neural networks can be conceived that contain both physical and digital weights, yielding an end-to-end pipeline that includes both physical data acquisition and digital data analysis. These concepts are relevant to all settings in which tailored wave-matter interaction is used to extract or transfer information. In imaging and sensing, programmable metamaterials are used for computational imaging. In wireless communication, programmable metamaterials are often referred to as reconfigurable intelligent surfaces and used to shape wireless channels for a desired purpose. In both scenarios, wave propagation in the scattering system can be intelligently tailored such that it simultaneously already performs a part of the subsequent data analysis. Thereby, remarkable improvements of a wide range of metrics such as latency and energy efficiency can be achieved.

For concreteness, I will discuss intelligent computational meta-imaging in detail. Conventional compressive computational meta-imagers indiscriminately acquire all scene information in a task-agnostic measurement process that aims at a near-isometric embedding; in contrast, intelligent computational meta-imagers highlight task-relevant information in a task-aware measurement process that is purposefully non-isometric. The measurement process of intelligent computational meta-imagers is thus simultaneously an analog wave processor that implements a first task-specific inference step “over-the-air”. This merging of the physical world of metamaterial engineering and the digital world of AI enables the remarkable latency gains of intelligent computational meta-imagers.

I will conclude by looking forward to how computational meta-imagers may be endowed with cognitive abilities in the future.

References

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