Neural holography enabled multi-beam steering for multi-task classifier

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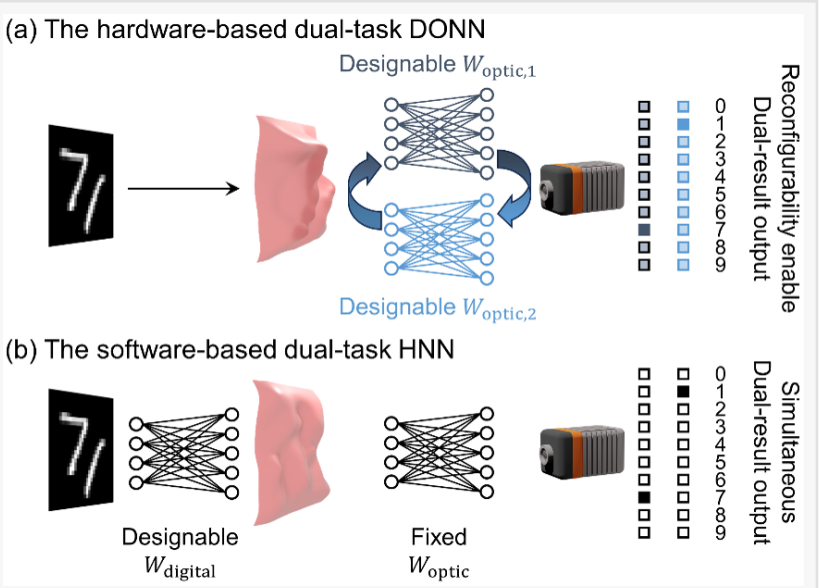


Figure 1. (a) The conventional multi-task DONNs rely on laser wavelength/polarization multiplexing or optical hardware reconfiguration. (b) The proposed multi-task HNNs operate within a unified and simple optical architecture.

In the era of rapid artificial intelligence (AI) development, traditional electronic computing architectures are facing bottlenecks in energy consumption, latency, and bandwidth. Optical and optoelectronic computing can accelerate AI inference. The Diffractive Optical Neural Network (DONN) utilizes light wave propagation to perform neural network computations, enabling ultra-high-speed and low-energy information processing. However, to achieve multi-task processing on a unified platform, it typically requires adjusting the laser wavelength/polarization or relying on complex mechanical hardware reconfiguration. This significantly increases the cost of optical hardware and the difficulty of system alignment. How to efficiently accomplish multiple tasks within a unified and compact optical architecture has become a key challenge in the field of optoelectronic computing.

To address this pain point, the research team from China Information Communication Technologies Group Corporation (CICT), in collaboration with Peng Cheng Laboratory, Wuhan University, and Nanyang Technological University, proposed to introduce neural holography technology into optoelectronic neural networks to construct an end-to-end Holographic Neural Network (HNN). This system utilizes a single phase-only spatial light modulator (SLM) to simultaneously implement the input layer based on electronic information phase encoding and the computing layer based on optical diffraction modulation. Benefiting from the simple optical architecture and flexible neural holographic algorithms, the system can simultaneously process multiple image recognition tasks through intelligent beam splitting and steering without the

need for physical hardware reconfiguration or multiplexing, achieving "one brain for multiple uses", as shown in Figure 1.

The State Key Laboratory of Optical Communication Technologies and Networks (OCTN), and the National Information Optoelectronics Innovation Center (NOEIC) affiliated with China Information and Communication Technology Group Corporation (CICT), together with Peng Cheng Laboratory, Wuhan University, and Nanyang Technological University, published a research article titled "Neural Holography enabled Multi-Beam Steering for Multi-Task Classifier" in the 2026 issue 3 of Opto-Electronic Technology. The system adopts an end-to-end optoelectronic joint training framework, using a single phase-only SLM to simultaneously undertake the dual roles of input data encoding and diffraction modulation. It then uses light propagation to complete complex parallel computations, with the camera ultimately directly outputting the classification results. This process fully exploits the nonlinear characteristics of the electrical-to-optical conversion process at the input layer. Due to the low complexity of the optical system, the offline simulation training highly aligns with the experimental inference results, as shown in Figure 2.

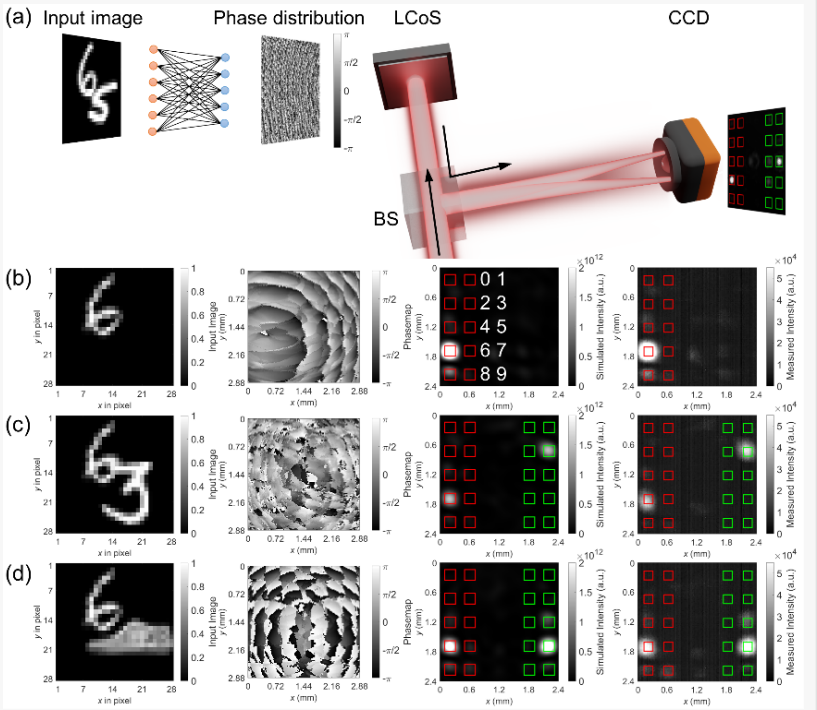


Figure 2. (a) Schematic diagram of the dual-task HNN architecture. (b-d) For the recognition results of a single handwritten digit, two handwritten digits, and one handwritten digit alongside a fashion item, the experimental and simulation results show hi

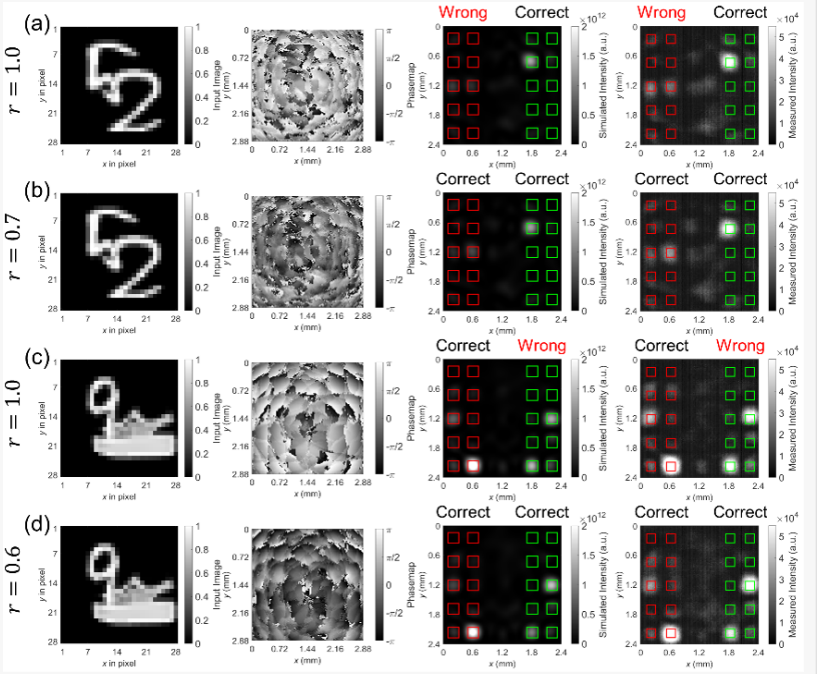


Figure 3. The multi-task learning performance can be improved by optimizing the task correlation factor during the training process.

Different from the conventional multi-task DONNs that rely on multi-dimensional physical quantity multiplexing or mechanical reconfiguration, the research team, inspired by the cross-stitch multi-task network architecture, proposed a phase-multiplexing

holographic scheme, and a corresponding joint training algorithm. By introducing a task correlation factor during the error backpropagation process, the crosstalk between multiple tasks is effectively reduced, and multi-task learning performance is improved. When two related tasks (such as dual-digit recognition) are trained together, the recognition accuracy of the multi-task network even exceeds that of a single-task network. For different types of tasks, such as handwritten digit and fashion item recognition, optimizing the task correlation factor can also effectively suppress task interference, as shown in Figure 3. Furthermore, the research team demonstrated the scalability of this method, achieving synchronous recognition of four tasks while maintaining a classification accuracy of approximately 90%.

Keywords: photonic neural network, pattern classification, optical wireless communications, intelligent beam steering, optical holography

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The Optoelectronic Devices Research Department of the State Key Laboratory of Optical Communication Technologies and Networks under CICT is dedicated to the basic and applied research in computational optics and holography, computing-oriented advanced optoelectronic devices, and intelligent optical wireless communications. The group has published multiple high-impact papers and received support from various national, provincial, ministerial, and corporate innovation projects, providing foundational support for the development of next-generation intelligent beam control and optoelectronic AI information processing technologies.

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