Deep Learning-Based Photonic Crystal Biosensor Automatic Design Framework for Cancer Detection

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Abstract

This research proposes an efficient and automated design method of integrated photonic devices, where conventional manual or parameter sweep optimization is time-consuming and highly dependent on expert vision. Although machine learning has recently been applied to photonic crystal (PhC) device modeling, most prior works have been limited to forward prediction of optical behavior and have not provided a practical inverse design strategy for generating new high-performance structures. To overcome these limitations, we propose a data-driven inverse design approach for developing a photonic crystal biosensor for cancer detection. A parallel simulation-based sampling method is employed using RSoft Photonics to construct a representative and accurate training dataset, significantly reducing computational cost compared to traditional parameter sweep techniques. A deep neural network is then trained to learn both the forward relationship between geometric parameters and optical response, as well as an inverse model capable of generating new sensor designs. Furthermore, an interval-based sampling strategy is used to explore the learned design space and adjust performance trade-offs according to user-defined criteria. Simulation results indicate that the proposed framework can automatically produce photonic crystal sensor designs with improved performance compared to previously reported structures, based on a multi-parameter merit score evaluation. These findings demonstrate that integrating parallel simulation-driven data generation with deep neural inverse modeling provides an effective and scalable route for automated photonic device design.