Machine Learning prediction of the superconducting pairing potential for disordered s-wave superconductors

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Machine Learning (ML), particularly neural networks and deep learning architectures, has emerged as a transformative force across multiple scientific domains, revolutionizing data-driven research and computational methodologies. From its inception, ML has evolved into a powerful analytical tool capable of processing high-dimensional datasets, extracting hidden correlations, and predicting complex physical phenomena with remarkable accuracy. These capabilities have significantly accelerated scientific discovery, enabling researchers to tackle problems that were previously computationally intractable.

In condensed matter physics, ML has opened new avenues for understanding strongly correlated systems, quantum materials, and emergent phenomena. A particularly compelling application lies in the study of superconductors, where inhomogeneities and disorder play a crucial role in determining electronic properties. Traditional approaches, such as solving the Bogoliubov-de Gennes (BdG) equations, provide a framework for analyzing inhomogeneous superconductors but often require substantial computational resources, especially when dealing with large systems.

In our work, we developed a machine learning algorithm designed to predict the spatial distribution of the pairing potential in a superconductor based on a given disorder profile. This approach uses the ability of neural networks to learn mappings between disorder configurations and the corresponding superconducting order parameter, bypassing the need for iterative numerical solutions of the BdG equations in many cases.