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Density-Distilled Neural Network Potentials for Capturing Charge Redistribution in Amino Acid–Ligand Interactions

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Electron density is a central physical quantity in density functional theory (DFT). Nevertheless, recently developed E(3)-equivariant neural network potentials (NNPs) with message passing architectures for biomolecular simulations do not internally represent or reason in terms of electron density when predicting DFT total energies. To accurately capture electronic interaction energies that arise from density and charge redistribution during molecular interactions, we propose a density-distillation framework in which a teacher network trained on DFT electron densities guides a student NNP to extract latent density features. Neural networks are trained on DFT electron densities computed from structures in the SPICE dataset for amino acid–ligand complexes. In this work, we discuss the predicted densities and the corresponding latent density features learned by the model and compare interaction energies of amino acid–ligand pairs to a baseline NNP.