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Sample-Efficient Active Learning Strategies for Deep Learning in Scientific Computing

We consider active learning strategies for recovering an unknown object from training data using a given model class. In the active learning scenario, one has the flexibility to choose where to sample the ground truth (or oracle) so as to enhance the generalization performance of the learning algorithm. We introduce a unified framework for this problem that allows for objects in Hilbert spaces, general types of (random) linear measurements as training data and general types of nonlinear model classes. We establish learning guarantees for this framework which provide explicit relations between the amount of training data and properties of the model class to ensure near-best generalization bounds. We demonstrate the efficacy of our framework for gradient-augmented learning with polynomials, Magnetic Resonance Imaging (MRI) using generative models, adaptive sampling for solving PDEs using Physics-Informed Neural Networks (PINNs), and operator learning for uncertainty quantification.