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Walk-on-Interfaces: A Monte Carlo Estimator for Elliptic Interface Problem

Elliptic interface problems arise in many areas of science and engineering, modeling heterogeneous materials whose physical properties change abruptly across internal boundaries. Computing solutions to these problems efficiently and accurately remains challenging, especially in domains with multiple irregular interfaces. In this poster, we present Walk-on-Interfaces (WoI), a grid-free Monte Carlo estimator for Neumann elliptic interface problems with general flux jump conditions. Unlike many numerical schemes, WoI maintains uniform accuracy throughout the domain and avoids near-interface singularities. Moreover, gradients of the solution can be estimated at almost no additional cost by differentiating the Green's function within WoI. Taking a scientific machine learning approach, we train a deep neural network to filter out high-frequency sampling noise, yielding a smooth and continuous representation of the solution. The resulting method is highly parallelizable, scales naturally to high dimensions, and can solve problems that are intractable for traditional numerical solvers. Numerical experiments demonstrate the effectiveness of the approach and highlight its potential for real-world applications.