Uncertainty Quantification

Karlsruhe Institute of Technology

Master Thesis:

Multilevel Regression for Optimal Experimental Design

Course of Study: Mathematics, Computer Science, Computational Engineering

Topic

Bayesian Optimal Experimental Design (BOED) is founded on the principles of Bayesian inference, focusing on designing experiments that maximize information gain regarding parameters of interest. This method represents a significant advancement in experimental methodologies, allowing researchers to tailor their designs based on prior knowledge and the outcomes of experiments, thus enhancing the efficiency and efficacy of data collection processes. However, BOED can become computationally prohibitive when expensive numerical simulations are involved, as traditional methods typically require a large number of high-fidelity model evaluations to accurately estimate the expected information gain.

This project aims to develop efficient multilevel regression techniques that combine the computational savings of multilevel Monte Carlo methods with the statistical rigor of Bayesian experimental design. The key idea is to leverage model evaluations at various levels of fidelity — ranging from coarse, low-cost approximations to fine, high-fidelity simulations — to construct surrogate models that can efficiently predict the expected utility of candidate experiments.

Tasks

- Conduct a literature review on BOED and multilevel Monte Carlo methods
- Extend state-of-the-art projection-based BOED approaches by incorporating multilevel Monte Carlo strategies
- Implement a regression-based multilevel BOED method
- Perform numerical experiments on benchmark problems
- Evaluate and compare performance with existing BOED strategies

Requirements

- Background in numerical methods, probability, and statistics
- Programming experience in Python
- Interest in Bayesian inference and uncertainty quantification

What we offer

We offer a cutting-edge research project at the intersection of uncertainty quantification and optimal experimental design. You will work on current and relevant research topics, with direct applications to engineering and scientific computing, and have the opportunity to collaborate closely with experienced researchers. This project also offers the chance to contribute to open-source scientific software and to work toward publication in high-impact scientific journals.

Contact: Sebastian Krumscheid, Stjepan Salatovic
E-mail: sebastian.krumscheid@kit.edu, stjepan.salatovic@kit.edu