Engineering and Physical Sciences Research Council Doctoral Landscape Award

PROJECT TITLE: Fast and Faithful: Multi-Fidelity Gaussian Process Emulation for Real-Time Prediction

Lead Supervisor: Dr Hossein Mohammadi

Co-Supervisors: Dr Tinkle Chugh, T.Chugh@exeter.ac.uk

Webpage: https://experts.exeter.ac.uk/26186-hossein-mohammadi

Project details: Real-time prediction is vital in applications such as climate science, where timely, informed decisions can save lives and protect critical infrastructure. Accurate forecasts of extreme weather events, flooding, or wildfire spread can give governments and emergency services the crucial lead time needed to respond effectively. Similar demands arise in engineering and aerospace, where rapid and trustworthy simulations are essential for ensuring safety and optimising performance. These examples highlight the urgent need for methodologies that can deliver both accuracy and computational efficiency. High-fidelity computational tools, such as finite element analysis are indispensable across domains ranging from aerospace engineering to climate change. These simulators provide detailed representations of physical systems, enabling decision-makers to test scenarios in a controlled, risk-free environment. They are particularly valuable in applications where physical experimentation is prohibitively costly or infeasible.

While high-fidelity models provide accurate representations of complex systems, they require considerable computational resources in terms of development time, computational cost, and energy consumption. For example, running a simulation of tree growth using the Joint UK Land Environment Simulator (JULES) can take several days to complete. Such computational demands severely limit the practicality of these models, especially in applications that require large numbers of simulations, such as optimisation or uncertainty quantification. A common strategy that mitigates this challenge is to employ hierarchies of high-fidelity and low-fidelity models that represent the same physical system at different levels of cost and accuracy. Lower-fidelity models are faster but less accurate, whereas high-fidelity models provide greater accuracy at a higher computational cost. Within such hierarchies, most simulation runs are performed using low-fidelity models to save resources, while high-fidelity simulations are reserved for a limited number of critical evaluations.

The objective is to develop novel approaches that can effectively combine and exploit information from lower-fidelity models to emulate high-fidelity simulators. This approach, known as multi-fidelity emulation, has gained considerable attention in recent years. However, despite this growing interest, relatively little research has been conducted in the area, and most existing methods lack robustness and scalability.

This PhD project proposal focuses on developing rigorous data-driven methods for real-time prediction of high-fidelity simulators in multi-fidelity settings. Specifically, the project aims to address common challenges that currently limit the applicability of existing methods to real-world problems, such as high dimensionality and the rigorous quantification of predictive uncertainty. The project will involve constructing advanced statistical emulators (or surrogates) based on Bayesian machine learning models such as Gaussian processes, which have become the gold-standard tool for emulating complex computer experiments, especially because of their ability in providing uncertainty information.

The methods developed in this project will benefit a wide range of scientific and engineering fields by enabling real-time predictions and supporting critical decisions in time-sensitive scenarios. The project will involve a real-world engineering and climate application that will be used to validate the proposed approach.

Project specific entry requirements: Applicants should hold (or be expected to achieve) a first-class or upper second-class degree (or equivalent) in statistics, mathematics, computer science, engineering, or a related quantitative discipline.

Essential skills include:

- Strong mathematical and statistical background.
- Proficiency in programming (R or Python).
- Interest in computational modelling, machine learning, and data-driven methods.

Desirable attributes:

- Experience with Gaussian processes, Bayesian modelling, or surrogate modelling.
- Familiarity with scientific computing and simulation models (e.g. engineering or climate applications).

Potential PhD programme of study: PhD in Mathematics

Department: Mathematics and Statistics

Location: Laver Building, Streatham Campus, University of Exeter

Please direct project specific enquiries to:

Please ensure you read the entry requirements for the potential programme you are applying for.

To Apply for this project please click on the following link - **APPLY HERE**