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Project title:

Coupling physics-informed machine-learning and human intuition for accelerated optimization

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Project Description:

Many engineering and scientific systems require the optimisation of expensive black-box functions where existing data is sparse or non-existent and generating new data via experiment or simulation is either very costly, time-consuming, or difficult. In such applications optimization techniques such as design of experiment, genetic algorithms, etc., are infeasible as they require too many evaluations of the expensive objective. Bayesian optimization (BO) is a proven technique often used in this application, being designed to reach an optimum in the least number of evaluations.

Key Challenges and Approaches:

To further accelerate BO, we can introduce additional knowledge of the system to restrict the solution space and guide the optimizer towards a more rapid convergence. Additional knowledge may be in the form of human intuition or physical laws or, considered here – a combination of the two. While progress has been made incorporating hard physical laws into these models, in non-trivial applications the interplay between the physics and the objective is often indirect. The inclusion of human intuition through ad-hoc methods goes some way toward bridging the gap, but this fails to leverage the fact that such intuitions are informed by hard physical laws.

This project aims to help bridge the gap between "hard", physics-informed BO, and "soft", human-intuition guided BO, building toward a hybrid approach better suited to optimizing physics-based systems guided by expert humans. Potential research directions include, but are not limited to:

- ✓ The use of alternative model surrogates such as physics informed neural networks (PINNs) in Bayesian Optimisation to capture the influence of both physical laws and human input.
- ✓ Exploring how to best capture human feedback - rank-based feedback, intuitions, partially guided search etc.
- ✓ Considering how to best bridge the gap between "hard" physics - the laws known to underlying a physical process - and "soft" utility measures that are indirectly determined by the hard physics in an indirect manner.