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Unlocking High-Dimensional Parameter Spaces: Bayesian Optimization in Beam-Driven Plasma Accelerators

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Artificial intelligence (AI) has become a cornerstone in addressing complex optimization challenges across scientific domains. Among AI techniques, Bayesian optimization (BO) has proven particularly effective for navigating high-dimensional and computationally expensive parameter spaces.
Recent studies have demonstrated BO's ability to optimize electron beam properties to achieve small energy spreads, improve stability across experimental runs, and reduce computational costs through multi-fidelity approaches. Multi-objective BO further expands its capabilities by simultaneously optimizing competing objectives while dynamically adjusting simulation fidelity.
Bayesian optimization (BO) offers a powerful probabilistic framework for optimizing plasma wakefield acceleration systems while simultaneously uncovering underlying physics. By constructing surrogate models that capture parameter uncertainties, BO enables efficient exploration of complex, high-dimensional spaces. This approach facilitates data-driven discovery and validation of scaling laws governing beam energy and accelerator performance.
Notably, EuPRAXIA project can benefit of Bayesian Optimization techniques for beam-driven plasma acceleration schemes. This contribution highlights the transformative role of BO in plasma accelerator research and its potential to advance cutting-edge technologies and applications in EuPRAXIA.

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