Multi-objective and multi-fidelity Bayesian optimization of laser-plasma acceleration

Faran Irshad[1], Stefan Karsch[1,2], Andreas Döpp[1,2]
[1] *Ludwig-Maximilian-Universität München, Garching, Germany,*
[2] *Max Planck Institut für Quantenoptik, Garching, Germany*
Faran.Irshad@physik.uni-muenchen.de

Beam parameter optimization in accelerators involves multiple, sometimes competing objectives. Condensing these individual objectives into a single figure of merit unavoidably results in a bias towards particular outcomes, in absence of prior knowledge often in a non-desired way. Finding an optimal objective definition then requires operators to iterate over many possible objective weights and definitions, a process that can take many times longer than the optimization itself. A more versatile approach is multi-objective optimization, which establishes the trade-off curve or Pareto front between objectives. Here we present the first results on multi-objective Bayesian optimization of a simulated laser-plasma accelerator [1, 2]. In Fig. 1, the 3D Pareto surface generated by a multi-objective optimization of distance to a target energy, standard deviation and total beam charge is presented. We find that multi-objective optimization reaches comparable performance to its single-objective counterparts while allowing for instant evaluation of entirely new objectives. This dramatically reduces the time required to find appropriate objective definitions for new problems. Additionally, our multi-objective, multi-fidelity method reduces the time required for an optimization run by an order of magnitude. It does so by dynamically choosing simulation resolution and box size, requiring fewer slow and expensive simulations as it learns about the Pareto-optimal solutions from fast low-resolution runs. The techniques demonstrated here can easily be translated into many different computational and experimental use cases beyond accelerator optimization.

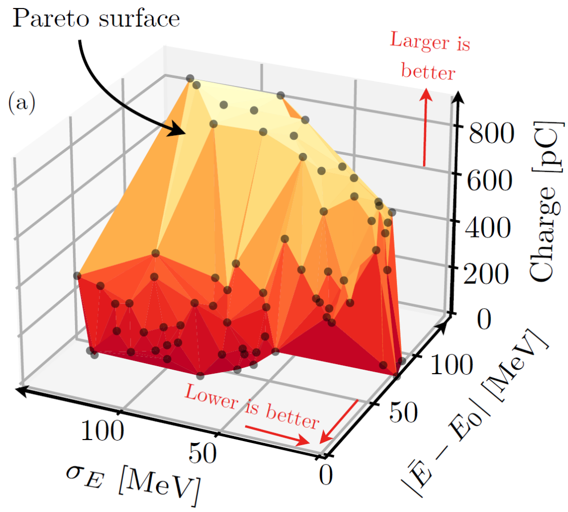

Figure 1: Visualization of the Pareto surface in the 3D output objective space where total charge, distance of mean energy to 300 MeV and standard deviation was optimized.

References

[1] F. Irshad, S. Karsch, and A. Döpp, Multi-objective and multi-fidelity Bayesian optimization of laser-plasma acceleration, arxiv:2210.03484

[2] F. Irshad, S. Karsch, and A. Döpp, Expected hypervolume improvement for simultaneous multi-objective and multi-fidelity optimization, arXiv:2112.13901