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Inference and use of uncertainty-aware Bayesian models

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Use of uncertainties is key to improving the efficiency and interpretability of ML algorithms. One interesting uncertainty-aware technique is Bayesian parameter inference, whereby posterior distributions are determined from experimental data though gradient-enabled methods like Hamiltonian Monte Carlo. Key to this idea is implementation of standard linear optics and tracking in a differentiable framework like Jax, which we previously demonstrated. In this paper we explore the usefulness of Bayesian inference methods by estimating Twiss parameters, magnet strengths, and response matrices of APS beamlines. Results show accuracy comparable to standard tools like LOCO but using fewer measurements. Moreover, this analysis does not require specific corrector patterns and can run non-destructively alongside orbit and trajectory feedback. The inferred parameter posteriors can be used to create uncertainty-aware surrogate models using Gaussian processes or neural networks, to be used as priors for Bayesian optimization (presented in our other papers). Overall, this work demonstrates a complete uncertainty-aware pipeline usable in any scenario where differentiable models are available.

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