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Machine learning for online optimization and characterization of X-ray FELs: developments and operational experience

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Scientific users of X-ray FELs require a wide range of custom photon beam parameters to be delivered within a limited window of time and maintained for the duration of the experiment. In addition, an increasing array of experiments require dynamic control over multiple aspects of the beam during the experiment. This requires precise adjustment of numerous coupled parameters in the accelerator, which is complicated by nonlinear, time-varying behavior and the large number of variables. Machine learning based approaches, such as Bayesian optimization and improvements to it, have enabled highly-efficient online optimization and characterization of particle accelerators and X-ray FELs. Improvements include, for example, addressing common issues such as magnetic hysteresis, accounting for physics-informed coupling between variables, tuning of multiple outputs simultaneously, handling learned output constraints (e.g. keeping a beam on a screen while optimizing), and dealing with nested optimization/measurement tasks. Simultaneously, a key component in bringing these algorithms into regular operation at X-ray FEL facilities is the availability of easy-to-use software that is readily transferable between facilities and tasks. We discuss an overview of these developments and experience at SLAC and collaborating facilities bringing these tools into operation, alongside the impact on operation. We also highlight community software tools that are under development and have been used at multiple light source facilities around the world, including LCLS/LCLS-II, NSLS-II, ESRF, and the European XFEL.

I plan to submit also conference proceedings

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