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Advancements in backwards differentiable beam dynamics simulations for accelerator design, model calibration, and machine learning

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Many accelerator physics problems such as beamline design, beam dynamics model calibration or interpreting experimental measurements rely on solving an optimization problem that use a simulation of beam dynamics. However, it is difficult to solve high dimensional optimization problems using current beam dynamics simulations because calculating gradients of simulated objectives with respect to input parameters is computationally expensive in high dimensions. To address this problem, backwards differentiable beam dynamics simulations have been developed that enable computationally inexpensive calculations of objective gradients that are independent of the number of input parameters. In this work, we highlight current and future applications of differentiable beam dynamics simulations in accelerator physics, such as improving accelerator design, model calibration, and machine learning. We also describe current collaborative efforts between SLAC, DESY, KIT, and LBNL to implement fast, backwards differentiable beam dynamics simulations in Python. These tools will enable unprecedented improvements in optimization efficiency and speed when using beam dynamics simulations, leading to enhanced control and detailed understanding of physical accelerator systems.

Footnotes

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