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Machine Learning-Based Reduced-Order Encoding of 6D Particle Phase Space for Accelerators

Monday 11 August 2025 16:00 (2 hours)

State-of-the-art simulation of accelerator facilities such as Linac Coherent Light Source (LCLS) involves modeling charged particle dynamics in six-dimensional (6D) phase space under the influence of nonlinear collective effects, including space charge and coherent synchrotron radiation (CSR). Accurately capturing these effects typically requires simulating hundreds of thousands of macroparticles, resulting in significant computational cost in both time and memory. This becomes a bottleneck for downstream tasks such as uncertainty quantification (UQ), model calibration, optimization, and control, which require multiple simulations. These challenges motivate the development of low-dimensional, lightweight surrogate models for accelerators, capable of enabling rapid predictions. However, the high dimensionality of the 6D phase space poses a major obstacle. In this work, we present a machine-learning-based approach for reduced-order encoding of high-dimensional particle phase-space data using autoencoders. In our approach, we learn low-dimensional latent representations that preserve the geometric and physical structure of the original beam distribution, enabling effective compression while retaining essential features. We evaluate this approach on datasets generated using the Bmad particle tracking library, demonstrating its potential as a foundation for fast surrogate modeling, differentiable simulations, and accelerator optimization workflows.

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Yes

Would you like to submit this poster in student poster session on Sunday (August 10th)

No

Footnotes

Funding Agency

I have read and accept the Privacy Policy Statement

Yes

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