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Symplectic surrogate models for beam dynamics in conventional and advanced accelerators

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Large scale particle accelerator facilities play essential roles in advancing the frontier of particle & nuclear physics, photon science and material research. The existing software for modeling the dynamics of these particle beam that can achieve fast turn-around time is either limited to linear analysis or only provides the preliminary lattice design evaluation, while first-principle codes (e.g., for coherent synchrotron radiation [1]) for detail study or spot-checking are too expensive for tackling inverse problems, parameter optimization and data-intensive applications. On the other hand, advanced accelerator concepts typically employ highly nonlinear interaction, often from high intensity lasers, to accelerate or control beams with high current density or brightness. The successful deployment of surrogate models for such beam dynamics can significantly help the design and optimization of both types of accelerators. We pursue design and development of novel structure-preserving neural networks [2] for practical accelerator applications. The robustness of the machine-learning surrogate model will be ensured by embedding fundamental symplectic constraints to the interaction and evolution of the beam. We demonstrate the advantage of these symplectic surrogate models [3] and discuss promising applications for realistic accelerator problems.

[1] C.-K. Huang et al., Nucl. Instruments Methods Phys. Res. Sect. A, vol. 1034, p. 166808, Jul. 2022.
[2] J. W. Burby, Q. Tang, and R. Maulik, Plasma Phys. Control. Fusion, vol. 63, no. 2, p. 024001, Feb. 2021.
[3] C.-K. Huang et al., Proceedings of North America Particle Accelerator Conference 2022, paper TUPA53, Albuquerque, NM.

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