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Advancing Accelerator Design and Control with Machine Learning: Case Studies from RAON LEBT Orbit Correction and Electron Linac Optimization

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Machine learning (ML) is emerging as a transformative tool in accelerator science, complementing physics-based approaches for design, optimization, and control. Modern accelerators—including heavy-ion drivers, electron linacs, and next-generation light sources—face challenges from high-dimensional parameter spaces, nonlinear beam dynamics, and limited diagnostic access. This presentation surveys the expanding role of ML in accelerator research, with emphasis on recent global progress and developments within the Korean accelerator community. Two case studies illustrate our contributions: (i) RAON's Low Energy Beam Transport (LEBT), where we developed synapticTrack, a Python-based framework for ML-driven orbit correction; and (ii) electron linac injector optimization, where Bayesian optimization techniques are employed for multi-objective tuning of emittance and energy spread. Beyond these case studies, we highlight broader ML applications across accelerator facilities worldwide, including online optimization at light sources, surrogate modeling of high-fidelity simulations, beam diagnostics reconstruction, and anomaly detection in high-power machines. We conclude with a discussion of future directions, emphasizing physics-informed ML, integration into accelerator control systems, and the path toward autonomous accelerator operation.

Paper submission Plan

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