Surrogate Models for Beam Transport and Particle Tracking*

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Abstract

Physics simulations of particle accelerators are essential tools for predicting optimal settings for different configurations. These simulations can also be computationally expensive, which can be prohibitive during the design stage as well as for online use in accelerator operations. Machine learning (ML) models of accelerator systems, which are called surrogate models, are a viable solution for many challenges faced while designing and operating particle accelerators. Although, data generation and model training might require significant computational resources, once trained, ML models offer orders of magnitude faster execution speed over classical simulation methods. Thus, they can be used for virtual diagnostics, offline experiment planning, design of new setups, control and tuning.

The development of surrogate models will be particularly useful for the Argonne Tandem Linear Accelerator System (ATLAS) which is a DOE/NP User Facility for the study of low energy nuclear physics with heavy ions. ATLAS reconfigures once or twice per week over 40 weeks of operation per year. The use of machine learning and artificial intelligence has the potential of significantly reducing the time needed to tune the accelerator and improve beam quality. Preliminary artificial intelligence modeling was performed where surrogate models were developed for the radio-frequency quadrupole (RFQ). The RFQ is the first accelerating section of the ATLAS linac and often the most time consuming when simulated with 3D fields and particle tracking using the beam dynamics code TRACK. The goal is to be able to reliably reproduce the physics model results in the shortest possible time to be able to use them online or accelerate the design optimization of future accelerators.

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