Contribution ID: **47** Type: **Oral (16mins + 4 mins)**

Leveraging Differential Algebraic Methods for Enhanced Beam Dynamics Simulation with Machine Learning

Friday, March 8, 2024 9:40 AM (20 minutes)

This study introduces an innovative approach that harnesses machine learning in conjunction with Differential Algebraic (DA) techniques to simulate beam dynamics in particle accelerators. Beam dynamics simulations are complex, involving high-dimensional phase spaces and intricate equations of motion. By integrating the DA method, which deals with function derivatives, with machine learning, we develop a novel framework that can efficiently model and predict beam behavior.

Our approach combines deep neural networks with DA to create a machine learning model capable of learning the underlying physics and dynamics of the accelerator system, including space charge and non-linear effects. The resulting model offers accelerated simulations and enables real-time optimization of accelerator parameters.

Several case studies showcase the effectiveness of this approach, revealing improved insight into system behavior. By bridging traditional symbolic methods with machine learning, this research propels accelerator physics into a new era. This synergy between DA and machine learning promises more accurate and efficient simulations, enhancing accelerator design, optimization, and real-time control for a wide range of scientific and industrial applications.

Primary Keyword

differentiable models

Secondary Keyword

Tertiary Keyword

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Session Classification: Methods

Track Classification: Methods