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From Simulation to Reality: Real-Time Control of Superconducting Linear Particle Accelerator using a Trend-Based Soft Actor-Critic Algorithm

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Superconducting linear accelerators play a vital role in advancing scientific discoveries by requiring frequent reconfiguration and tuning. Minimizing setup time is crucial to maximize experimental time. Recently, reinforcement learning (RL) algorithms have emerged as effective tools for solving complex control tasks across various domains. Nonetheless, deploying RL agents trained in simulated environments to real-world scenarios remains a challenge. To address this, we propose a novel paradigm for transferring RL agents from simulation to real accelerators. In this study, we introduce the trend-based soft actor-critic (TBSAC) method and showcase its effectiveness through two successful applications in real-world linear particle accelerators. TBSAC demonstrates strong robustness, allowing agents trained in simulated environments to be applied to real-world accelerators. We validated our method by performing a typical beam control tasks at the China Accelerator Facility for Superheavy Elements (CAFe II). In the orbit correction tasks at CAFe II, our approach reduces the tuning time conducted by human experts by tenfold, achieving a corrected orbit with RMS values of less than 1mm. These experiments clearly demonstrate the efficiency and effectiveness of our proposed approach while maintaining expert standards. Our method holds significant potential for future applications in accelerator commissioning fields.

Primary Keyword

AI-based controls

Secondary Keyword

reinforcement learning

Tertiary Keyword

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Primary author: CHEN, Xiaolong (Institute of modern physics)

Co-author: SU, Chunguang (Institute of modern physics, Chinese Academy of Sciences)

Presenter: SU, Chunguang (Institute of modern physics, Chinese Academy of Sciences)

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