Automatization of the Multi-Turn Injection into the SIS18 Synchrotron with Reinforcement Learning

TECHNISCHE UNIVERSITÄT DARMSTADT

Topic

Multi-Turn Injection (MTI) denotes the transition of a particle beam from a linear accelerator into a synchrotron. Until now, these key interfaces require cumbersome manual setup and control by humans. MTI in future accelerator projects like FAIR, currently under construction in Darmstadt, and upgrades to CERN facilities will become more challenging in operation and require automatization.

Reinforcement Learning (RL) is an active research topic from the field of artificial intelligence. In contrast to supverised / unsupervised learning, an RL agent learns to improve itself by interacting with its environment. Recently, RL learned to play ATARI computer games [1] and beat the world champion in the game of GO [2]. This thesis project shall employ RL to control MTI and particle accelerators.

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Work Plan

- implement minimalistic simulation of MTI
- optimize MTI with Reinforcement Learning
- submission in English or German

The topic can be extended in several directions based on your interests

- simulate advanced beam dynamics like space charge
- compare underlying Artificial Neural Networks to Quantum-Boltzmann machines
- test trained RL agent at real synchrotron SIS18 at GSI

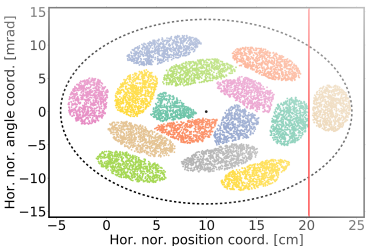

Figure 1: Phase-space diagram of beam after injection into synchrotron[1].

Prerequisites

- interest in Artificial Intelligence and its applications
- solid knowledge in programming, ideally experience with Python
- knowledge in accelerator physics or beam dynamics useful but not required

[1] Appel, S., Groening, L., El Hayek, Y., Maier, M. & Xiao, C. Injection optimization through generation of flat ion beams. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 866, 36–39 (2017).
[1] Mnih, V. et al. Playing atari with deep reinforcement learning. arXiv preprint arXiv:1312.5602 (2013).
[2] Holcomb, S. D., Porter, W. K., Ault, S. V., Mao, G. & Wang, J. Overview on deepmind and its alphago zero ai. in Proceedings of the 2018 international conference on big data and education 67–71 (2018).