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# Data-driven model predictive control for automated optimization of injection into the SIS18 synchrotron

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In this study, we introduce a novel application of data-driven Model Predictive Control (MPC) to enhance the multi-turn injection (MTI) process within the SIS18 synchrotron, diverging from traditional numerical optimization techniques our approach epitomizes a sample-efficient strategy that resides at the confluence of model-based reinforcement learning and advanced control theory. This synergy facilitates a reduction in optimization iterations while significantly improving the adherence to control performance criteria, crucially addressing delays and safety concerns such as septum protection.

Our methodology offers a unified framework that harnesses the predictive prowess of Gaussian processes within the MPC paradigm, achieving a state-based optimization process that transcends the capabilities of conventional reinforcement learning and Bayesian optimization. The proposed MPC framework not only ensures rapid convergence but also guarantees safety, paving the way for secure online training and real-time implementation in the SIS18 MTI scenario.

The findings demonstrate the efficacy of this data-driven MPC approach in optimizing complex non-linear control systems, setting a precedent for its application in similar high-stakes environments. This research thus establishes a foundational basis for the deployment of safe, efficient, and robust online control strategies in advanced accelerator physics control.

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