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ML Techniques in Spill Regulation for Mu2e

A third-integer resonant slow extraction system is being developed for the Fermilab's Delivery Ring to deliver protons to the Mu2e experiment. During a slow extraction process, the beam on target is liable to experience small intensity variations due to many factors. Owing to the experiment's strict requirements in the quality of the spill, a Spill Regulation System (SRS) is currently under design. The SRS primarily consists of three components - slow regulation, fast regulation, and harmonic content tracker. In this presentation, we shall present the investigations of using Machine Learning (ML) in the fast regulation system, including further optimizations of PID controller gains for the fast regulation, prospects of an ML agent completely replacing the PID controller using supervised learning schemes such as Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) ML models, the simulated impact and limitation of beam pipe's B-field screening bandwidth on both PID and ML regulation of the spill. We also present here nascent results of Reinforcement Learning efforts with and without neuralized PID, including continuous-action actor-critic methods and soft actor-critic methods, to regulate the spill rate.

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