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Development of adaptive feedback methods for the APS linac

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Maintaining beam transport efficiency in the APS linac requires several feedback mechanisms to control orbit, phase, and other parameters. Presently, we apply pre-computed matrices to sets of deviations from fixed setpoints, corresponding to proportional linear feedback. This approach works most of the time but is slow and can become unstable at low charge levels. We explore two alternative machine learning (ML) methods - adaptive Bayesian optimization (ABO, developed previously) and reinforcement learning (RL). To pre-train ML methods we use a differentiable linac simulation to generate a custom kernel and policy, respectively. All 3 methods are experimentally tested using a set of simulated disturbances, and performance in terms of charge stability and recovery speed analyzed. We find that both ABO and RL techniques are more flexible than standard feedback but behave quite differently if beam degradation is large. Overall, RL appears to be the more robust long-term method for rough correction, while ABO is best for fine tuning on recent history. Based on the above results we implemented a novel hybrid scheme that dynamically combines algorithm outputs using historical and expected performance. It also restricts parameter space to the most relevant region. Preliminary results show this to be both more stable and more accurate than the standard approach. We are now exploring strategies for dynamic retraining and other advanced capabilities.

Footnotes

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