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Experience with ML-driven applications at PETRA III

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We present experience with deploying several ML-based methods for control and optimization of the PETRA III storage ring.
First, we discuss the recent progress with the compensation of influence of insertion devices (IDs) on beam orbit using Deep Neural Networks. Different models were trained to predict the distortion in the closed orbit induced by movements of the IDs in the context of a feed-forward correction scheme. The networks accurately predict the transverse displacement of the beam along the ring for any given ID configuration allowing to compute the appropriate compensation.
In another activity, Bayesian Optimization routines implemented in the Badger/Xopt [1,2] optimization framework were used interfacing with the machine control system. Optimizations of lifetime, and injection efficiency were performed and compared with the results obtained with the current manual procedures during machine dedicated times.
Finally, the experience with the ACSS (Accelerator Control and Simulation Services) pipeline [3] is described together with application examples on PETRA III. The software framework provides an environment for scheduling and orchestrating of multiple intelligent agents, training and tuning of ML models, handling of data streams and for software testing and verification, addressing the need for significant reduction of the amount of human intervention in AI-based operation. The pipeline was successfully tested using the orbit correction service on the Petra III control network.

[1] Zhang, Z., et al., "Badger: The Missing Optimizer in ACR", IPAC'22
[2] Roussel, R., et al., "Xopt: A Simplified Framework for Optimization of Accelerator Problems Using Advanced Algorithms", IPAC'23
[3] Agapov, I., Böse, M., Malina, L., "A Pipeline for Orchestrating Machine Learning and Controls Applications", IPAC'22

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