Proxy Plasma State Reconstruction for a Reinforcement Learning Control System for Wendelstein 7-X


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Wendelstein 7-X (W7-X) aims to demonstrate the steady state capability of the optimized stellarator confinement concept. For this, real-time plasma control is required. One of the main tasks of a plasma control system is to prevent plasma facing component (PFC) overload due to the change of the PFC heat load pattern resulting from plasma evolution, combined with optimization of performance relevant parameters as e.g. plasma pressure. It was shown that PFCs can be overloaded for example by an establishing toroidal current in the first minutes of a discharge and that this specific scenario can be avoided by careful control of the island size by sweep coil actuation [Böckenhoff 2019]. A holistic control scheme can be implemented with the use of a reinforcement learning (RL) system. RL opens up the possibility to combine multiple control systems for specific targets and actuators into a global one and importantly allows for optimization by the definition of a global reward function. An especially interesting training scheme of RL is Automatic Domain Randomization (ADR) [OpenAi 2019] for a data-efficient application of simulation-trained networks to online real-world scenarios. Beyond application to W7-X this control scheme will also be of particular interest for ITER and tokamak research in general.

A first step towards employing ADR-RL is the reconstruction of a representation of the plasma state from heat load images. An additional benefit of intermediate state reconstruction is its potential to reveal relationships between physical parameters and optimization strategies found by the RL agent.

With this contribution, recent development regarding the reconstruction of proxies for plasma parameters (such as the rotational transform, radial axis shift and island size) from heat load images with Neural Networks [Böckenhoff 2018, Blatzheim 2019, Blatzheim 2019, Pisano 2019] are presented. We will also present plans for the further use of ADR-RL in control and optimization of stellarator experiments.