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Deep reinforcement learning for magnetic control on WEST

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Tokamaks require magnetic control across a wide range of plasma scenarios. The coupled behavior of plasma dynamics makes deep learning a suitable candidate for efficient control in order to fulfil these high-dimensional and non-linear situations. For example, on TCV, deep reinforcement learning has already been used for tracking of the plasma's magnetic equilibrium [1]. In this work, we apply such methods to the WEST tokamak, to address control of the plasma's shape, position, and current, in several relevant configurations.

To this end, we developed a distributed framework to train an actor-critic agent on a free boundary equilibrium code called NICE, written in C++. The first benefits from optimized deep learning libraries in Python, while the resistive diffusion mode of the second allows a more representative evolution of plasma current profile throughout the simulation. The interface between the two languages was done through UDS protocols for fast, asynchronous and reliable communication.

The implemented tool handles feedback control of plasma's shape, position, and current, with results showing flexibility of the method regarding the use of different training environments. It demonstrates the usefulness of reinforcement learning on WEST, without the need for extensive efforts during controller design to satisfy operational constraints. Moreover, by adding on reward constraints on the plasma profiles, it can address new problems like optimal fast landing control.

Further extensions will be discussed concerning the evolutions of the framework, particularly regarding the use of multi-fidelity learning and physics-informed neural networks. This could accelerate and stabilize the learning process, leading to the implementation of a routine within WEST operations.

[1] Degrave, J., Felici, F., Buchli, J. et al. Magnetic control of tokamak plasmas through deep reinforcement learning. Nature 602, 414–419 (2022)

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