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Multi-device dataset of infrared images for the control of thermal loads with machine learning

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Intelligent control of the thermal loads is required to guarantee the safety of fusion devices such as W7-X and ITER during quasi-steady-state operation with reactor-relevant performance. This feedback control system should implement preemptive strategies, enabling long-plasma operation by impeding thermal load escalation to dangerous levels and minimizing plasma terminations triggered by the interlock system.

Effective thermal load control demands in-depth knowledge about thermal events, including their nature, progression, and associated risks. The attainment of such understanding is possible through the application of machine learning techniques. These machine learning models are designed to promptly detect thermal events, track their evolution, and relay this information to the feedback control system, enabling the activation of suitable mitigation strategies within the required reaction time.

High-performing machines such as ITER or DEMO necessitate early thermal load protection, leaving scarce time for gathering sufficient data to train deep machine learning models. The answer to this lies in employing transfer learning, training models on data from current devices, and enabling zero or few-shot learning. Recent developments in artificial intelligence research demonstrate the feasibility of zero-shot learning in diverse domains, provided large-scale models and sufficient, diverse training data are employed. The construction of a substantial multi-device annotated dataset poses a challenge, particularly since manual annotation for video instance segmentation of thermal events is labor-intensive. Thus, we propose using semi-supervised learning techniques like active learning coupled with semi-automatic annotation tools to accelerate this process.

We introduce a multi-device dataset of infrared images, initially incorporating data from W7-X and WEST devices, with the plan to augment with additional devices' data. The intention is to integrate data from both tokamaks and stellarators, showcasing diverse types of first-wall materials, specifically, carbon and metallic walls. Ultimately, our objective is to train a large model on this dataset, capable of executing instance segmentation and classification of thermal events. By employing transfer learning with synthetic data, we aim to accomplish accurate zero-shot learning in new devices such as ITER, thereby paving the path toward the successful operation of future fusion power plants.

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