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AI/Machine Learning Enabled Advances with Real Time Control Validated on the DIII-D PCS

1. William Tang

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1. Heading

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##The US goal (March, 2022) to deliver a Fusion Pilot Plant [1] has underscored urgency for accelerating the fusion energy development timeline. This will rely heavily on validated scientific and engineering advances driven by HPC together with advanced statistical methods featuring artificial intelligence/deep learning/machine learning (AI/DL/ML) that must properly embrace verification, validation, and uncertainty quantification (VVUQ). Especially time-urgent is the need to predict and avoid large-scale “major disruptions”in tokamak systems. This presentation highlights the deployment of recurrent and convolutional neural networks in Princeton’s Deep Learning Code – “FRNN” –that enabled the first adaptable predictive DL model for carrying out efficient “transfer learning” while delivering validated predictions of disruptive events across prominent tokamak devices [2]. Moreover, the AI/DL capability can provide not only the “disruption score,” as an indicator of the probability of an imminent disruption but also a “sensitivity score”in real-time to indicate the underlying reasons for the predicted disruption [3]. A real-time prediction and control capability has recently been significantly advanced with a novel surrogate model/HPC simulator (”SGTC”) [4] – a first-principles-based prediction and control surrogate necessary for projections to future experimental devices (e.g., ITER, FPP’s) for which no “ground truth” observational data exist. Finally, an exciting and rapidly developing area that cross-cuts engineering design with advanced visualization capabilities involves AI-enabled advances in Digital Twins –with the FES domain providing stimulating exemplars. This has also witnessed prominent recent illustrations of the increasingly active collaborations between leading industries such as NVIDIA that enabled productive advances for tokamak digital twins with dynamic animations of the advanced AI-enabled surrogate model SGTC [4] and NVIDIA’s “Omniverse” visualization tool [5]. More generally, the scientific merits of Digital Twins are well analyzed in the recent US National Academies Report on “Foundational Research Gaps and Future Directions for Digital Twins”[6].

REFERENCES:
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[2] Julian Kates-Harbeck, Alexey Svyatkovskiy, and William Tang, “Predicting Disruptive Instabilities in Controlled Fusion Plasmas Through Deep Learning,” NATURE 568, 526 (2019)
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[4] Ge Dong, et al., 2021, Deep Learning-based Surrogate Model for First-principles Global Simulations of Fusion Plasmas, Nuclear Fusion 61 126061 (2021).
[5] William Tang, et al., 2023, AI-Machine Learning-Enabled Tokamak Digital Twin, Proceedings of 2023 IAEA FEC, London, UK (2023).
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Track Classification: Machine Learning