



Review of AI/ML for fusion systems

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Artificial intelligence (AI) and machine learning (ML) are rapidly developing to impact the global society in numerous ways, from personalized assistants to mastering board games. Given the dominant focus of machine learning research to areas such as language or computer vision, a natural question is: can AI/ML be useful in the sciences? This review talk will attempt to answer this question in the area of fusion energy systems, providing a primer on AI/ML for scientists, along with a wide review of the machine learning field relevant to science and engineering, and specifically fusion energy.

First, I will give a primer to introduce machine learning fundamentals, with a focus towards deep neural networks, as the most popular and (many times!) most performant machine learning model used today (other ML models and their usage will be discussed). This primer by nature of the talk can not be expansive but will give familiarity and intuition to understand literature related to machine learning.

Next, I will review many of the ML architectures in use today, and where they find the most utility. I will frame this conversation in the context of the fundamental ML concept of inductive bias, building structure into neural networks which can help them learn more quickly (or at all) a particular task. For example, the inductive bias of locality in convolutional neural networks (by

nature of the convolution operator) simplifies the task of recognizing objects in images.

Building on the concept of inductive bias, I will review how various ML models are being used in fusion energy research, focused mainly on magnetic fusion energy systems but also inertial confinement fusion and astrophysics. These applications range from utilizing digital twin models for control using reinforcement learning, to creating reliable ML surrogates of numerical simulations, to the intelligent combination of simulation and experimental data to aid researchers in verifying understanding.

Finally, I will discuss various future looking opportunities using AI/ML to enrich the research and capabilities of fusion scientists.