

The Potential of Physics-Informed Neural Networks to Analyse Tokamak Diagnostic Measurements

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Extracting net energy from fusion reactors will require a profound understanding of the underlying physics and the development of efficient control strategies. Plasma diagnostics are essential to these efforts, but obtaining accurate information from their measurements often involves solving quite delicate data analysis problems. Regrettably, many of the current approaches rely on simplifying assumptions, sometimes inaccurate or not completely verified, with consequent suboptimal outcomes. In order to overcome these challenges, the present study explores the potential of Physics-Informed Neural Networks (PINNs) to tackle various issues posed by the interpretation of diagnostic measurements in tokamaks. PINNs are a new branch of artificial intelligence that allows integrating data-driven methodology and physics equations in a very efficient way. The physics equations can be incomplete, leaving to the experimental data the task of providing the missing information. Moreover, they do not need a mesh and, with the approach of domain decomposition, can be easily applied to complex tasks. All these features have motivated the use of PINNs to address many challenging problems in various fields, ranging from fluid dynamics and physics to engineering and medicine. The present contribution describes the first attempts of developing PINNs to perform data analysis tasks in tokamaks. Various examples are provided ranging from equilibrium reconstruction to profile identification and tomography. The potential of the technology to perform integrated data analysis will also be briefly discussed. Overall, the undertaken study confirms the great potential of PINNs for data analysis in magnetic confinement thermonuclear fusion and highlights the benefits of using advanced machine learning techniques for the interpretation of several plasma diagnostic measurements.

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