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FusionMAE: large-scale pretrained model to optimize and simplify diagnostic and control of fusion plasma

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The complex multiscale nonlinear dynamics of magnetically confined plasmas necessitate integrating massive diagnostic systems with control actuators in tokamak reactors. The complexity brought by such massive systems and their tangled interrelations has been a main obstacle in the way of fusion power plant. In this work, a large-scale model, fusion masked auto-encoder (FusionMAE) is pretrained to compresses information from 88 diagnostic signals into a concrete embedding, trying to provide a unified interface between diagnostic systems and control actuators. Two mechanisms are introduced to ensure a meaningful embedding. Firstly, the dimensionality of input array must be reduced to generate a smaller vector, while still allowing a decoder to restore all the raw data with minimal loss. Therefore, FusionMAE must capture the intrinsic low-dimensional manifold of plasma dynamics. Secondly, FusionMAE is trained reconstruct randomly masked input signals based on the intercorrelation across different channels. Surprisingly, FusionMAE accomplished these pretraining tasks and emerge additional intelligent functionalities. It emulates conventional data analysis pipelines, generates an all-purpose vector that enhance downstream control/simulation tasks, and enables diagnostic channel reduction while improving operational performance. This work pioneers large-scale AI model integration in fusion energy, demonstrating how pre-trained embeddings can simplify the system interface, reducing necessary diagnostic systems and optimize operation performance for future fusion reactors.

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