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Cognitive Simulation Models for Inertial Confinement Fusion: Combining Simulation and Experimental Data

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The design space for inertial confinement fusion (ICF) experiments is incredibly broad. Researchers rely heavily on computer simulations to traverse this enormous parameter space in search of high-performing designs. However, complex ICF multiphysics codes must still make simplifying assumptions. While highly predictive for many classes of experiment, simulations deviate from precision measurements for the most challenging implosions. For more effective design and investigation, simulations require input from past experimental data to better predict future performance. In this talk, we describe a cognitive simulation method for improving numerical models using existing empirical data. It uses deep neural network models to calibrate ICF simulation results through a process called transfer learning. The technique was originally developed for pure machine learning tasks, like image recognition, to cope with limited data. As we apply it here, it serves as a powerful, nonlinear method for calibrating ICF simulations against a wide range of experimental observables. To build our improved model, we train advanced neural networks on thousands of computer simulations before partially retraining them on sparse sets of experimental data. We use our transfer learning methods to produce elevated models that are far more accurate than simulations alone. We demonstrate improved model performance for a range of ICF experiments at both the Omega Laser Facility and the National Ignition Facility. We end by demonstrating how the methods might be used to carry out a data-driven experimental campaign to optimize performance, illustrating the key product models that become increasingly accurate as data is acquired. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-809626.