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Machine learning algorithms for the conservative-to-primitive conversion in relativistic hydrodynamics

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Future detections of gravitational waves originating from binary neutron star mergers or core-collapse supernovae offer the potential to gain unprecedented insights into the structure of matter at densities far beyond those probed by Earth-based experiments. In order to be able to identify the correct equation of state of matter, a template bank of waveforms has to be generated by general relativistic magnetohydrodynamics simulations. However, state-of-the-art solvers are slowed down by the conservative-to-primitive transformation, a central algorithmic step in any relativistic hydrodynamics solver. We investigate the potential of three machine learning algorithms to improve existing conservative-to-primitive schemes. We find that fully replacing either the conservative-to-primitive transformation or the evaluation of the equation of state by a machine learning model is unable to provide any significant advantage. We propose a novel, hybrid scheme that unifies machine learning and state-of-the-art schemes, resulting in an acceleration of numerical solvers by up to 25% for general relativistic magnetohydrodynamics simulations involving microphysical equations of state, without compromising accuracy or robustness.

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