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ML4GW: An AI-based pipeline for Real-time Gravitational Wave Analysis

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Deep learning algorithms have excelled in various domains. Despite this success, few deep-learning models have seen full end-to-end deployment in gravitational-wave searches, both in real-time and on archival data. In particular, there is a lack of standardized software tools for quick implementation and development of novel AI ideas. We address this gap by developing the ML4GW and HERMES libraries. We show how these libraries enhance efficiency and AI model robustness in the context of a broad range of gravitational wave analyses with an emphasis on real-time application, scalability to heterogeneous computing resources, and streamlining the training to deployment cycles for machine learning models. Building on this toolkit, we present specific end-to-end searches in archival data from the O3 LIGO-Virgo-KAGRA observing run. These searches include A-frame, a low-latency machine learning pipeline for compact binary sources of gravitational waves, DeepClean, a deep learning-based denoising scheme for astrophysical gravitational waves, GWAK, a semi-supervised AI strategy to identify unmodeled gravitational wave transients, and AMPLFI, a pipeline for deep learning-based parameter estimation. In addition, we discuss how such pipelines can lead to latency improvements for multi-messenger targets. Finally, we show how ML4GW and HERMES can quickly integrate the plethora of deep learning based algorithms being developed for gravitational wave identification across the broader astrophysics community.

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