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Real-time Gravitational Wave Data Analysis with Machine Learning

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In recent years, deep learning algorithms have excelled in various domains, including Astronomy. Despite this success, few deep learning models are planned for online deployment in the O4 data collection run of the LIGO-Virgo-KAGRA collaboration. This is partly due to a lack of standardized software tools for quick implementation and deployment of novel ideas with confidence in production performance. Our team addressed this gap by developing ml4gw and hermes libraries. We'll discuss how these libraries enhanced efficiency and model robustness in several applications: Aframe, a low-latency machine learning pipeline for compact binary sources of gravitational waves, and a deep learning-based denoising scheme for astrophysical gravitational waves, covering Binary Neutron Stars (BNS), Neutron Star-Black Hole (NSBH), and Binary Black Hole (BBH) events. We'll explore the potential of machine learning for real-time detection and end-to-end searches for gravitational-wave transients. We also introduce anomaly detection techniques using deep recurrent autoencoders and a semi-supervised strategy called Gravitational Wave Anomalous Knowledge (GWAK) to identify binaries, detector glitches, and hypothesized astrophysical sources emitting GWs in the LIGO-Virgo-KAGRA frequency band. We discuss how in the future these developments can lead to rapid deployment of next-generation deep learning technology for fast gravitational wave detection.

Primary author: GOVORKOVA, Katya

Presenter: GOVORKOVA, Katya

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