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Optimization of model independent gravitational wave search using machine learning

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The Coherent WaveBurst (cWB) search algorithm identifies generic gravitational wave (GW) signals in the LIGO-Virgo data by looking for excess power events in the time-frequency domain, with minimal assumptions on the signal model. The standard cWB pipeline improves signal significance by removing excess noise through the application of a set of a priori defined vetoes on summary statistics estimated by the pipeline. Designing vetoes in the multidimensional space of the summary statistics is challenging, and requires re-tuning of the veto thresholds for each detector network configuration and each observing run. Furthermore, adding a detector to the detector network should improve detection efficiency, but this is not the case for the HLV network: when Virgo detector is added to the Hanford-Livingston (HL) detector network. We propose to use a machine learning (ML) method to automate the signal-noise classification in cWB, for each detector network, and optimize the pipeline sensitivity to a special class of GW events known as binary black hole (BBH) mergers. Here, we test the ML-enhanced cWB search on strain data from the first, second and first half of the third observing runs (O1, O2 and O3a) of Advanced LIGO and compare all BBH events previously reported by cWB from GWTC-1 and GWTC-2. We also discuss possible causes for the suboptimality of the HLV network. For simulated events found with a false alarm rate less than 1 yr^{-1}, we demonstrate the improvement in the detection efficiency of approximately 25% for stellar-mass BBH mergers and approximately 15% for intermediate mass black hole binary mergers. To demonstrate the robustness of the ML-enhanced search for the detection of generic BBH signals, we show that it has the increased sensitivity to the spin precessing or eccentric BBH events, even when trained on simulated quasi-circular BBH events with aligned spins.

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