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DeepExtractor: Time-domain reconstruction of signals and glitches in gravitational wave data with deep learning

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Gravitational wave (GW) interferometers detect faint signals from distant astrophysical events but are also highly susceptible to background noise. Among these noise sources are transient glitches, which can mimic or obscure astrophysical signals. The next-generation Einstein Telescope (ET) will offer unprecedented sensitivity that will yield significantly higher detection rates and enable the detection of longer duration signals. With approximately 1 in 4 events being impacted by glitches in current generation detectors, the increased sensitivity of ET will amplify glitch-related challenges, making fast and robust glitch reconstruction and mitigation strategies essential. This research presents DeepExtractor, a deep learning framework designed to reconstruct signals and glitches with power exceeding background noise. DeepExtractor operates by predicting and subtracting the noise component of the data, providing an accurate reconstruction of the underlying signal or glitch. Our model achieves a 0.9% median mismatch in simulated glitch reconstruction, outperforming several deep learning baselines. It also surpasses BayesWave in glitch recovery while providing a dramatic computational speedup—processing a glitch in 0.1 seconds on a CPU, compared to BayesWave's approximately one-hour runtime per glitch. Additionally, we validate DeepExtractor's effectiveness on real LIGO data using the Gravity Spy dataset. Beyond current detectors, DeepExtractor is already applicable to the null stream in ET's triangular configuration, enabling glitch removal to improve source parameter estimation. We also outline its potential for glitch mitigation in ET's 2-L configuration, where it learns to preserve signals that are coherent between detectors while removing incoherent glitches.

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