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A novel neural-network architecture for continuous gravitational waves

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The high computational cost of wide-parameter-space searches for continuous gravitational waves (CWs) significantly limits the achievable sensitivity. This challenge has motivated the exploration of alternative search methods, such as deep neural networks (DNNs). Previous attempts to apply convolutional image-classification DNN architectures to all-sky and directed CW searches showed promise for short, one-day search durations, but proved ineffective for longer durations of around ten days. In this paper, we offer a hypothesis for this limitation and propose new design principles to overcome it. As a proof of concept, we show that our novel convolutional DNN architecture attains matched-filtering sensitivity for a targeted search (i.e., single sky-position and frequency) in Gaussian data from two detectors spanning ten days. We illustrate this performance for two different sky positions and five frequencies in the $20 - 1000\mathrm{Hz}$ range, spanning the spectrum from an ''easy" to the ''hardest" case. The corresponding sensitivity depths fall in the range of $82 - 86/\sqrt{\mathrm{Hz}}$. The same DNN architecture is trained for each case, taking between $4 - 32\mathrm{hours}$ to reach matched-filtering sensitivity. The detection probability of the trained DNNs as a function of signal amplitude varies consistently with that of matched filtering. Furthermore, the DNN statistic distributions can be approximately mapped to those of the $\mathcal{F}$-statistic under a simple monotonic function.

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