Application of deep learning networks to GW astronomy

Gravitational wave astronomy has experienced remarkable progress since the seminal detection of gravitational waves in 2015. The ability to observe these elusive ripples in the fabric of spacetime has opened up new frontiers for understanding the universe, investigating black hole phenomena, and studying astrophysical events in extreme conditions. However, the growing volume and complexity of data from gravitational wave detectors pose significant challenges for extracting meaningful scientific insights. Consequently, there has been a surge of interest in harnessing the power of machine learning techniques to address these challenges within the field of gravitational wave astronomy.

Machine learning algorithms have exhibited promising results in characterizing and mitigating noise, thereby enhancing the quality of gravitational wave signals. Furthermore, unsupervised learning techniques, such as clustering algorithms, have proven effective in identifying subtle features within intricate datasets. This capability facilitates the discovery of novel gravitational wave sources and the classification of different astrophysical phenomena.

Moreover, machine learning plays a pivotal role in the challenging task of gravitational wave event detection and classification. By training deep learning models on extensive labeled datasets, researchers can achieve exceptional sensitivity and accuracy in discerning gravitational wave signals amidst the pervasive instrumental and environmental noise. This, in turn, enables prompt and automated detection of gravitational wave events, leading to optimized allocation of follow-up resources and a deeper understanding of the underlying astrophysical processes.

We present a comparison between different neural network (NN) architectures for a mock task of GW parameter estimation (as a proxy for feature extraction), as well as the effect of the approximant used to generate the dataset, showing that a careful choice of NN architecture is necessary in order to guarantee some level of performance and avoid overfitting. We also show that the effect of the choice of approximant, though small, can be somewhat significant.

Furthermore, we present a gravitational wave detection algorithm based on state of the art neural network architecture for time series analysis, InceptionTime, showing that it is capable of obtaining high accuracy (above 99%) in the task of GW detection in real detector noise. We also discuss the shortcomings of this method and necessary improvements to reach the necessary level of performance for use within the LIGO-Virgo-KAGRA (LVK) scientific collaboration.