Using machine learning to gain information about glitches in LIGO strain data

Melissa Kohl

May 2, 2018

1 Introduction

In the Advanced LIGO observation runs, detection of gravitational waves has occurred for multiple black hole mergers and one neutron star collision. Although the sensitivity of the detectors is enough to detect gravitational waves from these huge astronomical events, gravitational waves are also created from other astronomical events. To detect those gravitational waves, the sensitivity of the detectors needs to be better. The strain data from both the science and observation runs of the Advanced LIGO detectors contain "glitches" that can mimic gravitational waves and obscure real gravitational waves. If these glitches were eliminated, the sensitivity of the detectors would improve, making detection of gravitational waves from astronomical events other than black hole and neutron star mergers (including smaller black hole or neutron merger events) possible.

2 Classification of Glitches

To eliminate glitches, they must first be identified. The easiest way to identify a glitch is by looking at the same time frame at another detector that is in a different geographic location. Although the glitches can be eliminated from the data, they then must be classified so the source of the glitch can be identified and eliminated for future observing runs.

A group of scientists created a machine learning software package called GravitySpy to aid in classifying the monstrous amounts of glitches. Unlike previous machine learning techniques used on LIGO data that compared the waveforms of the glitches, GravitySpy's neural network uses spectrograms from four different time frames of each glitch to create a multi-layer network that utilizes image classification techniques. By checking four time frames of the same glitch, the network can identify glitches of different durations.

GravitySpy is great at classifying glitches into known classifications, but has trouble identifying new classifications. The output function in GravitySpy's neural network is *softmax*, which essentially just classifies the input glitch into the classification with the highest correlation, regardless of how high that correlation is. For example,

There are two main issues involving glitches that need improvement. The first is the classification of the glitches. Due to the sheer volume of data and the frequency at which glitches occur in the data, using machine learning is an attractive way to classify the glitches. However, current machine learning techniques have difficulty creating new classifications. In typical LIGO Collaboration-style, the task of designating new classifications is largely reliant on volunteers. To date, volunteers have identified (????) new glitch classifications. Unfortunately, human sorting is still quite inefficient, even with a large amount of people. Ideally, the machine learning algorithms could be improved to create new classifications of glitches.

3 Identification of Sources of Glitches

Classification of the glitches themselves is only one half of the problem with glitches in the strain data. Once glitches are classified, the source must be identified so the glitches can be eliminated from future observing runs. The reduction of glitches directly leads to more sensitive strain data.

Collaborators on the Advanced LIGO project use machine learning and volunteer classification to classify glitches from the most recent observing run. A fair amount of glitches have been eliminated by locating the source of the glitch. The most frequent glitch, referred to as a "blip," still has an unidentified source.

4 Project Ideas

5 References

1. Bahaadini, Sara, et al. *Deep Multi-View Models for Glitch Classification.* 2017 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 28 Apr. 2017, pp. 1?5., doi:10.1109/icassp.2017.7952693.

2. Mukherjee, S, et al. *Classification of Glitch Waveforms in Gravitational Wave Detector Characterization.* Journal of Physics: Conference Series, vol. 243, 1 Aug. 2010, pp. 1?9., doi:10.1088/1742-6596/243/1/012006.

3. Rampone, Salvatore, et al. *Neural Network Aided Glitch-Burst Discrimination And Glitch Classification.* International Journal of Modern Physics C, vol. 24, no. 11, 12 Sept. 2013, pp. 1-17., doi:10.1142/s0129183113500848.

4. Zevin, M, et al. *Gravity Spy: Integrating Advanced LIGO Detector Characterization, Machine Learning, and Citizen Science.* Classical and Quantum Gravity, vol. 34, no. 6, 28 Feb. 2017, p. 064003., doi:10.1088/1361-6382/aa5cea.