Identifying Noise in LIGO Gravitational Wave Data Using Machine Learning

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ABSTRACT

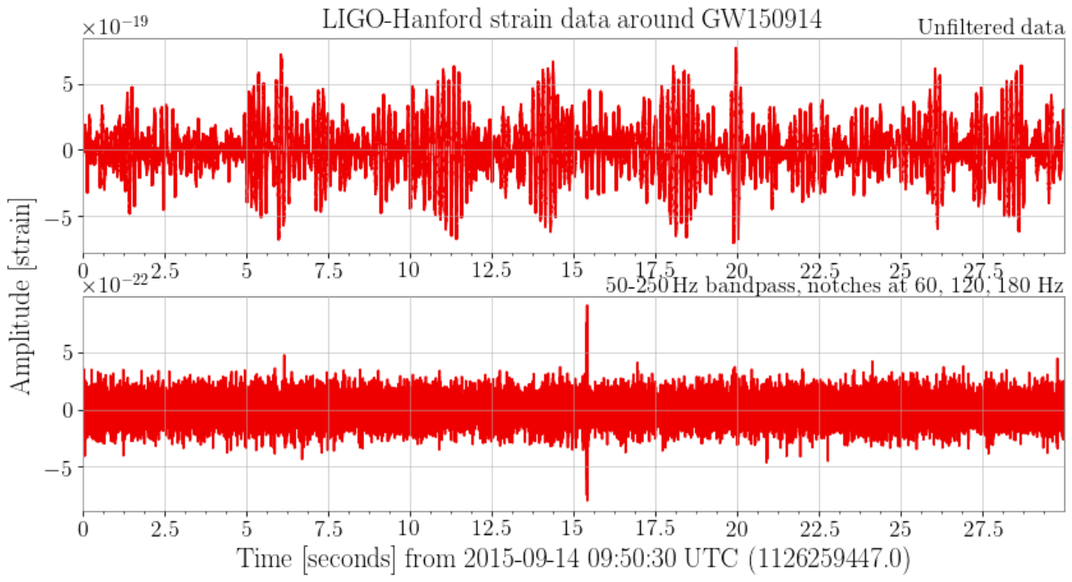
Gravitational waves (GW) detected on Earth originate from collisions between black holes, neutron stars, or combinations of these objects. Detection through laser interferometry is complicated by faint nature of signals and introduction of various types of noise. GW signals are measured as strain timeseries. Traditional supervised learning methods require large labelled datasets, which are challenging to obtain for strain data. In this study, I use deep transfer learning to classify noise in LIGO/Virgo detections. Using ResNet architecture, I trained the model on Q-transform images from the Gravity Spy project and classified GW data into noise classes. Results show that ResNet-based transfer learning provides accurate noise classification and is a promising tool for noise detection.

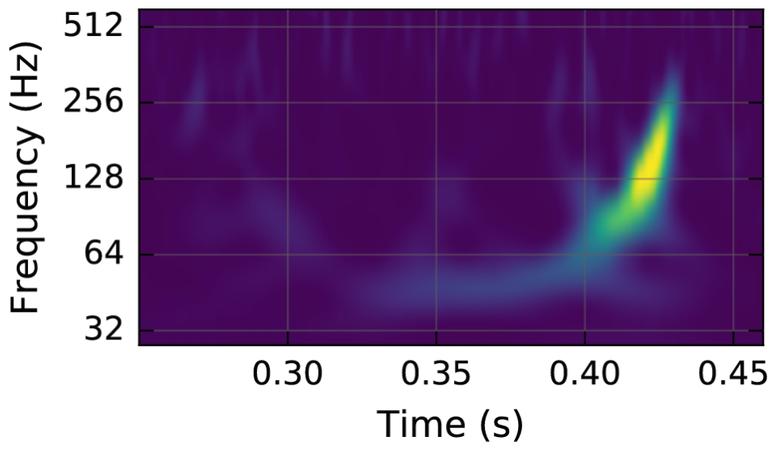
INTRODUCTION

Gravitational wave observation was recognised by the 2017 Nobel Prize in Physics. It offers clues into superdense objects like black holes and neutron stars. GW detection is done through super long L-shaped arms using laser interferometry. The data is called strain because it measures the fractional change in distance between the interferometer arms caused by GW.

The main challenge is faint signals mixed with various types of noise, including power transmission, thermal, seismic, and non-Gaussian noises and despite extensive noise reduction measures, various noise persists. This is where the demonstrated ResNet-50 model helps in effective detection and removal of noise.

Strain Data to Spectrogram





Deep Transfer Learning

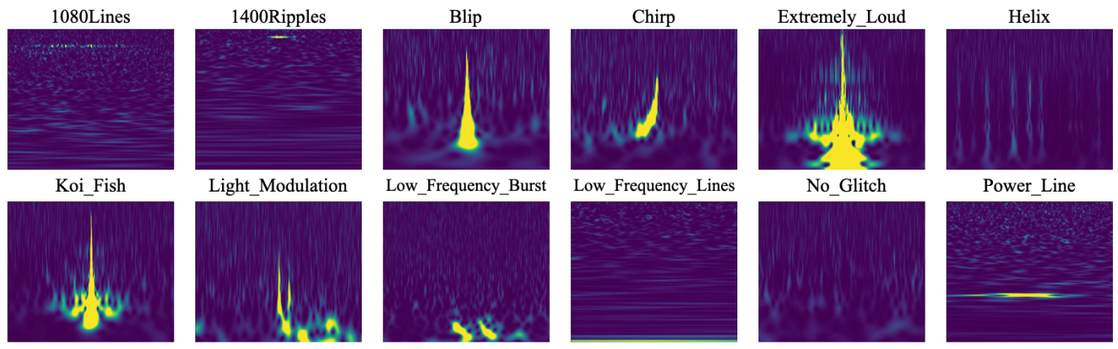
Similar to a true signal, noise also have a distinct spectrogram. The detection data has essentially been converted into image. I used deep transfer learning to classify different types of noise. Transfer learning uses a pre-trained model on a large dataset and fine-tunes it for a specific task with a smaller dataset.

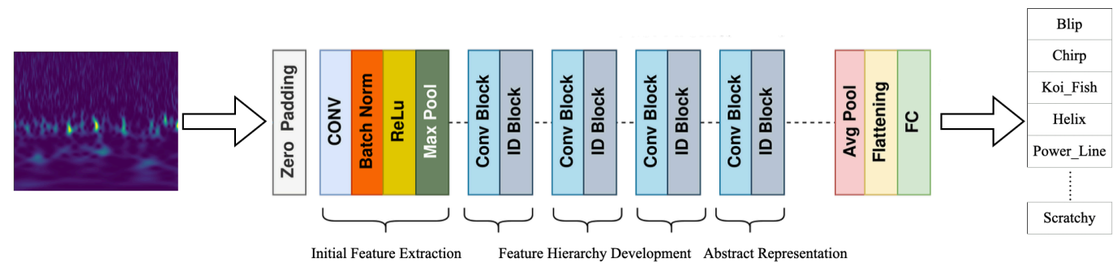
METHODOLOGY

ResNet-50 Architecture and Training Process

ResNet-50 is a CNN with 48 convolutional layers, 1 MaxPool layer, and 1 average pool layer, which allows it to learn complex features of the noise classes effectively.

The ResNet-50 model, pre-trained on ImageNet, was fine-tuned by adding fully connected layers. The model was trained using categorical cross-entropy loss, Adam optimiser, and class weights to handle imbalanced data. The images are taken from the Gravity Spy project. It has 21 classes of noise.

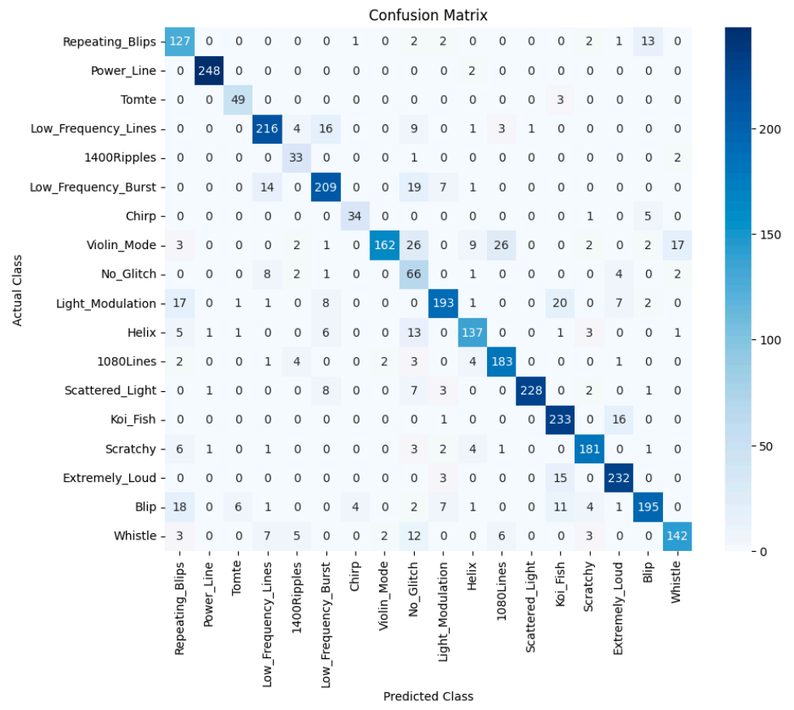




Training of ResNet-50 Model

RESULT

Test accuracy: **85.10%**



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1. Finding the origin of noise transients in LIGO data with machine learning. arXiv:1812.05225
2. GWpy
3. GWOSC

Trained Model