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Shirts, Phillip   
LM Solar and Astrophysics Laboratory  
Lockheed MartinPalo Alto, USA  
phillip.g.shirts@lmco.com  
  
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*Abstract*—Several data preprocessing, analysis and machine learning techniques were employed in our group’s effort to identify synthetic gravitational waves from data provided by the Kaggle.com G2NetGravitation Wave Detection Research Prediction Competition, “Find gravitational wave signals from binary black hole collisions.”

Keywords—gravitational waves, machine learning, Convolutional Neural Net (CNN), Q-Transforms, data pre-processing, continuous wavelet transform, spectrograms, Kaggle contest

# Introduction

Gravitational waves are “ripples” in space time caused by the movement of massive objects. The faster the movement and the more massive the object, the stronger the gravitational wave created. Albert Einstein’s 1915 general theory of relative predicted the existence of gravitational waves, and they were detected for the first time 100 years later, in 2015, by twin Laser Interferometer Gravitational-wave Observatory (LIGO) observatories. The gravitational waves that were detected were generated by colliding black holes.

The gravitational wave signals are very weak, of order 10^-21. Convolutional Neural Networks (CNN) approaches are a promising avenue for identifying the weak gravitational wave signals. In order to encourage development of CNN approaches to Gravitational wave detection, Kaggle.com is hosting a competition, “G2Net Gravitational Wave Detection, “Find gravitational wave signals from binary black hole collisions” with $15,000 in prizes for top signal detectors using CNN. (https://www.kaggle.com/c/g2net-gravitational-wave-detection). The final submission deadline is September 20, 2021.

# Data Set

The data set consists of 560,000 training records and 226,000 test records: 50% of the records contain a signal and 50% do not. The embedded signals were synthetically generated. “The parameters that determine the exact form of a binary black hole waveform are the masses, sky location, distance, black hole spins, binary orientation angle, gravitational wave polarisation, time of arrival, and phase at coalescence (merger). These parameters (15 in total) have been randomised according to astrophysically motivated prior distributions and used to generate the simulated signals present in the data, but are not provided as part of the competition data. Each data sample (npy file) contains 3 time series (1 for each detector) and each spans 2 sec and is sampled at 2,048 Hz.” There are approximately 77 GB of data in the test and train data sets.

# survey of related work and background material

## Fourier Transforms

Identifying signals using Fourier Transforms

### Periodograms

## Continuous Wavelet Transform

Identify applicable funding agency here. If none, delete this text box.

Identifying signals using Continuous Wavelet Transform

## Convolutional Neural Net with Wavelet Transform

## Not completed: Transfer Learning

# Our technical approach

We identified data pre-processing as key to signal identification in data. We explored several pre-processing approaches:

### Co-addition of the three synthetic signals.

Any gravitational wave signal should appear at all LIGO observatories. Even though any signal present in the data might be offset by as much as 7 milliseconds due to speed-of-light (and gravitational waves) between the different LIGO observatories, depending on the orientation of the signal in space relative to the observatories, we thought it reasonable to see if co-addition of co-temporal data instances (where were ingested into our computing environment as equal length numpy arrays) would increase the relative strength of the signal, and hence its detectability. Prior to coaddition each signal channel was standardized.

### Interleaving the three co-temporal synthetic signals.

Similarly, for three LIGO instance data elements, the array elements were combined into a single numpy arraved with their elements interleaves, with the thought that that might make it easier for a periodogram, or other technique to identify a common signal:

#interleave and then standardize three co-temporal gravitational wave signal candidates

def interleave\_samples( \_id, target):

path = convert\_id\_to\_path(\_id)

x = np.load(path)

print(\_id)

x0 = x[0].reshape(-1,1)

x1 = x[1].reshape(-1,1)

x2 = x[2].reshape(-1,1)

x\_123 = np.dstack((x0,x1,x2)).ravel()

x\_123 = x\_123.reshape(-1, 1)

scaler\_xcomposite=StandardScaler() #original

scaler\_xcomposite.fit(x\_123) #original

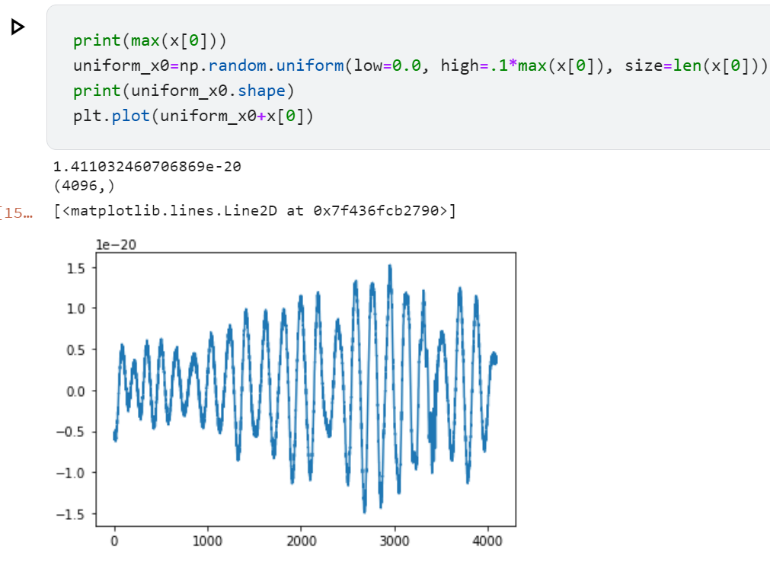
x\_out = scaler\_xcomposite.transform(x\_123)

print("\_id == ", \_id)

return x\_out

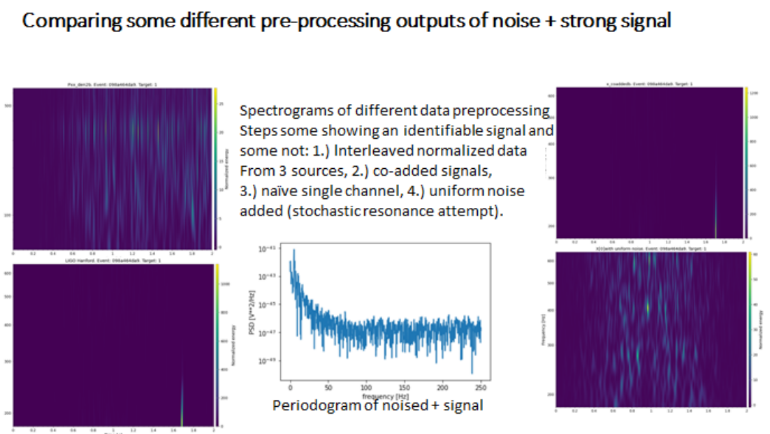
### Stochastic resonance

In the cited paper, a non-linear cavity was used to enhance in the LIGO to enhance the detectability of the gravitational wave signal. We experimented with injecting uniformly distributed noise of low relative strengths into the provided data set elements. So far, no enhanced detectability of gravitational signals was noticed.



### Periodograms & Q Transforms

A strong known signal from the data set of signals was identified and the above preprocessing steps were there analyzed with periodograms and Q-transform to see if the strong signal still retained visible identifiability. In the case of simple coaddition this was still true.



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Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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* Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
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* Use a zero before decimal points: “0.25”, not “.25”. Use “cm3”, not “cc”. (*bullet list*)

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The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

Number equations consecutively. Equation numbers, within parentheses, are to position flush right, as in (1), using a right tab stop. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

*a**b* 

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## Some Common Mistakes

* The word “data” is plural, not singular.
* The subscript for the permeability of vacuum **0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
* In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
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* The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
* There is no period after the “et” in the Latin abbreviation “et al.”.
* The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

An excellent style manual for science writers is [7].

# conclusion

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## Authors and Affiliations

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Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

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1. Table Type Styles

| Table Head | Table Column Head | | |
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1. Sample of a Table footnote. (*Table footnote*)
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##### Acknowledgment *(Heading 5)*

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##### References

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1. G.G. Karapetyan, “Application of stochastic resonance in gravavitational-wave interferometer,” Phys.Rev.D 73, 24 pages, Jan, 2006.
2. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
3. I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
4. K. Elissa, “Title of paper if known,” unpublished.
5. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
6. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
7. M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.

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