Solar Flare Predictions Based on CNN

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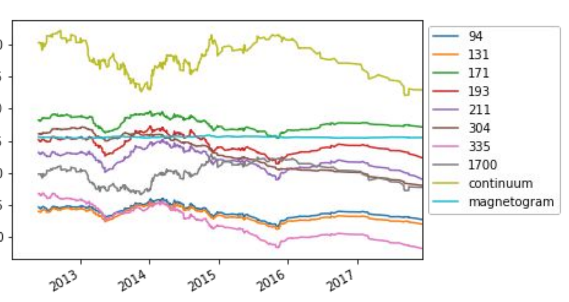
Predicting

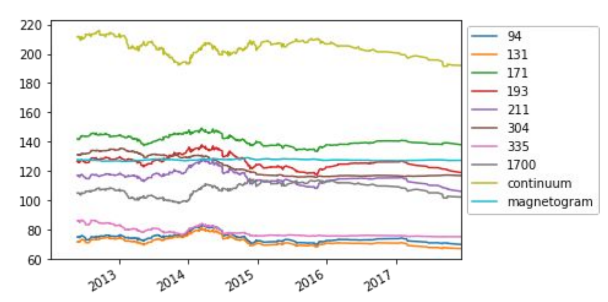
The motivation for this topic is the accurate prediction of an unpredictable celestial event: solar flares. Solar flares are studied using 10 sensors on the SDO NASA satellite mission, and the data consists of images from that mission. For our project, we built CNNs using both a regression model and a binary classification model as well as a vgg16-based network and a pre-trained autoencoder network. The results showed that with auto-encoded data and a binary classification model, the network is relatively successful at predicting the presence of a solar flare with an appropriately chosen threshold.

Features

1. Brightness correction: The average brightness degraded over time, so an offset is needed to correct the trend before we feature extraction

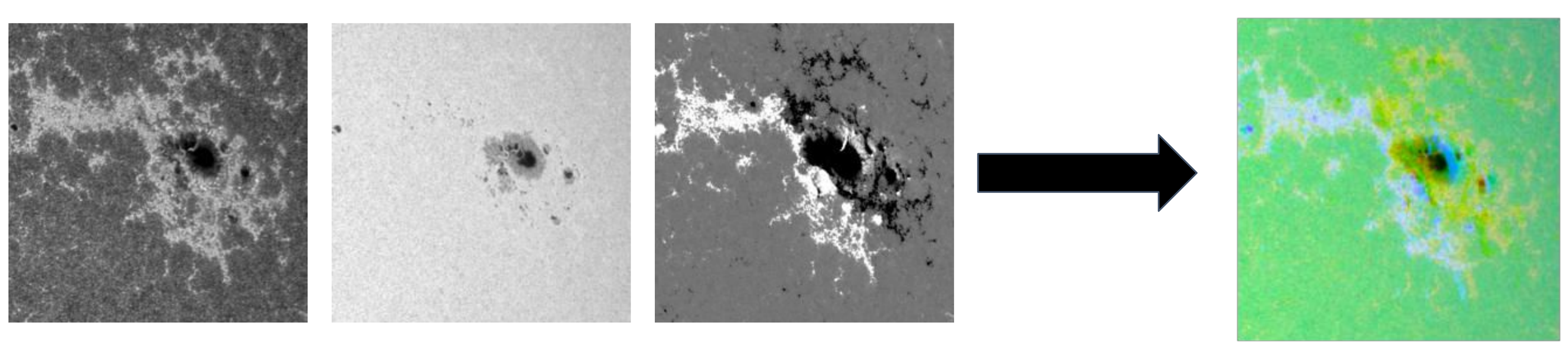


before correction



after correction

2. Combinations of image: We choose 3 kinds of image with a flat brightness curve and combine them together in 3 channels as an input to our network.

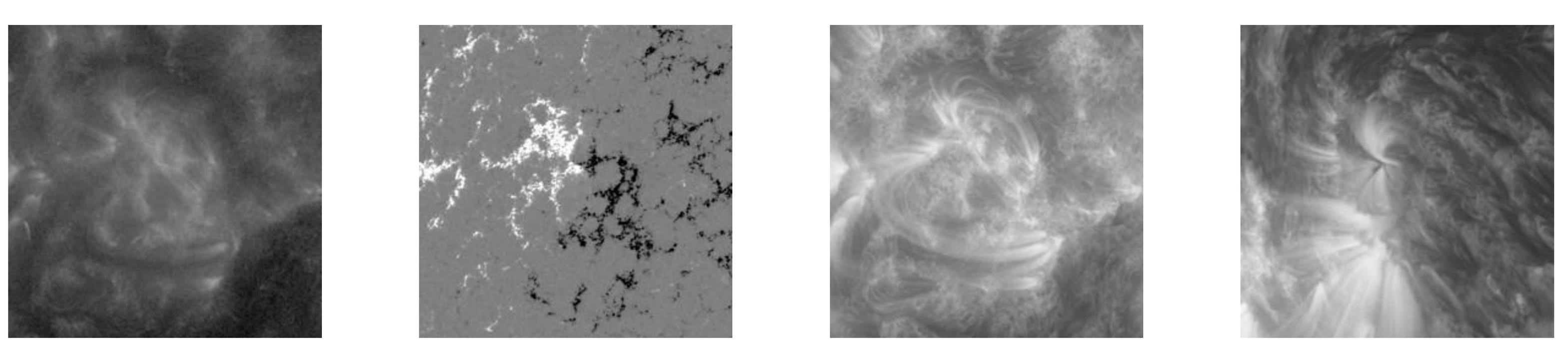


3. Autoencoder feature extract: Extract features in an unsupervised process from images and try to recover images from the feature bank.

Data

Our dataset was from the Institute for Data Science, FHNW, Switzerland and downloaded from kaggle. It contains 10 differents kind of Solar Flare image taken from satellite corresponding to different wavelength.

(Data from: https://i4ds.github.io/SDOBenchmark/)



The samples in this dataset have up to 40 images, but the total number of samples is only 8,000. Because all the images are taken in the time range from 2012 to 2018, they are correlated in time domain.

All the Images are labeled with “peak_flux,” which represents the probability of a Sun flare event occurring. It ranges from 1e-03 to 1e-09, divided into 157 classes.

Future

If work on this project continued for another 6 months, we would investigate other ways of combining image data to improve learning since our models use three channels when taking the sensors in total yields 10 sensors.

Models

1. Using CNN to train a regression model and a binary classification model:

   4 layers: input → conv2d(32, 5*5) → conv2d(32, 5*5) → conv2d(64, 3*3) → conv2d(64, 3*3) → output

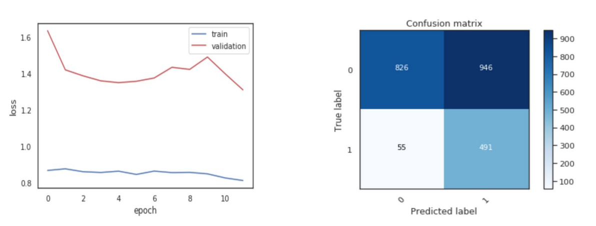
2. Using vgg16 to train a 5-classes classification model and a binary classification model:

   16 layer: input → 13 * conv2d → 3 * FC(fully connected layer) → output

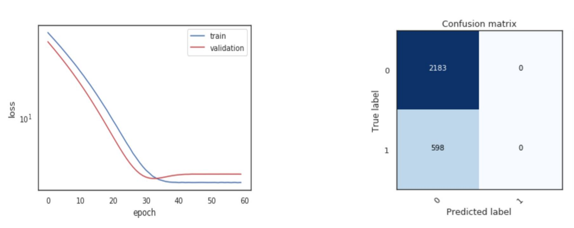
3. A pre-trained deep autoencoder model[1] connect the feature layer to two FCs.

Results

1. CNN:

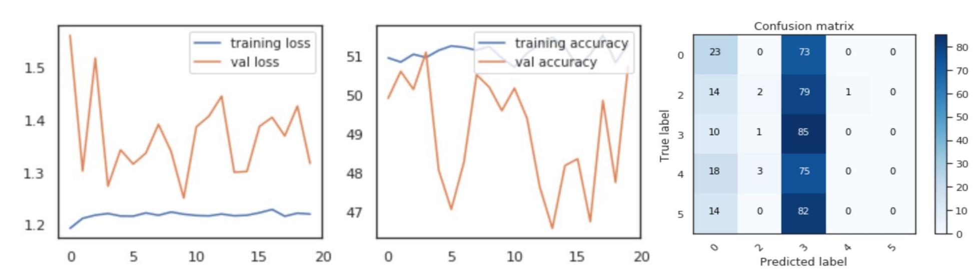


Binary classification

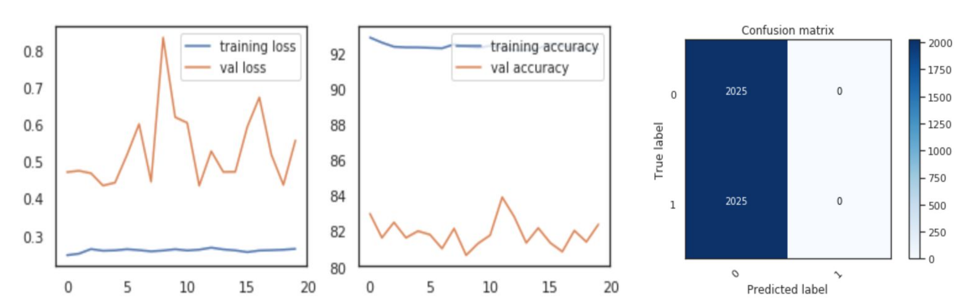


Regression

2. Vgg16:

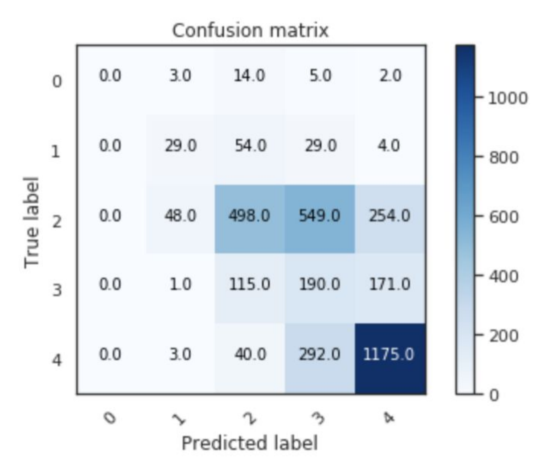


5-classes classification

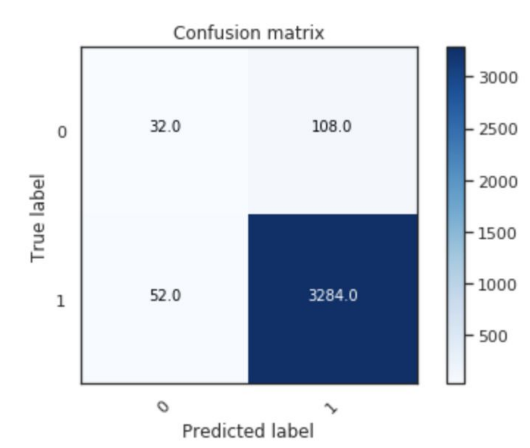


binary classification

3. Pre-trained autoencoder model



5-classes classification



binary classification

Discussion

In practice, the learning time for 1 epoch for the vgg16 network using cuda is over 250 seconds, and we can see that the loss on the validation set is not converging. Overall, the performance on Vgg16 is poor, and it shows that our data (images) is not suitable for deep learning with many layers.

With our first simple CNN network, we can see the performance is better for binary classification than regression. This improvement is due to the choice of peak flux as our prediction value in the regression problem, and this value is so small (from 1e-3 to 1e-9) such that taking a logarithm still does not sufficiently separate the classes. Therefore, our dataset is more suitable for a classification problem.

The most amazing outcome is from pre-trained autoencoder network. For the autoencoder part, it is capable of fully recovering the image from features, which means that the features extracted are a good match for this type of network. After connecting the autoencoder to two fully connected layers, the performance is the best among all the methods we used.

References

[1] V. Badrinarayanan, A. Kendall and R. Cipolla, "SegNet: A Deep Convolutional Encoder-Decoder Architecture for Image Segmentation," in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 39, no. 12, pp. 2481-2495, 1 Dec. 2017.

[2] G. Barnes and K.D. Leka NWRA, 3380 Mitchell Ln., Boulder, CO 80301, USA, “A COMPARISON OF FLARE FORECASTING METHODS, I: RESULTS FROM THE “ALL-CLEAR” WORKSHOP”.

[3] Yassine Ghouzam, PhD “Introduction to CNN Keras - Acc 0.997 (top 8%)”, 18/07/2017.