Classifying Seyfert galaxies with deep learning

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ABSTRACT

Seyfert galaxies have several subclasses according to features of their optical spectra. Traditional classification for intermediate Seyfert galaxies is usually visual check or using a quantity which is defined as the ratio between Balmer line and forbidden line. However, the visual check usually takes a lot of and a quantity does not really reflect the information about the shape of the emission line. The shape of the emission line is the original classification features and usually contain physic information. Deep learning is a category of machine learning and has an algorithm which is wildly used for classification. This algorithm is called convolution neural network (CNN) and extracts feature though a specified filter. In this work, we build a 1D Convolution Neural Network as our classification model to distinguish Seyfert 1.9 galaxies from Seyfert 2 galaxies.

INTRODUCTION

Active Galactic Nuclei (AGN) is a galaxy shows strong emission activity in the galaxy center and this is believed to accrete gas near the central supermassive black hole. Seyfert galaxy is a type of AGN and was first discovered by Seyfert (1943). Seyfert galaxies have two main classes according to their optical spectrum features; Seyfert 1 galaxies have broad Blamer emission lines whereas Seyfert 2 galaxies have only narrow Balmer emission lines (Khachikian & Weedman 1971, 1974). Besides the two main Seyfert classes, there are few Seyfert galaxies showing feature between Seyfert 1 and Seyfert 2 galaxies and these intermediate Seyfert galaxies are classified into Seyfert 1.2, Seyfert 1.5, Seyfert 1.8, and Seyfert 1.9 depending on the relative ratio between Hα and Hβ emission lines (Osterbrock 1977, 1981).

As the development of technology, we can obtain more and more observation data through the all-sky survey. This also brings a new challenge to dealing with the huge amount of data. The traditional classifying method is by visual check and is time-consuming. It could have a potential bias due to check by different people. But this can be solved by the progress of computer science. Nowadays, one category of machine learning is called deep learning which has an algorithm for recognizing feature and is shown to apply successfully at image classifying. This algorithm is call convolution neural network (CNN) and it can extract feature through moving a filter along a direction of data. By applying the classifying method on observation data could reduce the time of classification and potential bias from human. This can also provide us a more precise sample without human bias.

The only difference between optical spectra of Seyfert 1.9 and Seyfert 2 galaxies is the Hα emission line. Seyfert 1.9 galaxy has a weak broad Hα component superimposed by a strong narrow Hα component whereas Seyfert 2 galaxy has only a strong narrow Hα component. This work is to distinguish optical spectra of Seyfert 1.9 galaxies from those of Seyfert 2 galaxies by building a convolution neural network (CNN) model.

DATA SELECTION

We select our Seyfe from Chen and Hwang (2019). This sample includes 53794 Seyfert 2 galaxies and 745 Seyfert 1.9 galaxies with $0 < z < 0.2$. We obtain the optical spectra from Sloan Digital Sky Survey (SDSS) Data Release 10. We only use a segment of the spectrum as our input because this range coverage the Hα emission feature in the optical spectrum. The segment range is from 6400Å to 6700Å and all spectra are shifted back to rest frame. In order to learn the nature difference between Seyfert 1.9 and Seyfert 2 galaxies instead of their distribution, we choose the same ratio between Seyfert 1.9 and Seyfert 2 for our training dataset. We use 300 Seyfert 1.9 and 300 Seyfert 2 as our training data and 445 Seyfert 1.9 and 53494 Seyfert 2 as our test dataset. We normalize every spectrum to its peak value to make value range between 0 to 1 before we pass our spectrum into the neural network model.

CNN MODEL

We build a 1D Convolution Neural Network and show the architecture in Table 1. Our model has total 6 layers and one output layer. We use Cross-Entropy loss and Stochastic Gradient Descent in our model. We set learning rate=0.01 and epoch =100.

Table. 1

Layer	Type	Channel$_{in}$	Channel$_{out}$	kernel size	stride	Activation
1	Convolution	1	10	200	1	ReLU
2	Pooling			2	2	
3	Convolution	10	30	100	1	ReLU
4	Pooling			5	2	
5	Convolution	30	36	56	1	ReLU
6	Linear	3384	94			ReLU
out	Linear	94	2			

RESULTS

We show loss and accuracy value of training and valid sample with the epoch in Fig. 1. We find the loss of training and valid decrease with epoch. The final loss value of training and valid are 1.86 and 1.11, respectively. The valid accuracy is 98%. The test accuracy is 98% and this value represents all sample including Seyfert 1.9 and Seyfert 2.0. For Seyfert 1.9, the test accuracy is 84% for classifying correct 376 out of 445 sample. For Seyfert 2, the test accuracy is 98% for classifying correct 52802 out of 53494.
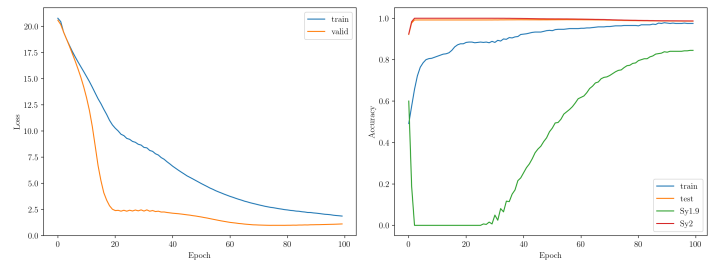

Fig. 1. Results of training and valid. Left: Loss value of training and valid as a function of epoch. Right: Accuracy of training, test, Seyfert 1.9, and Seyfert 2 galaxies as a function of epoch.

We show the spectra and output from the first convolution layer of Seyfert 1.9 and Seyfert 2.0 in Fig. 2. The middle panel of Fig. 2 is the results of visualization output from the first convolution layer of our model. The x-axis represents the reduced length of the spectrum due to convolution and y-axis represents the ten output from the first convolution layer. We find there are some channels have stronger value than the other channel. We further pick out the channels of the top three and show the results in the bottom panel of Fig. 2. We find the three channel have similar shape in the Seyfert 1.9 and Seyfert 2 galaxies. However, the shapes of the channels of Seyfert 1.9 are different from that of Seyfert 2 galaxies.
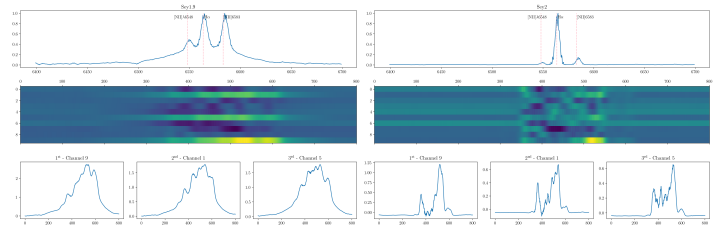

Fig. 2. Results of spectra before input CNN model and production after CNN model. Left: Seyfert 1.9 galaxy. Right: Seyfert 2. Top panel: input spectrum. Middle panel: output of first convolution layer. Bottom panel: Top 3 high value of the output channel of first convolution layer.

DISCUSSION & FUTURE WORK

Our model can recognize Seyfert 1.9 galaxies with 80% accuracy and this indicates that a 1D CNN model can work well on the classification of Seyfert 1.9 and Seyfert 2 galaxies. This classification is based on the intrinsic shape of the emission line which usually reflects how the gas move and their temperature. After we obtain more observation data in the future we can use this model to pick up Seyfert 1.9 galaxies immediately. By gathering more Seyfert 1.9 source, we can derive gas temperature and density from the spectrum. This can help us understand why Seyfert 1.9 galaxies have narrow emission line component and broad weak emission line component while Seyfert 2 galaxies only have narrow emission line component.

In order to increase accuracy, we can add more convolution layer into our model or use a changing learning rate in iterative. The learning rate is the step in gradient descent. In the late stage, it is better to use a small step to find a minimum in gradient descent. If we always use the same learning rate value, it is possible that we will never reach the minimum point in gradient descent.

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