**Hyperspectral image classification using ResNeXt with Squeeze and Excitation block**

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**Abstract**

**I modify and train an implementation of ResNeXt with Squeeze and Excitation block to classify hyperspectral images between five classes. I compare classification accuracies used neural networks with different configurations, namely the cardinality of ResNeXt and the number of building blocks for each residual layer, and datasets with different numbers of spectral channels to. It is shown that even the least powerful neural network trained with dataset having the fewest information performs well, achieving 96.67% accuracy on the testing dataset.**

**1. Problem Statement**

Image classification is a common problem that can be solved by neural network. CNN is the earliest popular neural network architecture [1]. During the recent years, ResNet has proven itself to be the more favorable architecture. Many improvements have been made to this architecture, leading to either new architectures like ResNeXt [2], or additions to original ResNet architecture which can be applied universally to other popular architectures as well, such as Squeeze and Excitation (S&E) block [3].

Most image classifications using neural networks are done on RGB images. The company Middleton Spectral Vision that I am currently working for as an intern focuses on building hyperspectral imaging solutions. I want to see how neural network handles image classification on images that contain more spectral channels than just RGB. After some preliminary research, I discover that image classification on hyperspectral images (HSIs) is an already widely explored topic because of HSIs are produced and utilized extensively in fields like remote sensing, although the classification is not necessarily done by neural network.

**2. Method**

The dataset consisting of HSIs in raw files is provided by my internship company mentioned above. There are five classes associated with all the HSIs, which are almond, amber, shell (of the almond), stone, and wood chip. One sample HSI from each class showing only RGB channels is shown in Figure1 – Figure 5.

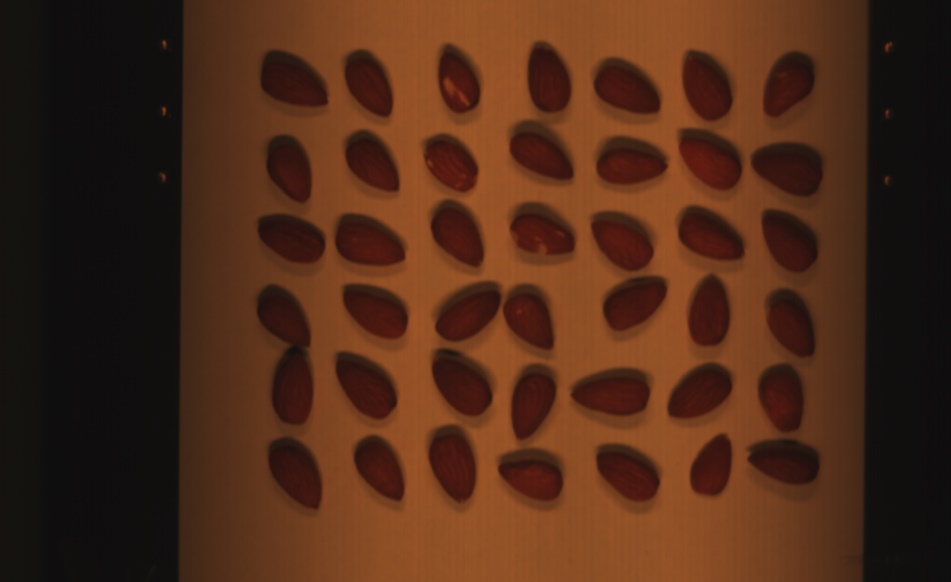


Figure 1: Sample HSI from the *almond* class showing only RGB channels.



Figure 2: Sample HSI from the *amber* class showing only RGB channels.

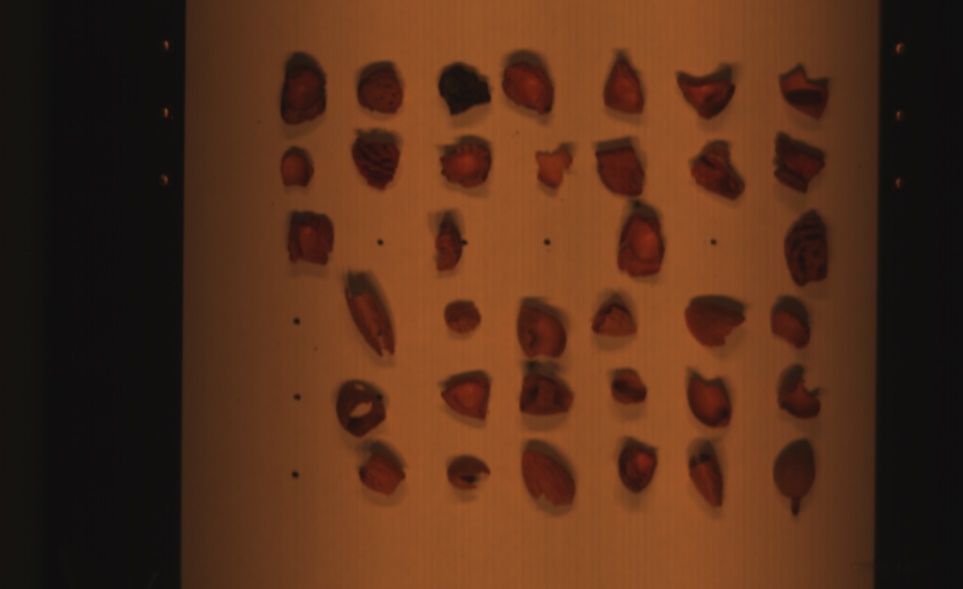


Figure 3: Sample HSI from the *shell* class showing only RGB channels.



Figure 4: Sample HSI from the *stone* class showing only RGB channels.



Figure 5: Sample HSI from the *wood chip* class showing only RGB channels.

First, I use a Windows Form application I wrote in C# before during work to crop original images into same-sized 100 x 100 pixels sub-images, all of which contain only a single object. The sample sub-images from each class and their spectral plots are shown in Figure 6 – Figure 10. Their spectral After this step, there are a total of 604 images from five classes. I withhold 10% of the images from each class to form the testing dataset. The remaining 90% constitutes the training dataset. The specific composition is listed in Table 1.



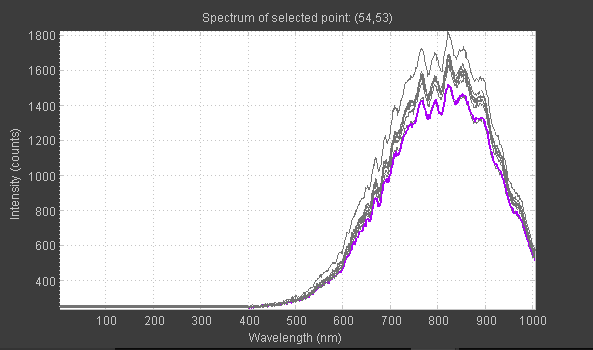


Figure 6: Sample HS sub-image from the *almond* classes showing only RGB channels, and its spectral plot. Each curve represents the spectral intensity distribution of one selected pixel on the image.



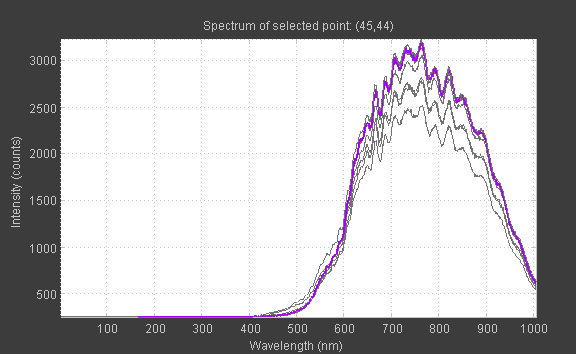


Figure 7: Sample HS sub-image from the *amber* classes showing only RGB channels, and its spectral plot. Each curve represents the spectral intensity distribution of one selected pixel on the image.



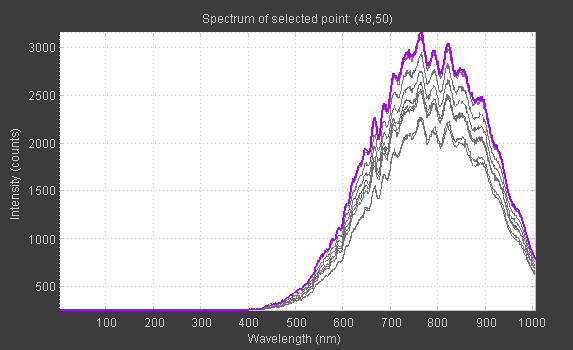


Figure 8: Sample HS sub-image from the *shell* classes showing only RGB channels, and its spectral plot. Each curve represents the spectral intensity distribution of one selected pixel on the image.



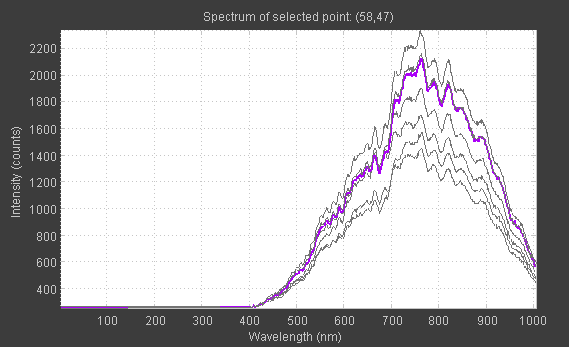


Figure 9: Sample HS sub-image from the *stone* classes showing only RGB channels, and its spectral plot. Each curve represents the spectral intensity distribution of one selected pixel on the image.



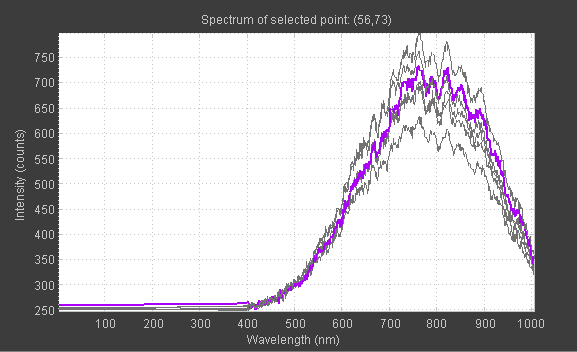


Figure 10: Sample HS sub-image from the *wood chip* classes showing only RGB channels, and its spectral plot. Each curve represents the spectral intensity distribution of one selected pixel on the image.

| **Image class** | **Training size** | **Testing size** | **Total** |
| --- | --- | --- | --- |
| Almond | 189 | 21 | 210 |
| Amber | 108 | 12 | 120 |
| Shell | 97 | 11 | 108 |
| Stone | 113 | 13 | 126 |
| Wood Chip | 36 | 4 | 40 |
| **Total** | **543** | **61** | **604** |

Table 1: Training and testing dataset distribution among five classes.

Then I write a Python program image\_data.py to process the raw files of sub-images and create labels. The program extracts image data from all sub-images and format it as needed for the neural network input. HSIs contain spectral channels many more than common RGB ones which only have 3. HSIs in this dataset have 448 spectral channels, ranging roughly from 400nm to 1000nm, with about 1.5nm apart between consecutive channels. I have an adjustable parameter called spectral\_step in this program, which controls the number of spectral channels of all sub-images to extract. For example, if the step is set to 100, then only data from spectral channels starting at 400nm and 100 channels apart will be extracted from the raw files to be used as inputs to the neural network.

This program image\_data.py also generates the label for each image. The five classes, almond, amber, shell, stone, and wood chip, have integer labels 0, 1, 2, 3, and 4.

Regarding image classification on HSIs to be viable, I decide to experiment using neural networks. The architecture I use is the combination of the two improvements to ResNet mentioned above, ResNeXt and S&E block. The performance evaluation metrics are simply the accuracy of classification and losses on both the training and testing dataset.

ResNeXt is based on ResNet. The main difference is that ResNeXt splits the path in ResNet into many small ones and then recombines them. The similarity and difference between ResNeXt and ResNet are illustrated in Figure 11. The number of splitting is called cardinality, which is used later by me as a parameter to build different neural networks.

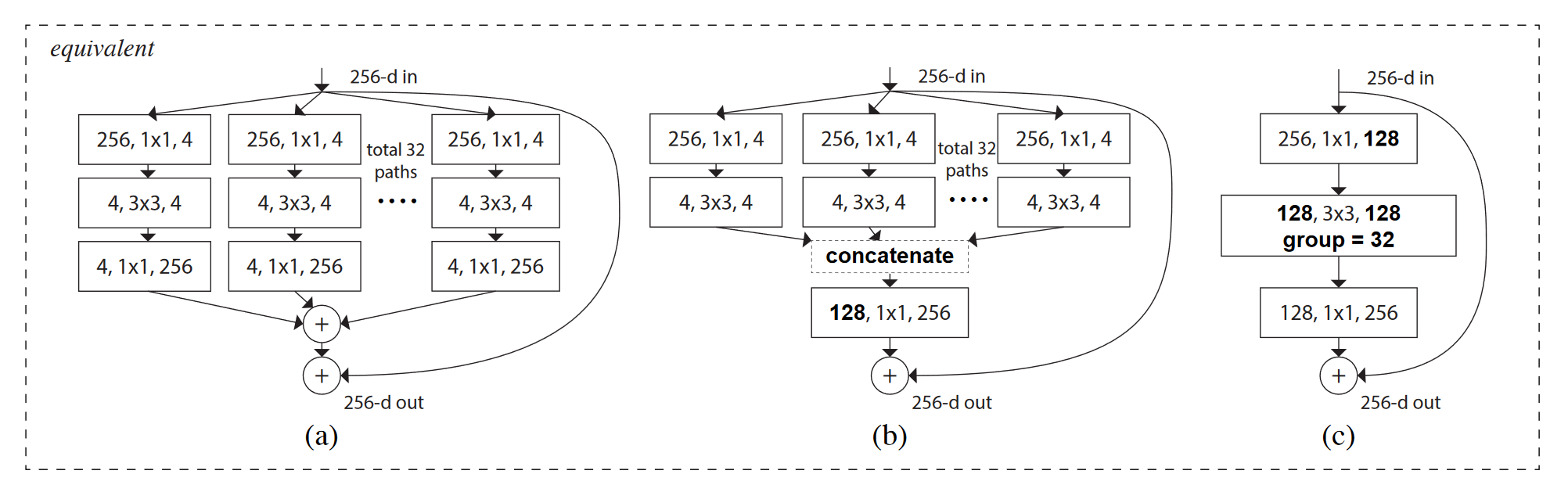
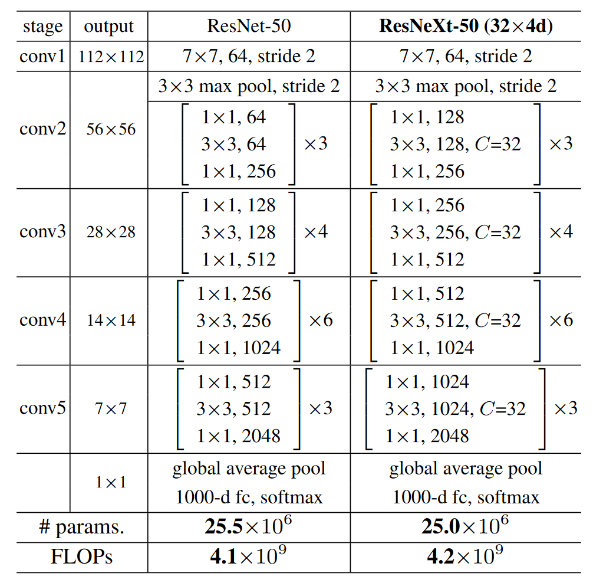


Figure 11: Illustration of the similarity and difference between ResNeXt and ResNet. [2]

S&E block is a performance improvement block that can be added into almost any neural network architecture. It adds a path which reduces dimensionality, gates the data, and expands back. The methodology of S&E block and the way to add it to ResNet are illustrated in Figure 12.

![A screenshot of a cell phone

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDaRXhpZgAATU0AKgAAAAgABAE7AAIAAAAFAAAISodpAAQAAAABAAAIUJydAAEAAAAKAAAQyOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAEJpYXMAAAAFkAMAAgAAABQAABCekAQAAgAAABQAABCykpEAAgAAAAM1OQAAkpIAAgAAAAM1OQAA6hwABwAACAwAAAiSAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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A close up of text on a white background

Description automatically generated

Figure 12: The methodology of S&E block and how it can be incorporated into ResNet.

Originally, I planned to implement ResNet with S&E block but did not build a working network. Given the time constraint, I turn to an existing implementation of ResNeXt with S&E block [4] and modify it accordingly.

Other than the cardinality of ResNeXt mentioned above, I also adjust the number of ResNeXt building blocks to use in each of the three residual layers to create different neural networks.

I use Euler as my platform to run training and testing. I combine neural networks with different cardinalities and numbers of building blocks, with datasets containing different numbers of spectral channels to form various experiments. Each combination of the model and the input data runs for 30 minutes. All combinations run at least 130 epochs in 30 minutes. The more complex thus powerful the model and the more spectral channels extracted in the data, the fewer epochs this combination can run in 30 minutes.

All codes written or modified by me specifically for this project are currently stored in the company’s private GitHub repository. I will post them in a public repository soon excluding company-restricted parts. They are also available upon direct request.

**3. Results and analysis**

I intended to do ten-fold cross-validation while training. I planned to divide the training data into ten groups of roughly the same size and to withhold one group as the validation data every 100 epochs. However, looking back at the code, I realize that I mixed the testing data with the training data while dividing. As a result, although I have accuracy and loss data spanning more than 100 epochs, only those within the first 100 epochs are valid.

For the three parameters that I use to create combinations of different neural network and input data as mentioned above, I find the bound for them given the maximal hardware resources that I can deploy on Euler. The largest cardinality that I can set is 3. The largest number of building blocks to use in each residual layer is 2. The smallest spectral step, which creates the largest size of data per image, is 13. I choose the largest spectral step to be 100, which only extracts 6 spectral channels. Using c for cardinality, b for number of blocks, and s for step to create shorthand names for combinations, all the combinations I can run and get a result are c1b1s13, c1b1s14, c1b1s16, c1b1s20, c1b1s25, c1b1s33, c1b1s50, c1b1s100, c1b2s100, c2b1s100, c3b1s100.

I run the training and testing and plot both accuracy and loss over epochs for each possible combination. Three groups of plots are shown in Figure 13 – Figure 15. Each group only has one changing parameter and the other two are fixed

In Figure 13, the neural network has fixed cardinality being 1 and fixed number of building blocks in each residual layer being 1. The spectral steps changes from 13 to 100 nonlinearly. For spectral steps of 13, 14, 16, 20, and 50, the final testing accuracies at 100th epoch are all 100%. For spectral steps of 25, 33, and 100, the final testing accuracies at 100th epoch are 98.33%, 98.33%, and 96.67% accordingly, which corresponds to roughly 1, 1, and 2 wrong classifications out of 61 images. As the spectral step decreases, more spectral channels thus more information is included for each input image. Meanwhile, the test accuracy increases. This trend is within expectation. Being able to actually reach 100% for testing is partly due to the limited amount of testing data. The true accuarcy is believed to be in the high ninties, meaning about 3 wrong classifications out of 100 images.

Interestingly, all accuracy plots in Figure 13 show that, no matter what the spectral step is, the neural network converges almost at the same epoch which is 30th. Looking at the differences between final results of input data with small spectral steps and input data with large spectral steps, I believe they are dismissable. As a result, when dealing with HS image classification in this case, it is safe to down sample the HSIs to have fewer than 10 spectral channels.

The loss plots in Figure 13 show an interesting trend. As the spectral step decreases, which means the data per input image is becoming larger, the test loss before reaching the minimum shows more intense fluctuation.

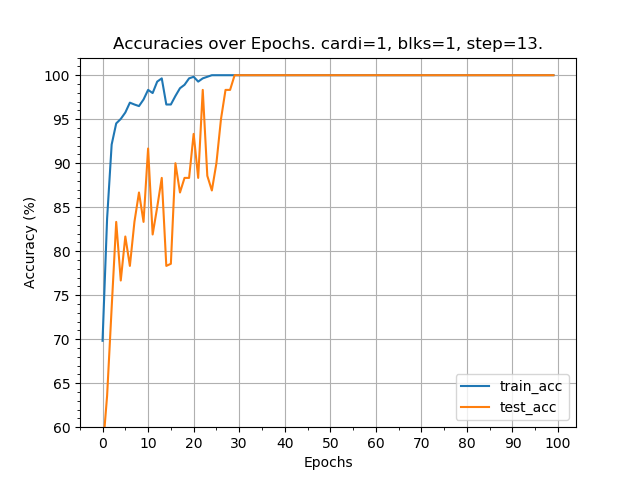
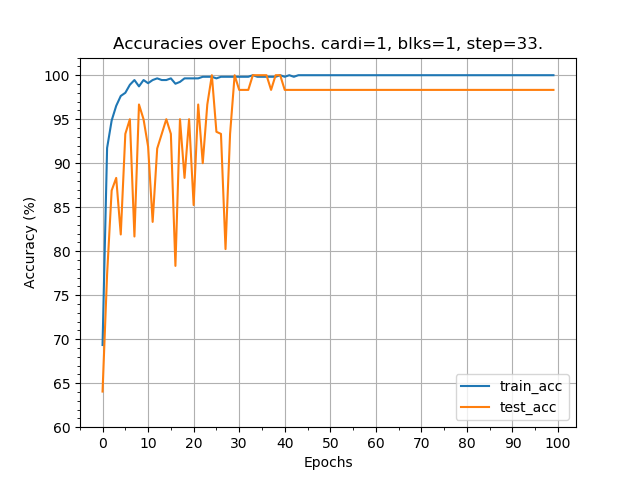
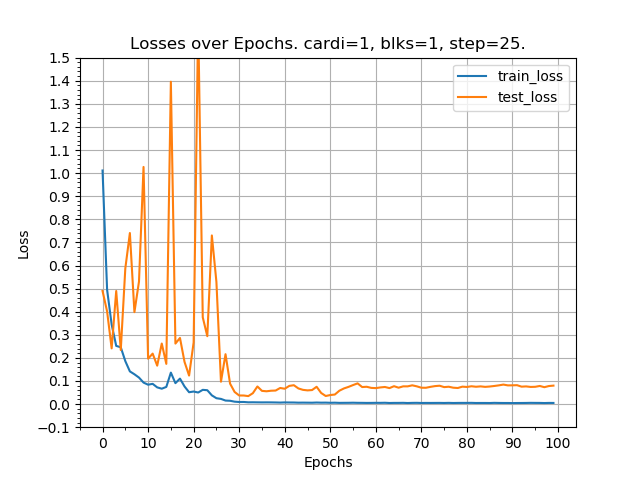
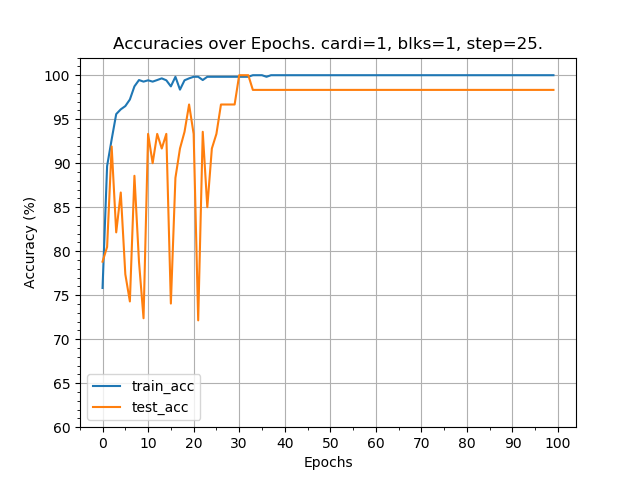
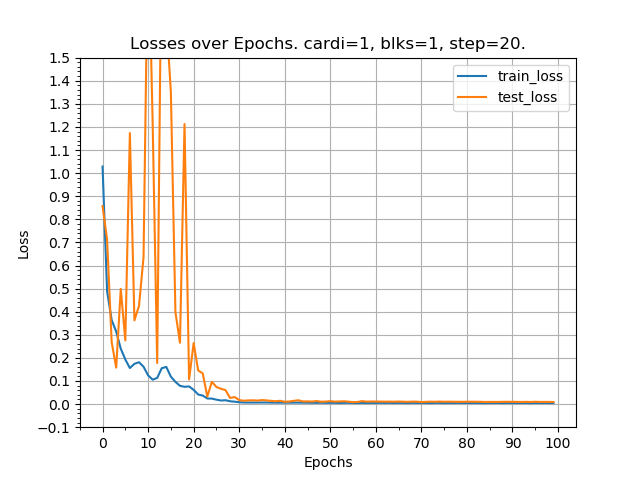
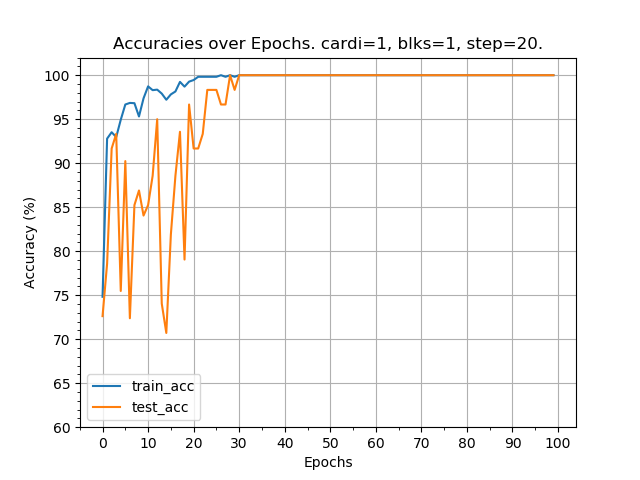
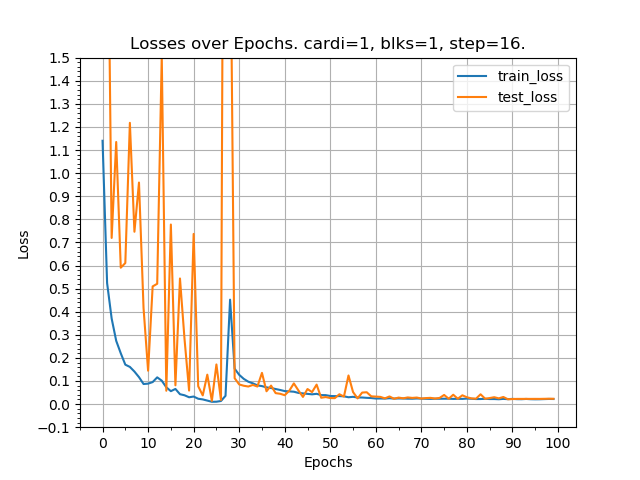
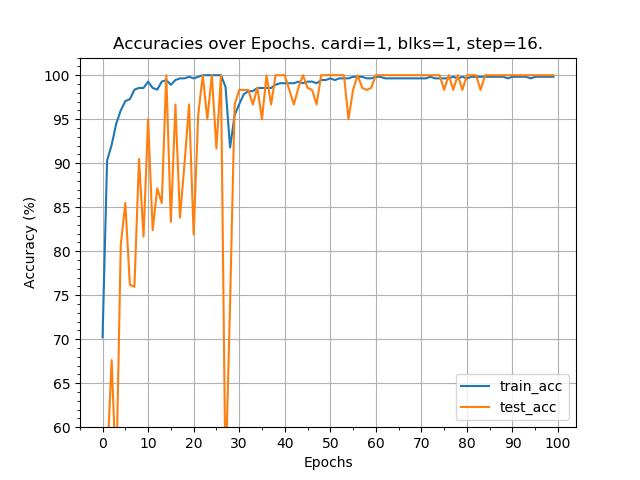
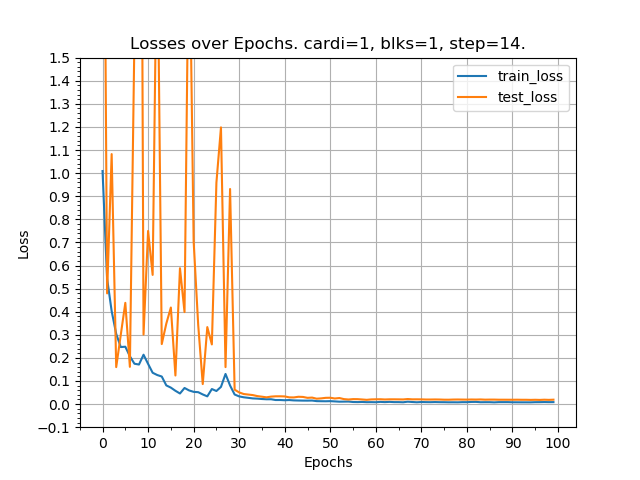
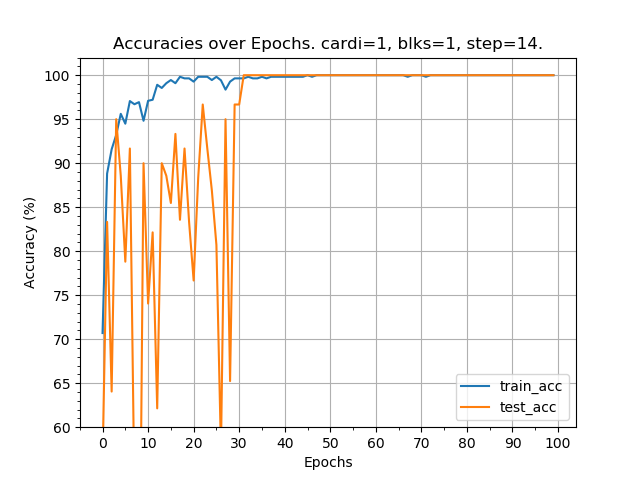
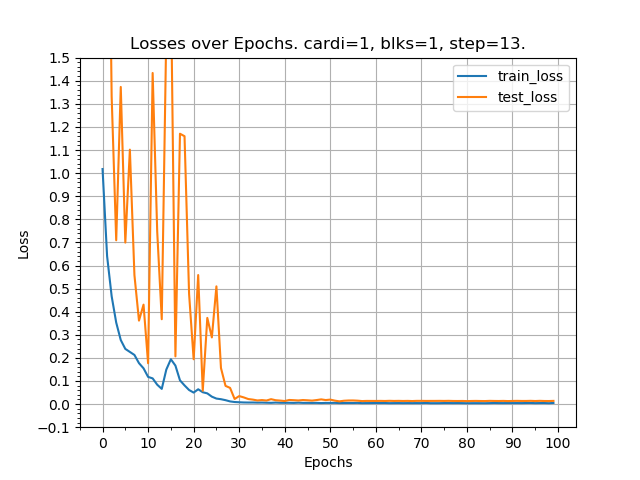
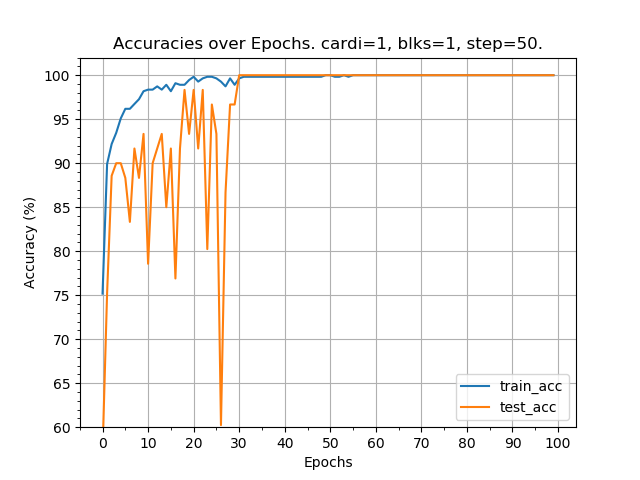
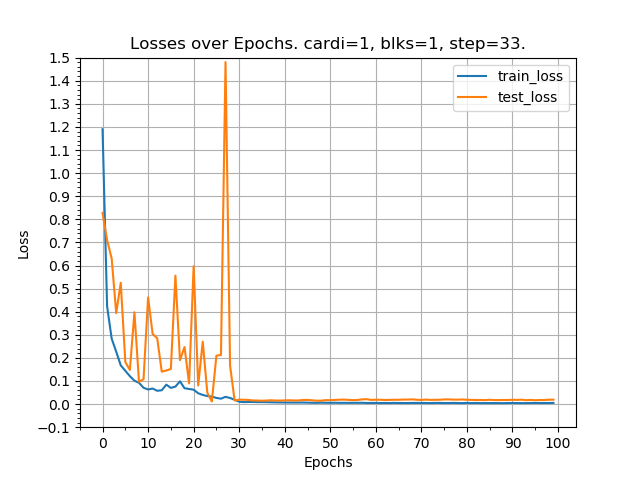
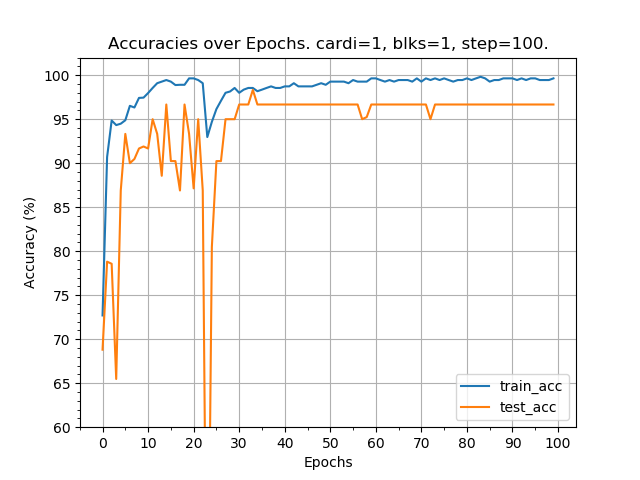
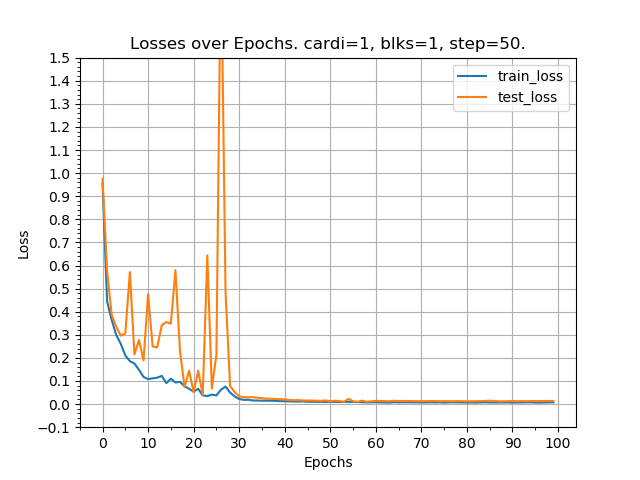
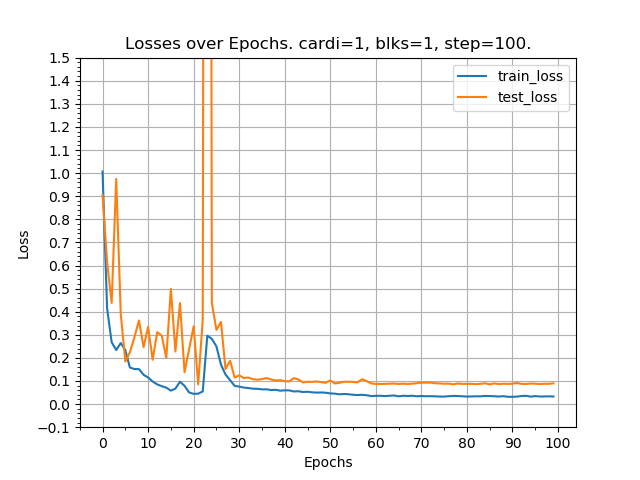
    

Figure 13: The neural network has fixed cardinality being 1 and fixed number of building blocks in each residual layer being 1. The spectral steps changes from 13 to 100 nonlinearly. Accuracies and losses of training and testing during the first 100 epochs are plotted for each spectral step.

In Figure 14, The neural network has fixed cardinality being 1 and the spectral step is fixed to be 100. The number of building blocks changes from 1 to 2. The final testing accuracies at 100th epoch for both neural networks are 96.67%. The final training loss and testing loss for the neural network with only 1 building block for each residual layer are 0.0330 and 0.0899. The training accuracy for it is 99.64%. By comparison, these three metrics for the neural network with 2 building blocks for each residual layer are 0.0053, 0.0698, and 100%. It is clear that more builidng blocks give better performance overall. This is within expectation because more builiding blocks means a more complex and thus pwoerful neural network.

Similar to the situation when input data becomes larger, for the neural network with more builidng blocks, both the accuracy plot and the loss plot show more intense fluctuation before reaching its optimum.

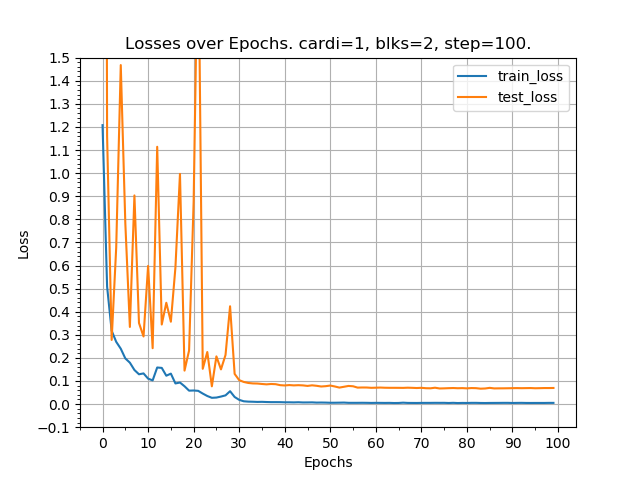
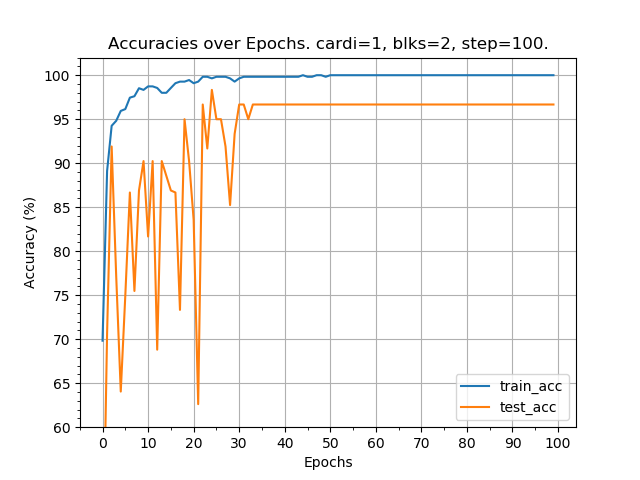
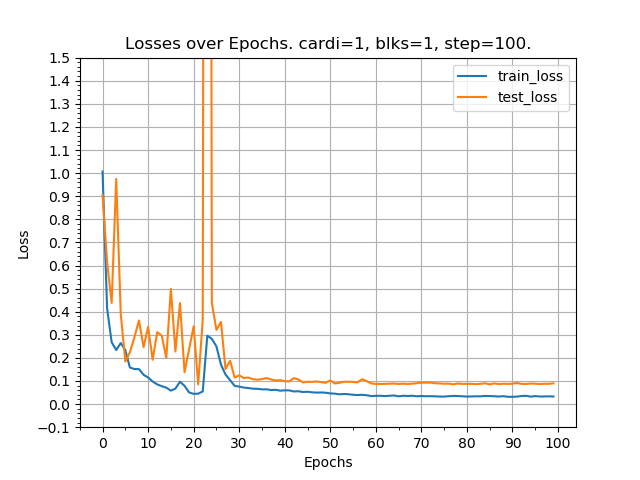
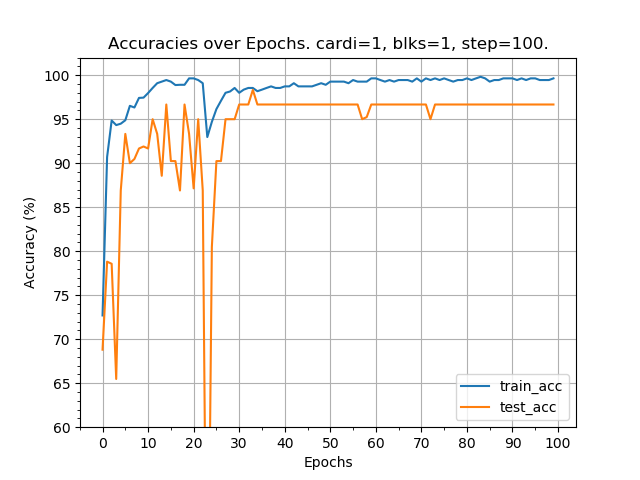


Figure 14: The neural network has fixed cardinality being 1 and the spectral step is fixed to be 100. The number of building blocks changes from 1 to 2. Accuracies and losses of training and testing during the first 100 epochs are plotted for each spectral step.

In Figure 15, The neural network has fixed number of building blocks being 1 and the spectral step is fixed to be 100. The cardinality changes from 1 to 2 and to 3. The final testing accuracies at 100th epoch for all three are 96.67%, 100%, and 98.33%. The final training accurcacies are 99.64%, 100%, and 100%. The final testing lossses are 0.0899, 0.0210, and 0.0393. The final training losses are 0.0330, 0.0069, and 0.0060. Undoubtedly, increasing cardinality gives better performance, especially for the training aspect. This is within expectation because larger cardinality means a more complex and thus pwoerful neural network.

Contrary to previous two parameters, as the complexity of the model and computation increases here, which is indicated by increasing cardinality, both the accuracy plot and the loss plot show less fluctuation before reaching its optimum.

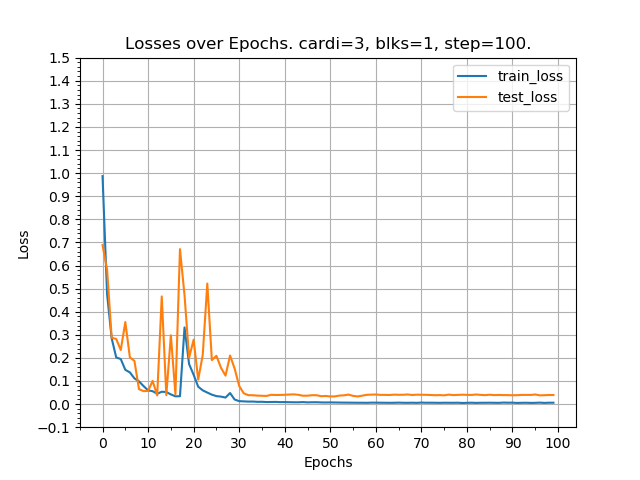
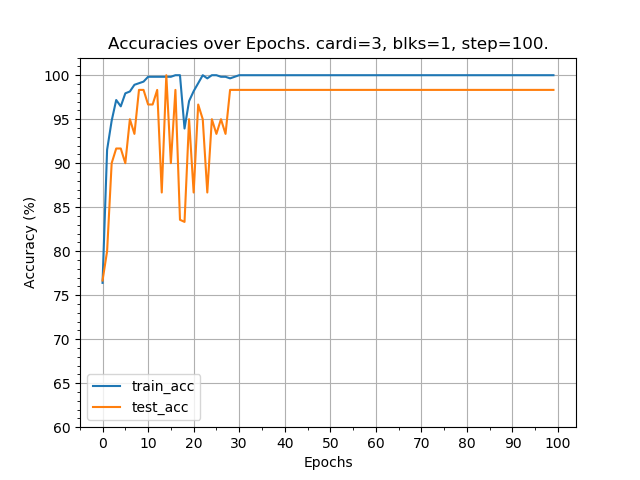
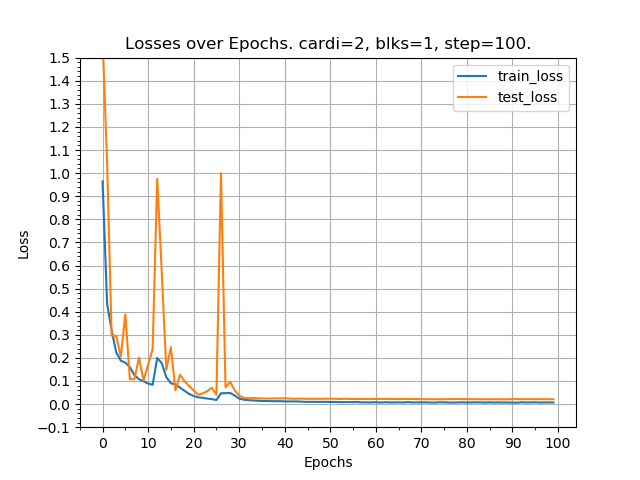
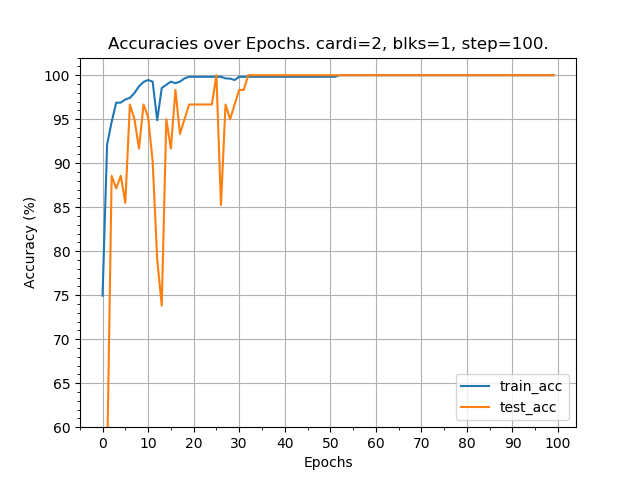
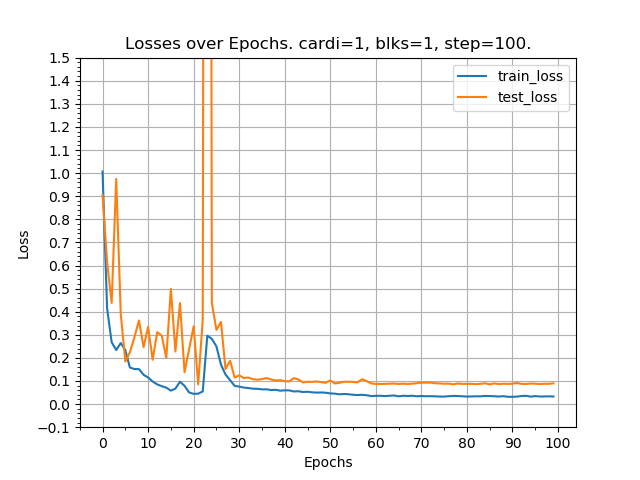
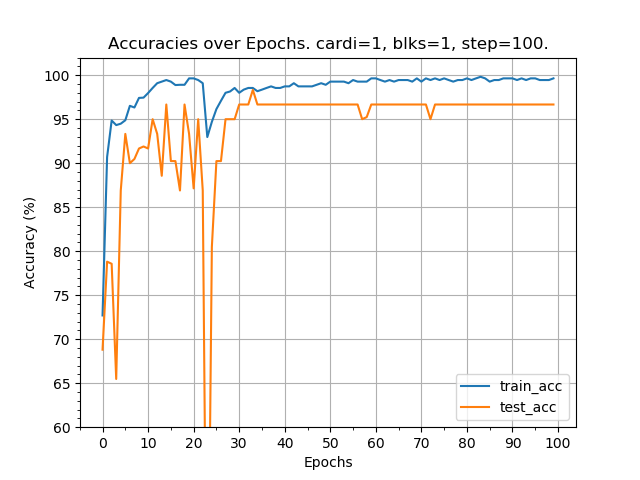


Figure 15: The neural network has fixed number of building blocks being 1 and the spectral step is fixed to be 100. The cardinality changes from 1 to 2 and to 3. Accuracies and losses of training and testing during the first 100 epochs are plotted for each spectral step.

**Conclusion**

Making the neural network more complex, here by increasing cardinality and number of building blocks, and enlarging the size of information held by the dataset, here by decreasing the spectral steps, are correct directions of generating an accurate prediction model. Do note that, the least powerful neural network fed with the dataset with smallest information already performs outstandingly overall.

For the purpose of applying machine learning techniques to solve specific problems, one should use existing implementations whenever possible. Because for past concepts, there are always people who have built those wheels. Those well-maintained and popularly recommended codes are proven to be working smoothly. One should not spend too much time building an existing wheel. Instead, time should be better devoted to find out solution to the problem at hand.

Nowadays the neural network architectures are very well developed and polished. A popular neural network can be very powerful even after being simplified. When computational resources are limited, one should not be afraid to simplify the model. In some cases, data can even be down sampled. The task is very likely to be accomplished successfully with these seemingly deteriorating conditions.

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