Homework 2(Part 2) – Yutae Lee (CSCE 636 – 600)

10/20/2022

Problem 6

All implemented in the zip file called HW2_Yutae_Lee.zip. The data was acquired from https://www.cs.toronto.edu/~kriz/cifar.html (Used cifar-10-python.tar.gz file).

Explanation of the code:

a) After downloading the file and unzipping the tar.gz file, I distributed all the data_batch_# files into a folder named training and put the test_batch file into a folder named testing. Then, using os.listdir function I inputted every training data into list named x_train_list, y_train_list and test data into a list named x_test_list, y_test_list. As I was doing that I had to use the starter code (one that uses pickle) that was given from the https://www.cs.toronto.edu/~kriz/cifar.html in order to successfully load the file.

b) In "ImageUtils.py" file, I had to preprocess the image data by adding 4 extra pixels of zero padding on both sides of the data. I did that by first making a np.zero of height + 8 and weight + 8. And then add the values of the image in the middle of the data. Then I had to pick random x,y (in the code I used numbers only up to 9) to pick starting point where we can start the 32x32 crops. Then I added random_flip to decide if we should horizontally flip the data or not.

c) In "NetWork.py" file, the job was to implement two versions of ResNet (standard, bottleneck):

First, in the standard residual blocks, I made a model with 2 convolution layers which both intakes in_channels as given filters and out_channels as given filters. After the convolution, the model is continued by batch normalization which the number of filters should be the same as out_channels of the convolution layer.

Second, in the bottleneck(pre-activation) residual blocks, I made 3 convolution layers which are different from each other unlike standard one. First layer will intake the given filter with out_filter with filter // 4. Second layer will intake and output filter // 4. Third layer will intake filter//4 and output with the size that has been given.

d) Next in the "Model.py" file, I had to make a model that trains and test. There I had to optimize my model according to cross entropy loss. And in the train function I had to set the learning rate as well as implement the parse_record function that I made in ImageUtils.py

e) Lastly I tuned hyperparameters such as resnet_version(standard,bottleneck), resnet_size, batch_size etc. After running codes with few variation of parameters the parameters I

choosed resnet_size of 5, 10 number of classes and 16 initial number of filters. Also because of the technical limits, I was able to run the code up to 50 epochs.

Below is the testing result of the two versions with the parameters with 50 epochs that was chosen above:

Version / Set Type	Standard ResNet	Bottleneck ResNet
x_valid, y_valid	0.7674	0.7622
x_test, y_test	0.7969	0.7733

The reason why I have chosen 50 epochs (which is the maximum number of epochs that I tried) is because when running the training I saw as epochs increases the loss number decreases. This is mainly because as we use more epochs, we would have more chance that the weight is changed optimally to the data. However just concluding that more number epoch is better because testing accuracy rises may be dangerous because it may cause an overfitting problem for our data. Also looking at the table we are able to see that in general x_valid, y_valid that we created by our own train_test_split had lower accuracy than the original x_test and y_test. This is because we tested x_test and y_test after retraining the original x_train and y_train which was after training the x_train_new and y_train_new. Also one that stands out to me is that Standard ResNet, although it had little difference when we are testing the original sets, were nearly identical to the Bottleneck.

In the next page, I have included the screenshots of my testing and training results as an appendix.

Appendix

Version 1 (Standard Residual Block):

First step,

```
--- Preparing Data ---
Train data X and Y shape: x_train: (50000, 3072) , y_tr
Test data X and Y shape: x_test: (10000, 3072) , y_test
Resnet version:  1 , Standard Resnet layer
### Training... ###
/content/drive/My Drive/Colab Notebooks/HW2/Model.py:62
.ndarray with numpy.array() before converting to a tens
  x_batch_tensor = torch.tensor(x_batch).float().cuda()
Epoch 1 Loss 2.107333 Duration 38.749 seconds.
Epoch 2 Loss 2.075870 Duration 36.544 seconds.
Epoch 3 Loss 2.017302 Duration 36.733 seconds.
Epoch 4 Loss 1.981671 Duration 36.595 seconds.
Epoch 5 Loss 1.971205 Duration 38.192 seconds.
Checkpoint has been created.
Epoch 6 Loss 1.923281 Duration 36.756 seconds.
Epoch 7 Loss 1.858972 Duration 36.685 seconds.
Epoch 8 Loss 1.802495 Duration 36.705 seconds.
Epoch 9 Loss 1.950325 Duration 36.717 seconds.
Epoch 10 Loss 1.889709 Duration 36.834 seconds.
Checkpoint has been created.
Epoch 11 Loss 1.807378 Duration 37.033 seconds.
Epoch 12 Loss 1.894549 Duration 37.485 seconds.
Epoch 13 Loss 1.805064 Duration 36.697 seconds.
Epoch 14 Loss 1.806318 Duration 36.568 seconds.
Epoch 15 Loss 1.827565 Duration 36.760 seconds.
Checkpoint has been created.
Epoch 16 Loss 1.740083 Duration 36.619 seconds.
Epoch 17 Loss 1.723925 Duration 36.616 seconds.
Epoch 18 Loss 1.727167 Duration 38.032 seconds.
Epoch 19 Loss 1.766595 Duration 36.674 seconds.
Epoch 20 Loss 1.781106 Duration 36.827 seconds.
Checkpoint has been created.
Epoch 21 Loss 1.762328 Duration 36.685 seconds.
Epoch 22 Loss 1.725868 Duration 36.702 seconds.
Epoch 23 Loss 1.693273 Duration 36.782 seconds.
Epoch 24 Loss 1.705346 Duration 38.070 seconds.
Epoch 25 Loss 1.735546 Duration 36.881 seconds.
Checkpoint has been created.
```

```
Epoch 26 Loss 1.736058 Duration 36.535 seconds.
Epoch 27 Loss 1.694587 Duration 36.733 seconds.
Epoch 28 Loss 1.631336 Duration 36.589 seconds.
Epoch 29 Loss 1.709680 Duration 36.743 seconds.
Epoch 30 Loss 1.632481 Duration 37.991 seconds.
Checkpoint has been created.
Epoch 31 Loss 1.717270 Duration 36.680 seconds.
Epoch 32 Loss 1.726854 Duration 36.429 seconds.
Epoch 33 Loss 1.760957 Duration 36.554 seconds.
Epoch 34 Loss 1.704938 Duration 36.453 seconds.
Epoch 35 Loss 1.639373 Duration 36.433 seconds.
Checkpoint has been created.
Epoch 36 Loss 1.681496 Duration 37.996 seconds.
Epoch 37 Loss 1.674469 Duration 36.348 seconds.
Epoch 38 Loss 1.651201 Duration 36.314 seconds.
Epoch 39 Loss 1.723591 Duration 36.742 seconds.
Epoch 40 Loss 1.668741 Duration 36.493 seconds.
Checkpoint has been created.
Epoch 41 Loss 1.660923 Duration 36.405 seconds.
Epoch 42 Loss 1.619832 Duration 37.978 seconds.
Epoch 43 Loss 1.651995 Duration 36.617 seconds.
Epoch 44 Loss 1.641201 Duration 36.709 seconds.
Epoch 45 Loss 1.683738 Duration 36.702 seconds.
Checkpoint has been created.
Epoch 46 Loss 1.677817 Duration 36.482 seconds.
Epoch 47 Loss 1.678778 Duration 36.862 seconds.
Epoch 48 Loss 1.690432 Duration 37.986 seconds.
Epoch 49 Loss 1.685136 Duration 36.825 seconds.
Epoch 50 Loss 1.626292 Duration 36.713 seconds.
Checkpoint has been created.
```

Testing results:

```
### Test or Validation ###
Restored model parameters from model_v1/model-10.ckpt
100%|████████████████████████████████████████████████████████████| 5000/5000 [00:28<00:00, 176.15it/s]
Test accuracy: 0.4800
Restored model parameters from model_v1/model-20.ckpt
100%|████████████████████████████████████████████████████████████| 5000/5000 [00:28<00:00, 175.71it/s]
/content/drive/My Drive/Colab Notebooks/HW2/Model.py:97: UserWarning: To copy construct from a tensor, it is recommended to use sourceTensor.clone().detach() or sourceTensor.clone().detach()
.requires_grad_(True), rather than torch.tensor(sourceTensor).
  y = torch.tensor(y)
Test accuracy: 0.6668
Restored model parameters from model_v1/model-30.ckpt
100%|████████████████████████████████████████████████████████████| 5000/5000 [00:28<00:00, 177.15it/s]
Test accuracy: 0.7112
Restored model parameters from model_v1/model-40.ckpt
100%|████████████████████████████████████████████████████████████| 5000/5000 [00:28<00:00, 174.84it/s]
Test accuracy: 0.7420
Restored model parameters from model_v1/model-50.ckpt
100%|████████████████████████████████████████████████████████████| 5000/5000 [00:29<00:00, 170.86it/s]
Test accuracy: 0.7674
```

Second step,

```
### Training... ###
Epoch 1 Loss 1.622694 Duration 40.806 seconds.
Epoch 2 Loss 1.664940 Duration 40.467 seconds.
Epoch 3 Loss 1.665814 Duration 40.655 seconds.
Epoch 4 Loss 1.716745 Duration 40.553 seconds.
Epoch 5 Loss 1.714731 Duration 40.645 seconds.
Checkpoint has been created.
Epoch 6 Loss 1.654044 Duration 42.368 seconds.
Epoch 7 Loss 1.663400 Duration 40.799 seconds.
Epoch 8 Loss 1.677845 Duration 40.755 seconds.
Epoch 9 Loss 1.680647 Duration 41.070 seconds.
Epoch 10 Loss 1.607496 Duration 40.807 seconds.
Checkpoint has been created.
Epoch 11 Loss 1.660562 Duration 42.381 seconds.
Epoch 12 Loss 1.598896 Duration 40.892 seconds.
Epoch 13 Loss 1.656131 Duration 40.950 seconds.
Epoch 14 Loss 1.646467 Duration 40.865 seconds.
Epoch 15 Loss 1.632150 Duration 41.072 seconds.
Checkpoint has been created.
Epoch 16 Loss 1.583964 Duration 42.668 seconds.
Epoch 17 Loss 1.598782 Duration 41.185 seconds.
Epoch 18 Loss 1.658527 Duration 41.042 seconds.
Epoch 19 Loss 1.633568 Duration 40.837 seconds.
Epoch 20 Loss 1.661293 Duration 40.964 seconds.
Checkpoint has been created.
Epoch 21 Loss 1.631131 Duration 41.312 seconds.
Epoch 22 Loss 1.642064 Duration 42.506 seconds.
Epoch 23 Loss 1.634360 Duration 41.417 seconds.
Epoch 24 Loss 1.655838 Duration 41.081 seconds.
Epoch 25 Loss 1.619540 Duration 40.956 seconds.
```

```
Epoch 26 Loss 1.608370 Duration 41.197 seconds.
Epoch 27 Loss 1.637147 Duration 42.590 seconds.
Epoch 28 Loss 1.653623 Duration 41.159 seconds.
Epoch 29 Loss 1.668112 Duration 41.153 seconds.
Epoch 30 Loss 1.655049 Duration 41.238 seconds.
Checkpoint has been created.
Epoch 31 Loss 1.635193 Duration 40.917 seconds.
Epoch 32 Loss 1.598102 Duration 42.511 seconds.
Epoch 33 Loss 1.666027 Duration 41.060 seconds.
Epoch 34 Loss 1.615457 Duration 41.233 seconds.
Epoch 35 Loss 1.602206 Duration 41.072 seconds.
Checkpoint has been created.
Epoch 36 Loss 1.623678 Duration 41.058 seconds.
Epoch 37 Loss 1.679138 Duration 42.412 seconds.
Epoch 38 Loss 1.644798 Duration 40.913 seconds.
Epoch 39 Loss 1.677826 Duration 40.787 seconds.
Epoch 40 Loss 1.622072 Duration 40.923 seconds.
Checkpoint has been created.
Epoch 41 Loss 1.650060 Duration 41.003 seconds.
Epoch 42 Loss 1.695109 Duration 42.199 seconds.
Epoch 43 Loss 1.626593 Duration 41.200 seconds.
Epoch 44 Loss 1.647925 Duration 40.932 seconds.
Epoch 45 Loss 1.600095 Duration 41.354 seconds.
Checkpoint has been created.
Epoch 46 Loss 1.626074 Duration 41.102 seconds.
Epoch 47 Loss 1.631339 Duration 42.268 seconds.
Epoch 48 Loss 1.602855 Duration 40.816 seconds.
Epoch 49 Loss 1.602810 Duration 40.799 seconds.
Epoch 50 Loss 1.659787 Duration 40.936 seconds.
Checkpoint has been created.
```

Third step,

Testing results:

```
### Test or Validation ###
Restored model parameters from model_v1/model-50.ckpt
100%|████████████████████████████████████████████████████████████████████████████| 10000/10000 [00:57<00:00, 174.91it/s]
Test accuracy: 0.7969
```

Version 2 (Bottleneck):

First step,

```
  x_batch_tensor = torch.tensor(x_batch).float().cuda()
Epoch 1 Loss 2.064010 Duration 70.618 seconds.
Epoch 2 Loss 2.083178 Duration 63.448 seconds.
Epoch 3 Loss 1.966496 Duration 64.392 seconds.
Epoch 4 Loss 1.999337 Duration 64.684 seconds.
Epoch 5 Loss 1.989098 Duration 63.550 seconds.
Checkpoint has been created.
Epoch 6 Loss 1.924633 Duration 64.106 seconds.
Epoch 7 Loss 1.803744 Duration 65.134 seconds.
Epoch 8 Loss 1.854455 Duration 63.442 seconds.
Epoch 9 Loss 1.838723 Duration 63.211 seconds.
Epoch 10 Loss 1.832903 Duration 64.968 seconds.
Checkpoint has been created.
Epoch 11 Loss 1.792530 Duration 62.932 seconds.
Epoch 12 Loss 1.857781 Duration 63.627 seconds.
Epoch 13 Loss 1.759240 Duration 64.262 seconds.
Epoch 14 Loss 1.784272 Duration 63.058 seconds.
Epoch 15 Loss 1.744015 Duration 63.219 seconds.
Checkpoint has been created.
Epoch 16 Loss 1.813801 Duration 64.234 seconds.
Epoch 17 Loss 1.786372 Duration 63.722 seconds.
Epoch 18 Loss 1.762522 Duration 63.559 seconds.
Epoch 19 Loss 1.715832 Duration 63.783 seconds.
Epoch 20 Loss 1.696882 Duration 64.402 seconds.
Checkpoint has been created.
Epoch 21 Loss 1.747748 Duration 63.668 seconds.
Epoch 22 Loss 1.786425 Duration 63.824 seconds.
Epoch 23 Loss 1.760835 Duration 64.333 seconds.
Epoch 24 Loss 1.798489 Duration 63.275 seconds.
Epoch 25 Loss 1.717533 Duration 63.280 seconds.
Checkpoint has been created.
```

```
Epoch 26 Loss 1.726478 Duration 64.264 seconds.
Epoch 27 Loss 1.691685 Duration 63.401 seconds.
Epoch 28 Loss 1.710429 Duration 63.246 seconds.
Epoch 29 Loss 1.653743 Duration 64.458 seconds.
Epoch 30 Loss 1.671315 Duration 62.930 seconds.
Checkpoint has been created.
Epoch 31 Loss 1.717764 Duration 62.878 seconds.
Epoch 32 Loss 1.668558 Duration 64.107 seconds.
Epoch 33 Loss 1.700345 Duration 63.294 seconds.
Epoch 34 Loss 1.674975 Duration 63.202 seconds.
Epoch 35 Loss 1.670164 Duration 64.250 seconds.
Checkpoint has been created.
Epoch 36 Loss 1.692845 Duration 63.131 seconds.
Epoch 37 Loss 1.675929 Duration 62.992 seconds.
Epoch 38 Loss 1.677669 Duration 64.359 seconds.
Epoch 39 Loss 1.661206 Duration 63.190 seconds.
Epoch 40 Loss 1.671650 Duration 63.299 seconds.
Checkpoint has been created.
Epoch 41 Loss 1.675583 Duration 64.540 seconds.
Epoch 42 Loss 1.672953 Duration 63.413 seconds.
Epoch 43 Loss 1.651433 Duration 63.459 seconds.
Epoch 44 Loss 1.680889 Duration 64.226 seconds.
Epoch 45 Loss 1.667001 Duration 63.449 seconds.
Checkpoint has been created.
Epoch 46 Loss 1.666154 Duration 63.403 seconds.
Epoch 47 Loss 1.663211 Duration 64.312 seconds.
Epoch 48 Loss 1.662832 Duration 63.591 seconds.
Epoch 49 Loss 1.643954 Duration 63.386 seconds.
Epoch 50 Loss 1.621341 Duration 65.172 seconds.
Checkpoint has been created.
```

Testing results:

```
### Test or Validation ###
Restored model parameters from model_v1/model-10.ckpt
100%|| 5000/5000 [00:41<00:00, 121.40it/s]
Test accuracy: 0.5934
Restored model parameters from model_v1/model-20.ckpt
100%|| 5000/5000 [00:41<00:00, 121.76it/s]
/content/drive/MyDrive/Colab Notebooks/HW2/Model.py:97: UserWarning: To copy construct from a tensor, it is recommended to use sourceTensor.clone().detach() or sourceTensor.clone().detach().
requires_grad_(True), rather than torch.tensor(sourceTensor).
  y = torch.tensor(y)
Test accuracy: 0.6754
Restored model parameters from model_v1/model-30.ckpt
100%|| 5000/5000 [00:40<00:00, 122.47it/s]
Test accuracy: 0.7296
Restored model parameters from model_v1/model-40.ckpt
100%|| 5000/5000 [00:42<00:00, 118.45it/s]
Test accuracy: 0.7774
Restored model parameters from model_v1/model-50.ckpt
100%|| 5000/5000 [00:40<00:00, 122.13it/s]
Test accuracy: 0.7622
```

Second step:

```
Epoch 1 Loss 1.620794 Duration 70.318 seconds.
Epoch 2 Loss 1.661672 Duration 70.032 seconds.
Epoch 3 Loss 1.669976 Duration 71.877 seconds.
Epoch 4 Loss 1.599193 Duration 70.770 seconds.
Epoch 5 Loss 1.690351 Duration 72.882 seconds.
Checkpoint has been created.
Epoch 6 Loss 1.711099 Duration 72.115 seconds.
Epoch 7 Loss 1.674995 Duration 72.957 seconds.
Epoch 8 Loss 1.680366 Duration 73.489 seconds.
Epoch 9 Loss 1.667848 Duration 71.872 seconds.
Epoch 10 Loss 1.699731 Duration 72.622 seconds.
Checkpoint has been created.
Epoch 11 Loss 1.668181 Duration 71.410 seconds.
Epoch 12 Loss 1.710662 Duration 71.234 seconds.
Epoch 13 Loss 1.648327 Duration 72.488 seconds.
Epoch 14 Loss 1.662166 Duration 71.768 seconds.
Epoch 15 Loss 1.619443 Duration 71.970 seconds.
Checkpoint has been created.
Epoch 16 Loss 1.611636 Duration 72.193 seconds.
Epoch 17 Loss 1.681040 Duration 71.733 seconds.
Epoch 18 Loss 1.653355 Duration 72.629 seconds.
Epoch 19 Loss 1.681038 Duration 71.778 seconds.
Epoch 20 Loss 1.591177 Duration 71.500 seconds.
Checkpoint has been created.
Epoch 21 Loss 1.647784 Duration 71.914 seconds.
Epoch 22 Loss 1.631090 Duration 70.472 seconds.
Epoch 23 Loss 1.634093 Duration 71.753 seconds.
Epoch 24 Loss 1.636091 Duration 73.269 seconds.
Epoch 25 Loss 1.623426 Duration 70.876 seconds.
Checkpoint has been created.
```

```
Epoch 26 Loss 1.620472 Duration 71.877 seconds.
Epoch 27 Loss 1.642470 Duration 70.850 seconds.
Epoch 28 Loss 1.640624 Duration 72.047 seconds.
Epoch 29 Loss 1.642105 Duration 70.881 seconds.
Epoch 30 Loss 1.625110 Duration 70.824 seconds.
Checkpoint has been created.
Epoch 31 Loss 1.607425 Duration 71.865 seconds.
Epoch 32 Loss 1.669642 Duration 71.031 seconds.
Epoch 33 Loss 1.626505 Duration 72.355 seconds.
Epoch 34 Loss 1.630418 Duration 71.142 seconds.
Epoch 35 Loss 1.578228 Duration 70.896 seconds.
Checkpoint has been created.
Epoch 36 Loss 1.630462 Duration 72.260 seconds.
Epoch 37 Loss 1.651142 Duration 71.015 seconds.
Epoch 38 Loss 1.614355 Duration 71.816 seconds.
Epoch 39 Loss 1.590316 Duration 70.494 seconds.
Epoch 40 Loss 1.662004 Duration 70.406 seconds.
Checkpoint has been created.
Epoch 41 Loss 1.588571 Duration 71.365 seconds.
Epoch 42 Loss 1.590914 Duration 70.210 seconds.
Epoch 43 Loss 1.622784 Duration 71.259 seconds.
Epoch 44 Loss 1.617389 Duration 70.173 seconds.
Epoch 45 Loss 1.651695 Duration 70.061 seconds.
Checkpoint has been created.
Epoch 46 Loss 1.689515 Duration 71.031 seconds.
Epoch 47 Loss 1.655907 Duration 70.019 seconds.
Epoch 48 Loss 1.604846 Duration 71.514 seconds.
Epoch 49 Loss 1.630259 Duration 71.384 seconds.
Epoch 50 Loss 1.592499 Duration 71.270 seconds.
Checkpoint has been created.
```

Third step:

Testing results: