Project 0: Convolutional Neural Network

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1. **Optimization of LeNet**

   In order to achieve the test_accuracy > 70%, I adjusted the learning_rate and epochs. When setting learning_rate = 3e-3, epochs = 80, the final test_accuracy got close to 78%. Below are two figures of training loss and test accuracy over epochs:

Figure 1. Training loss over epochs

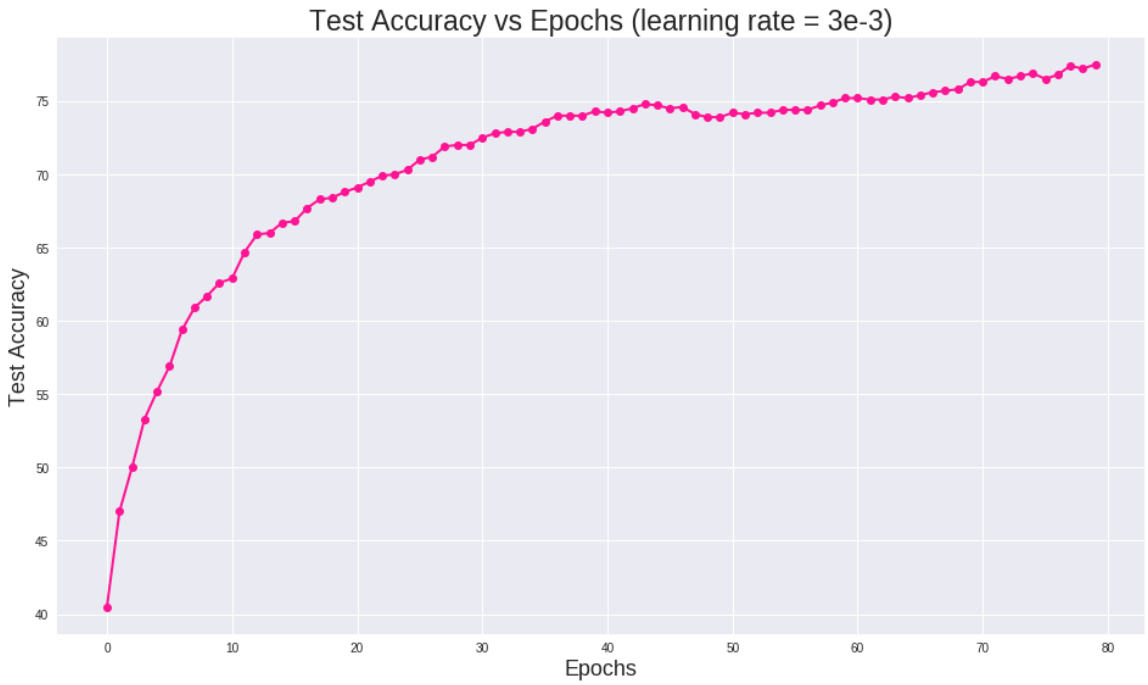

Figure 2. Test accuracy over epochs

From the figure 1, we can find that the training loss decreases from about 1.8 to 0.3 smoothly. And in figure 2, the test accuracy increases from about 40% to 78%, with some slight fluctuations in later phase. When adjusting learning rate, in one hand, it should not be too large, or we will get wrong results with training loss as nan. In other hand, the learning rate should not be too small, as that will lead to local optimum and the test accuracy may stuck at some point.

2. Alteration of LeNet

We need to adjust the filter size in block 5 according to the previous layers. Then we can adjust learning rate and epochs to get the best test accuracy for each alteration of LeNet. The results are shown in table 1.

Table 1. Compare performance of different LeNet

	Filter Size in Block 5	Learning Rate	Epochs	Test Accuracy
Block 1	16 x 16 x 32 x 10	3e-3	80	66.80%
Block 1 & Block 2	8 x 8 x 32 x 10			74.00%
Block 1 & Block 2 & Block 3	4 x 4 x 64 x 10			76.50%
All Blocks (1~5)	1 x 1 x 64 x 10			77.90%

From the table above, we can find that with the same values of learning rate and epochs, the first alteration (Block 1 + Block 5) has the lowest test accuracy, and the third alteration

(Block 1 + Block 2 + Block 3 + Block 5) achieves the highest test accuracy (76.50%) in all alterations of LeNet. And all those three alterations have lower accuracies than that of all blocks. Thus, we can infer that with more blocks (layers, but not too many) in ConvNet, higher test accuracies we can get. This conclusion is intuitive. Adding more blocks can retain more information and features in the image, because we can use smaller size of filters and strides so that to keep consecutiveness of each area.

3. Visualization of Filters and Activations

a) The learned 32 filters of the first convolutional layer in LeNet are as below:

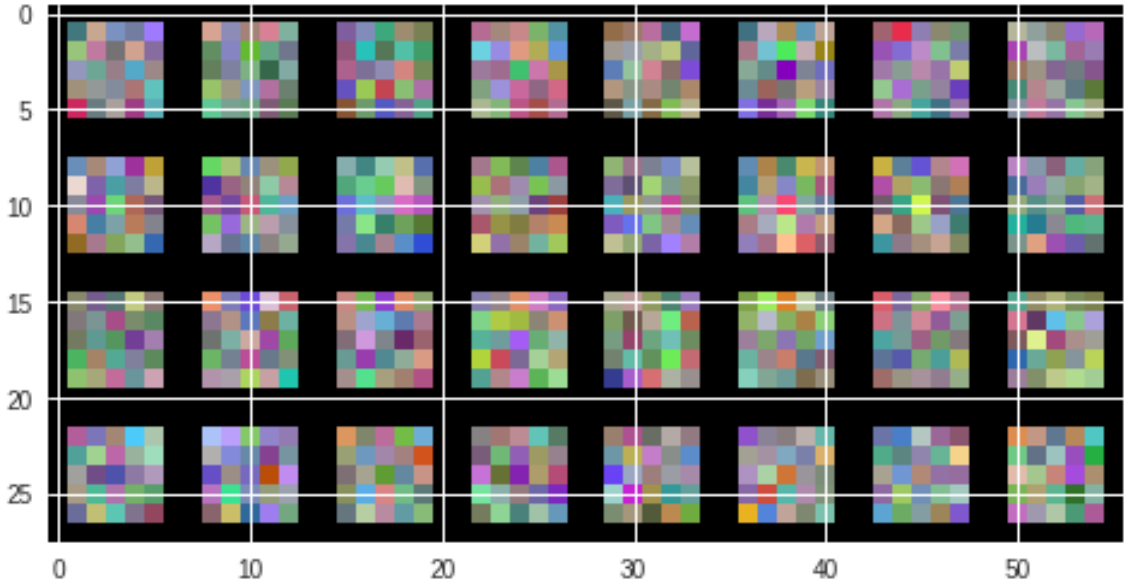

Figure 3. Learned 32 filters of the first convolutional layer

b) The filter response maps for the given sample image of CIFAR – 10 are as below:

Figure 4. Given sample image

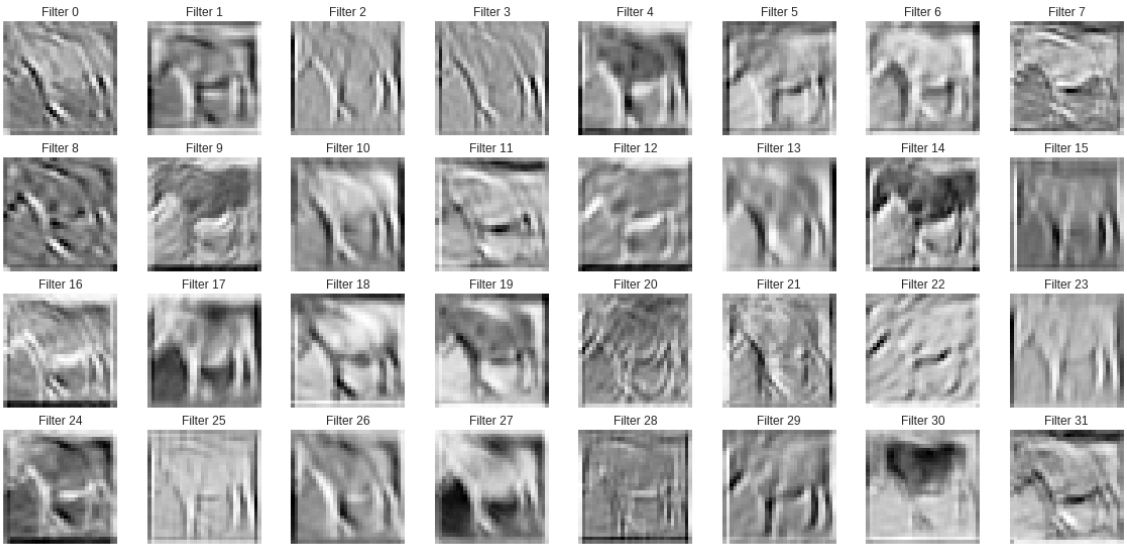

Figure 5. Filter response maps for the given sample image