Lab Assignment 2
CSCI 5992 - Neural Networks and Deep Learning

Rajeev R Menon - 110581437

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Problem 1

The dataset used for this experiment is the CIFAR-10 dataset. It consists of 60000 color images of dimension 32 x 32. It consists of 10 classes with 6000 images each. All the classes are mutually exclusive and there are no overlaps between any of them.

The experiment was conducted on a 14-inch MacBook Pro with an 8-core M1 Pro CPU. The dataset was split into three - training (70%), validation (15%), and test (15%) datasets. A total of eight different models were trained using a combination of two different architectures along with various regularization techniques.

The first architecture consisted of 2 convolutional layers with 16 filters each using the ReLU activation function. The second architecture consisted of 4 convolutional layers using the ReLU activation function with 16 filters each. The convolutional layers in both architectures were followed by max-pooling layers and two fully connected layers employing ReLU and softmax activation functions. Both the architectures were combined with no regularization, batch normalization, dropout, and L2 regularization to create 8 different models as shown in 1. Adam algorithm was used for optimization and the learning rate was set to the default value of 0.001. A categorical cross-entropy loss function was used to train all models. All the models were trained for 30 epochs using the Keras library for Tensorflow in Python and accuracy was plotted against the number of epochs as shown in [4].

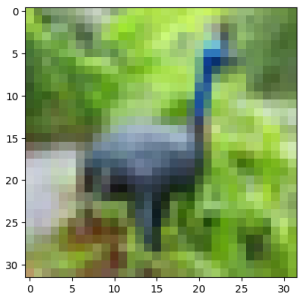

Figure 1: Random image chosen from dataset

Model	Convolutional Layers	Regularization	Training time (s)	Training accuracy	Validation accuracy
Model 1	2 layers with 16 filters each	No regularization	136	0.82	0.65
Model 2	2 layers with 16 filters each	Batch Normalization	154	0.93	0.62
Model 3	2 layers with 16 filters each	Dropout	135	0.53	0.52
Model 4	2 layers with 16 filters each	L2 regularization	115	0.85	0.67
Model 5	4 layers with 16 filters each	No regularization	133	0.61	0.59
Model 6	4 layers with 16 filters each	Batch Normalization	160	0.66	0.60
Model 7	4 layers with 16 filters each	Dropout	149	0.28	0.15
Model 8	4 layers with 16 filters each	L2 regularization	134	0.58	0.56

Table 1: Models trained

It was observed that the best validation accuracy was provided by the first architecture with 2 convolutional layers and L2 regularization of each layer. L2 regularization helps in optimizing the mean cost. The better performance of L2 regularization may be attributed to the absence of not many outliers within the dataset. Batch normalization in the first architecture caused overfitting resulting in low validation accuracy compared to training accuracy. The two models using dropout for regularization resulted in the lowest accuracy in the experiment. This might be because dropout introduces errors that the network might not be able to correct because of the small dataset and a limited number of epochs. Two models not using any regularization reported high accuracy compared to other models using regularization. Regularization presents a trade-off by introducing errors while training to reduce overfitting. If the coefficients are not tweaked properly it might also result in skewing of the results not making any improvements.

Model 4 was chosen to be the best performing model among the 8 models trained. It was then trained again with both training and validation datasets. The training accuracy of the model was reported to be around 0.86 and the testing accuracy came up to 0.67.

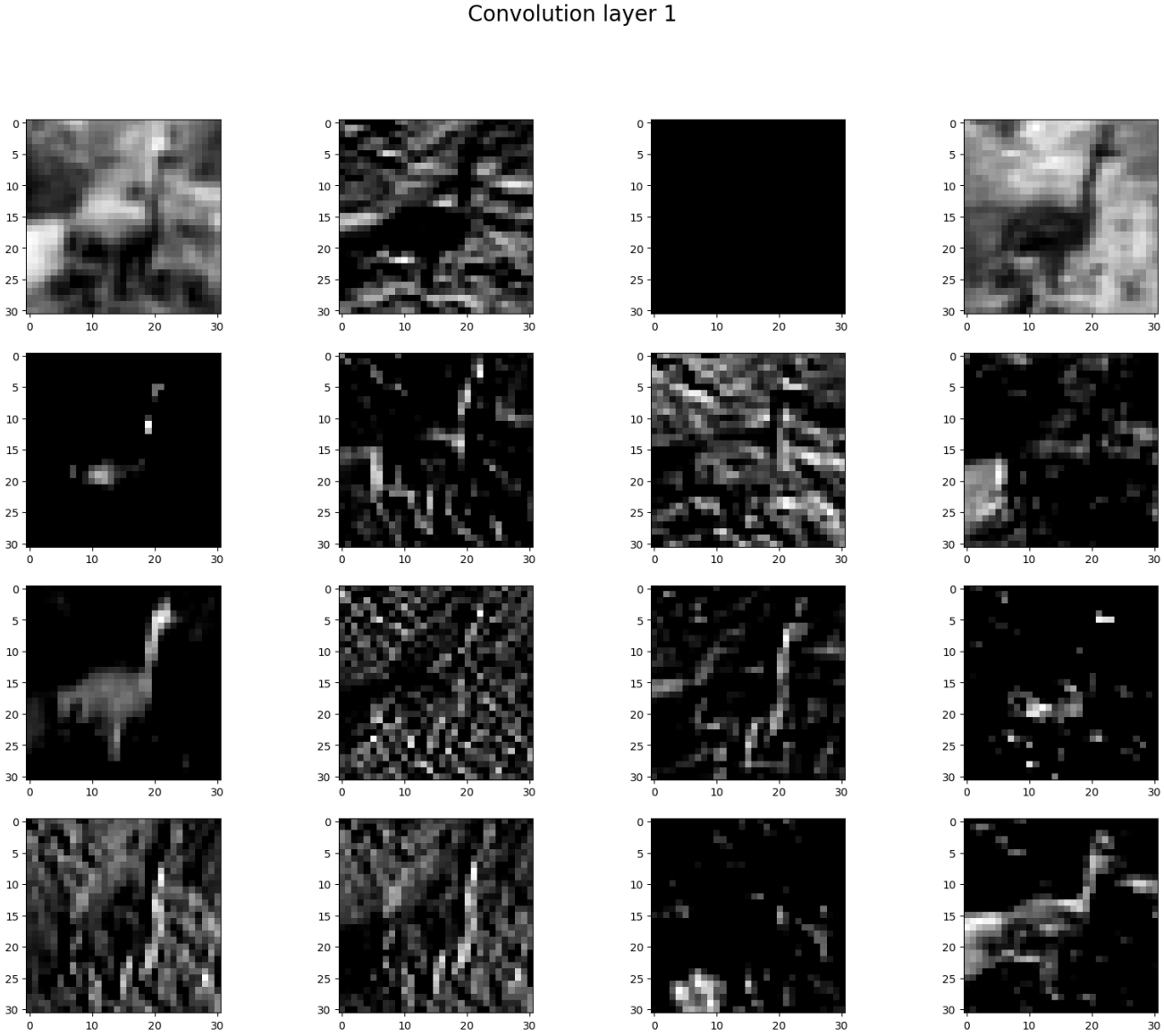

Figure 2: Visualization of convolutional filters in layer 1

Problem 2

This experiment was conducted with the help of Model 4 trained in problem 1. A random image [1] was chosen from the dataset to visualize the convolutional filters in the model.

Model 4 consisted of 2 convolutional layers with 16 filters each along with L2 regularization. The L2 regularization coefficient was set to 0.00001. Keras library was used to visualize the filters of both the convolutional layers of Model 4.

Figure 2 shows the visualization of the first convolutional filter. It can be noticed that the filters are able to identify the shape of the bird. Figure 3 shows the visualization of the

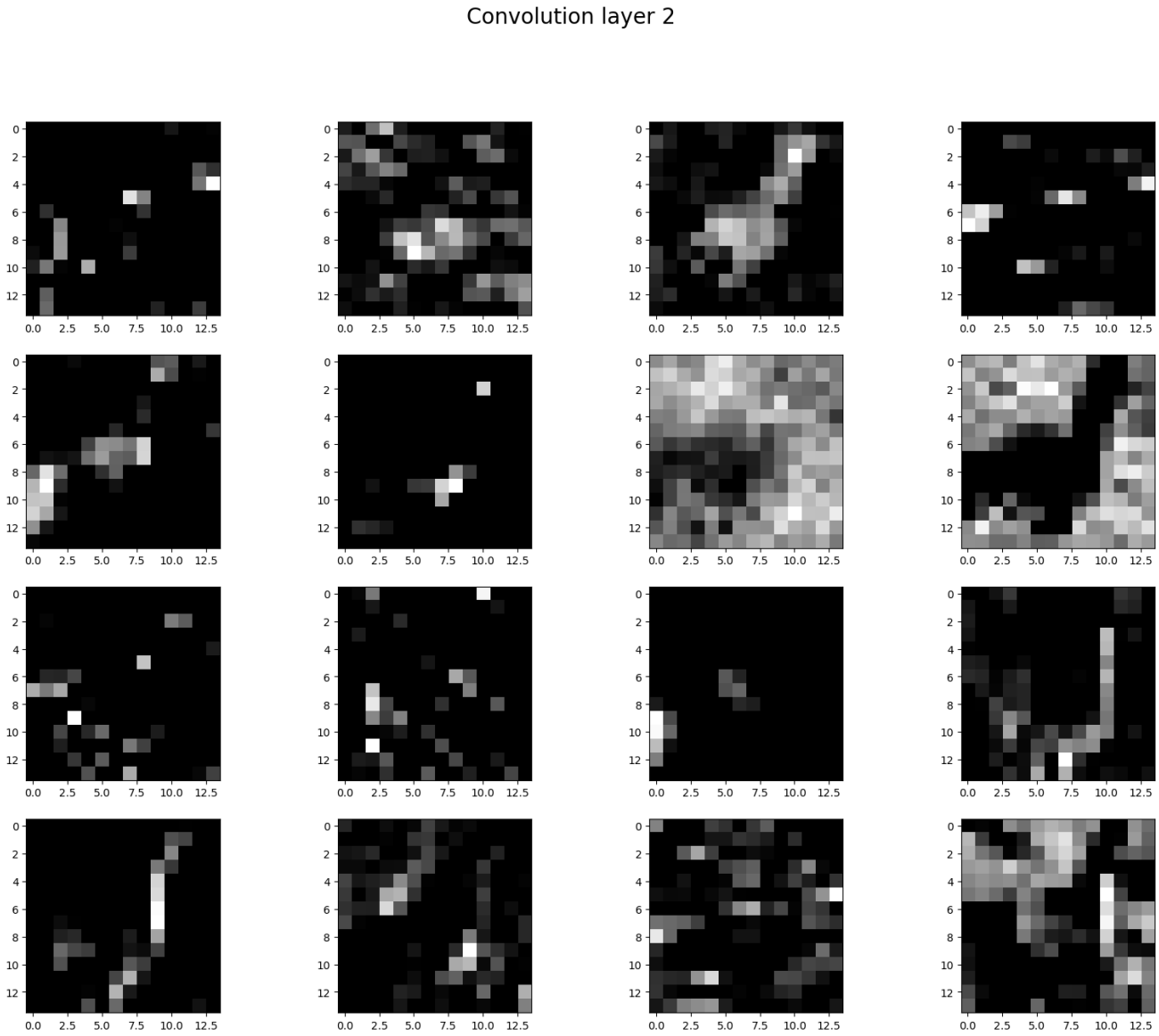

Figure 3: Visualization of convolutional filters in layer 2

second convolutional filter. Here, we are able to notice patterns in the region of the picture where the bird is present. The patterns shown identified in the second filter are not as well defined as the ones identified in the first filter. This is a visual representation of what kind of input would maximize the activation for any given filter. In this scenario, the first filter was highly activated for the random image that was chosen while the activation of the second filter was relatively lower.

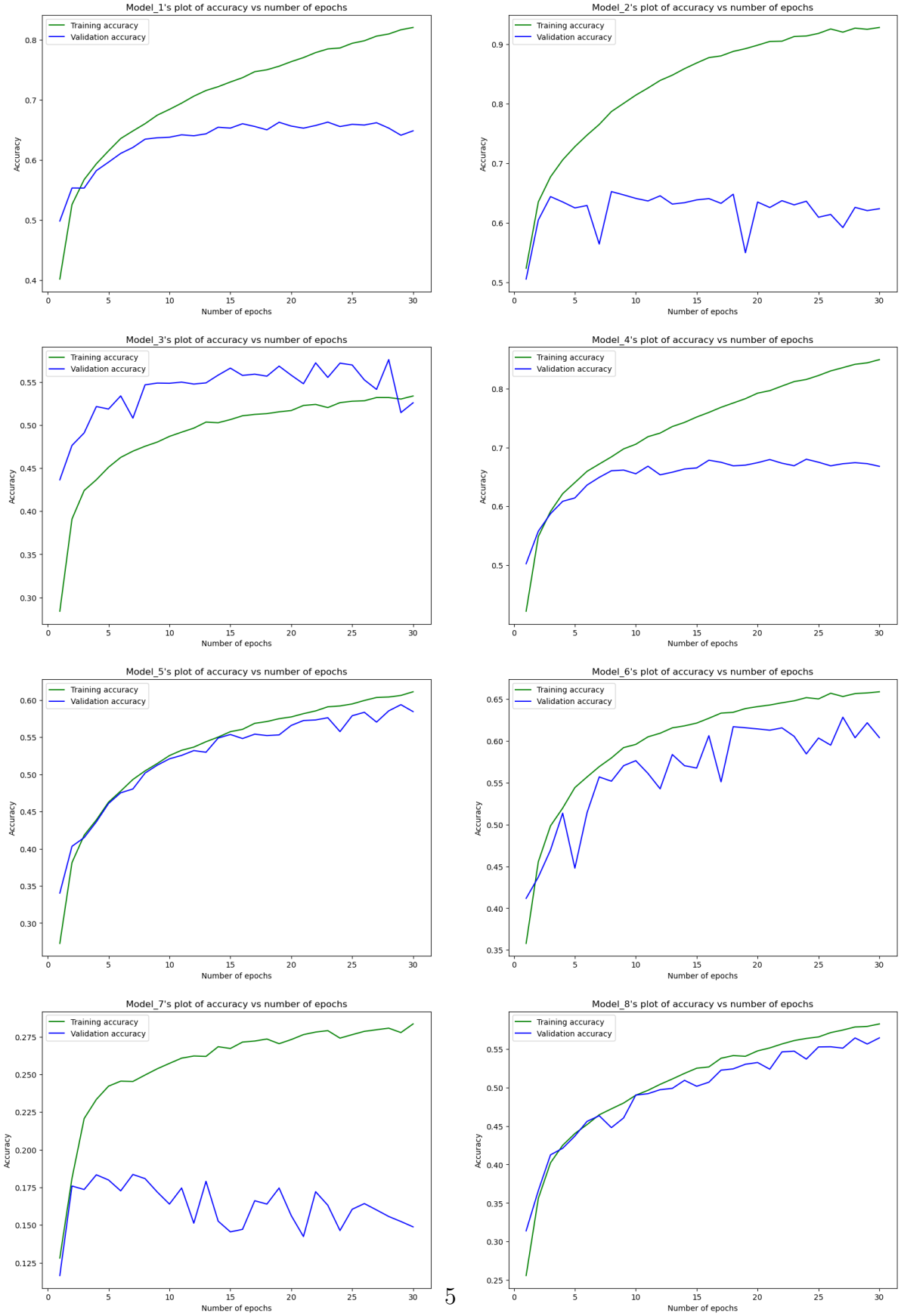

Figure 4: Plot of accuracy against number of epochs