Assignment 2

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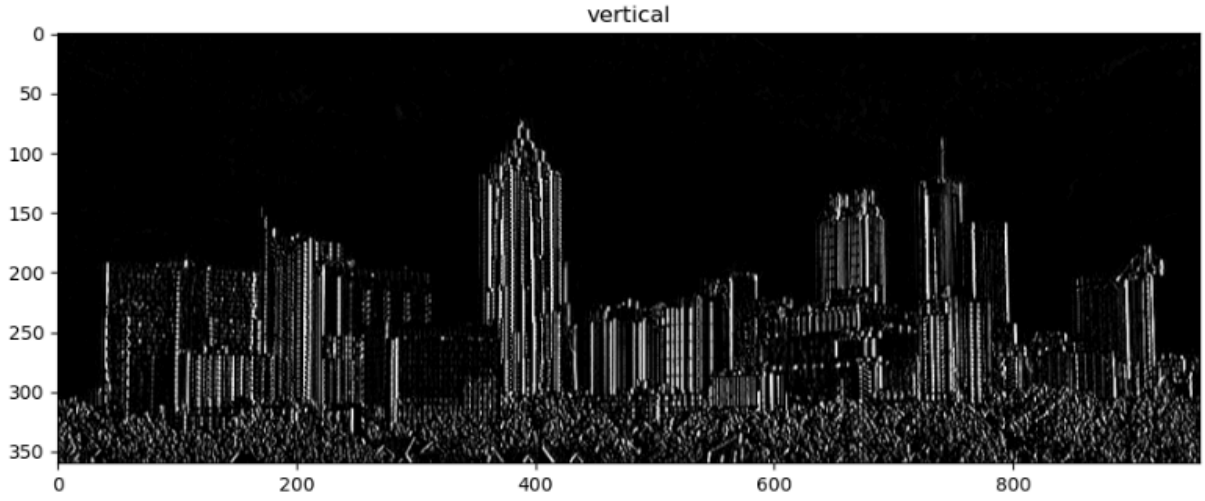
CSCI 611 - 601 Applied Machine Learning Summer 2025

June 22, 2025

Part One

This part of the assignment involved image processing using the OpenCV library. First, I created a vertical edge filter to filter the vertical features of the image. This process first involves converting the image to a grayscale image then using the OpenCV function cv2.filter2D passing the vertical kernel to filter the image. Next, I created a kernel to blur the image.



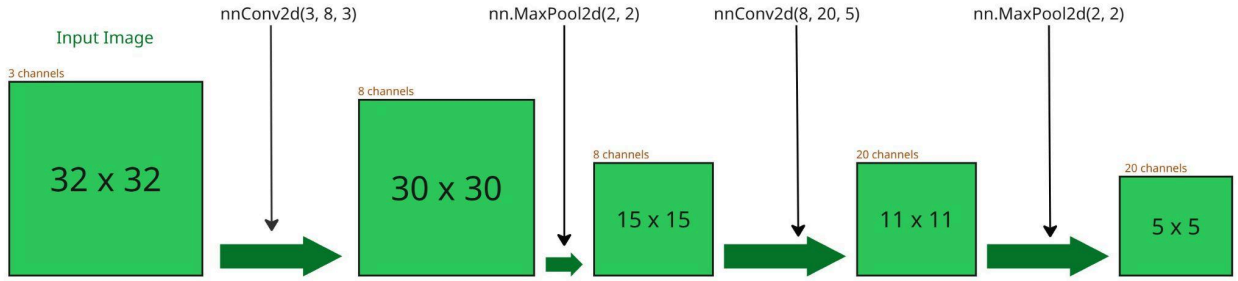

original
0
200
400
600
800
000
200
0
250
500
750
1000
1250
1500
1750
2000

Part Two

Model Architecture

The second part of the assignment required developing a Convolutional Neural Network. The architecture of my neural network consists of two convolution layers followed by two fully connected hidden layers. Between each convolution process I implement max pooling. There are

500 parameters entering the fully connected layers.



Training Process

Stochastic Gradient Descent

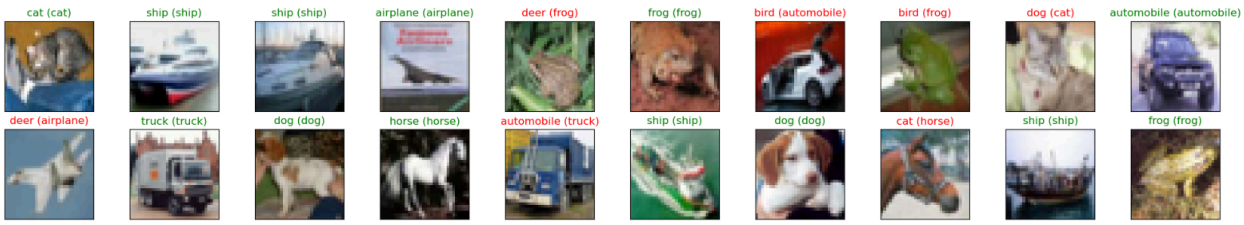
The first training process utilized the Stochastic Gradient Descent method for updating the weights. Using a learning rate of 0.01, the closest I could get the overall prediction accuracy was 64% through 16 epochs. This resulted in a predication rate on the images to be slightly under 70%. The training time took almost three minutes to complete.

```
Epoch: 1        Training Loss: 1.961491         Validation Loss: 1.716415
Validation loss decreased (inf --> 1.716415).  Saving model ...
Epoch: 2        Training Loss: 1.572279         Validation Loss: 1.573211
Validation loss decreased (1.716415 --> 1.573211).  Saving model ...
Epoch: 3        Training Loss: 1.419741         Validation Loss: 1.400046
Validation loss decreased (1.573211 --> 1.400046).  Saving model ...
Epoch: 4        Training Loss: 1.327052         Validation Loss: 1.331902
Validation loss decreased (1.400046 --> 1.331902).  Saving model ...
Epoch: 5        Training Loss: 1.251090         Validation Loss: 1.263876
Validation loss decreased (1.331902 --> 1.263876).  Saving model ...
Epoch: 6        Training Loss: 1.191141         Validation Loss: 1.247414
Validation loss decreased (1.263876 --> 1.247414).  Saving model ...
Epoch: 7        Training Loss: 1.139447         Validation Loss: 1.206834
Validation loss decreased (1.247414 --> 1.206834).  Saving model ...
Epoch: 8        Training Loss: 1.090763         Validation Loss: 1.170275
Validation loss decreased (1.206834 --> 1.170275).  Saving model ...
Epoch: 9        Training Loss: 1.050857         Validation Loss: 1.157738
Validation loss decreased (1.170275 --> 1.157738).  Saving model ...
Epoch: 10       Training Loss: 1.012916         Validation Loss: 1.123260
Validation loss decreased (1.157738 --> 1.123260).  Saving model ...
Epoch: 11       Training Loss: 0.976151         Validation Loss: 1.132520
Epoch: 12       Training Loss: 0.942110         Validation Loss: 1.112048
Validation loss decreased (1.123260 --> 1.112048).  Saving model ...
Epoch: 13       Training Loss: 0.909358         Validation Loss: 1.109097
Validation loss decreased (1.112048 --> 1.109097).  Saving model ...
Epoch: 14       Training Loss: 0.879805         Validation Loss: 1.072696
Validation loss decreased (1.109097 --> 1.072696).  Saving model ...
Epoch: 15       Training Loss: 0.847922         Validation Loss: 1.067978
Validation loss decreased (1.072696 --> 1.067978).  Saving model ...
Epoch: 16       Training Loss: 0.818596         Validation Loss: 1.061200
Validation loss decreased (1.067978 --> 1.061200).  Saving model ...
Time of Training:  290.2335159778595
```

```
Test Loss: 1.054885

Test Accuracy of airplane: 73% (732/1000)
Test Accuracy of automobile: 72% (727/1000)
Test Accuracy of  bird: 55% (554/1000)
Test Accuracy of   cat: 49% (490/1000)
Test Accuracy of  deer: 50% (505/1000)
Test Accuracy of   dog: 50% (508/1000)
Test Accuracy of  frog: 70% (700/1000)
Test Accuracy of horse: 67% (676/1000)
Test Accuracy of  ship: 82% (827/1000)
Test Accuracy of truck: 70% (707/1000)

Test Accuracy (Overall): 64% (6426/10000)
```



ADAM

The second training session used the Adaptive Moment Estimation method for updating the weights during backpropagation. With this method I was able to achieve a higher success rate. The success rate for the images was 70%. The learning rate was set to 0.0001 through 30 epochs. The training time here took ten minutes to complete.

```
Epoch: 6        Training Loss: 1.371120         Validation Loss: 1.367099
Validation loss decreased (1.400407 --> 1.367099).  Saving model ...
Epoch: 7        Training Loss: 1.339679         Validation Loss: 1.344580
Validation loss decreased (1.367099 --> 1.344580).  Saving model ...
Epoch: 8        Training Loss: 1.307569         Validation Loss: 1.342025
Validation loss decreased (1.344580 --> 1.342025).  Saving model ...
Epoch: 9        Training Loss: 1.283391         Validation Loss: 1.295685
Validation loss decreased (1.342025 --> 1.295685).  Saving model ...
Epoch: 10       Training Loss: 1.257831         Validation Loss: 1.272738
Validation loss decreased (1.295685 --> 1.272738).  Saving model ...
Epoch: 11       Training Loss: 1.235638         Validation Loss: 1.272850
Epoch: 12       Training Loss: 1.213181         Validation Loss: 1.244484
Validation loss decreased (1.272738 --> 1.244484).  Saving model ...
Epoch: 13       Training Loss: 1.194898         Validation Loss: 1.227743
Validation loss decreased (1.244484 --> 1.227743).  Saving model ...
Epoch: 14       Training Loss: 1.175757         Validation Loss: 1.225958
Validation loss decreased (1.227743 --> 1.225958).  Saving model ...
Epoch: 15       Training Loss: 1.160800         Validation Loss: 1.208369
Validation loss decreased (1.225958 --> 1.208369).  Saving model ...
Epoch: 16       Training Loss: 1.144353         Validation Loss: 1.190705
Validation loss decreased (1.208369 --> 1.190705).  Saving model ...
Epoch: 17       Training Loss: 1.130262         Validation Loss: 1.191982
Epoch: 18       Training Loss: 1.115676         Validation Loss: 1.201666
Epoch: 19       Training Loss: 1.102644         Validation Loss: 1.168387
Validation loss decreased (1.190705 --> 1.168387).  Saving model ...
Epoch: 20       Training Loss: 1.091366         Validation Loss: 1.166080
Validation loss decreased (1.168387 --> 1.166080).  Saving model ...
Epoch: 21       Training Loss: 1.077742         Validation Loss: 1.169561
Epoch: 22       Training Loss: 1.067272         Validation Loss: 1.160825
Validation loss decreased (1.166080 --> 1.160825).  Saving model ...
Epoch: 23       Training Loss: 1.054990         Validation Loss: 1.142856
Validation loss decreased (1.160825 --> 1.142856).  Saving model ...
Epoch: 24       Training Loss: 1.043634         Validation Loss: 1.144813
Epoch: 25       Training Loss: 1.032190         Validation Loss: 1.137386
Validation loss decreased (1.142856 --> 1.137386).  Saving model ...
Epoch: 26       Training Loss: 1.021180         Validation Loss: 1.126098
Validation loss decreased (1.137386 --> 1.126098).  Saving model ...
Epoch: 27       Training Loss: 1.011488         Validation Loss: 1.119554
Validation loss decreased (1.126098 --> 1.119554).  Saving model ...
Epoch: 28       Training Loss: 1.001330         Validation Loss: 1.122378
Epoch: 29       Training Loss: 0.992486         Validation Loss: 1.111746
Validation loss decreased (1.119554 --> 1.111746).  Saving model ...
Epoch: 30       Training Loss: 0.982607         Validation Loss: 1.116513
Time of Training:  591.1837201118469
```

```
Test Loss: 1.104081

Test Accuracy of airplane: 66% (669/1000)
Test Accuracy of automobile: 67% (678/1000)
Test Accuracy of  bird: 50% (500/1000)
Test Accuracy of   cat: 44% (444/1000)
Test Accuracy of  deer: 54% (540/1000)
Test Accuracy of   dog: 50% (503/1000)
Test Accuracy of  frog: 73% (737/1000)
Test Accuracy of horse: 62% (624/1000)
Test Accuracy of  ship: 75% (757/1000)
Test Accuracy of truck: 72% (725/1000)

Test Accuracy (Overall): 61% (6177/10000)
```