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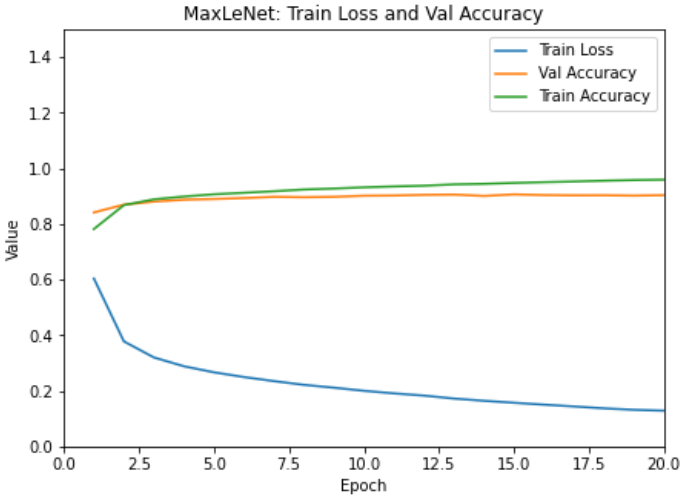
HW2

Github Link:

Problem 1




```
Epoch 15
loss: 0.07433485239744186
loss: 0.03841002658009529
Validation Accuracy: 90.62     Validation Loss:  0.28944

Epoch 16
loss: 0.025794582441449165
loss: 0.03645904362201691
Validation Accuracy: 90.38000000000001     Validation Lo

Epoch 17
loss: 0.09444670379161835
loss: 0.2125445306301117
Validation Accuracy: 90.28     Validation Loss:  0.30686

Epoch 18
loss: 0.3425464332103729
loss: 0.22572341561317444
Validation Accuracy: 90.3     Validation Loss:  0.305198

Epoch 19
loss: 0.10637159645557404
loss: 0.1293027549982071
Validation Accuracy: 90.18     Validation Loss:  0.31781

Epoch 20
loss: 0.18390409648418427
loss: 0.14328217506408691
Validation Accuracy: 90.33     Validation Loss:  0.31958
```

The MaxLeNet model with ReLU activations and MaxPooling2d layers displayed a considerable improvement in performance. The model reached a stable validation accuracy of 90.3%, compared to the baseline LeNet model's validation accuracy of approximately 75%. Training

losses were also noticeably lower than those of the baseline LeNet model, reaching a minimum value of 0.18 compared to the baseline's minimum value of roughly 0.7.

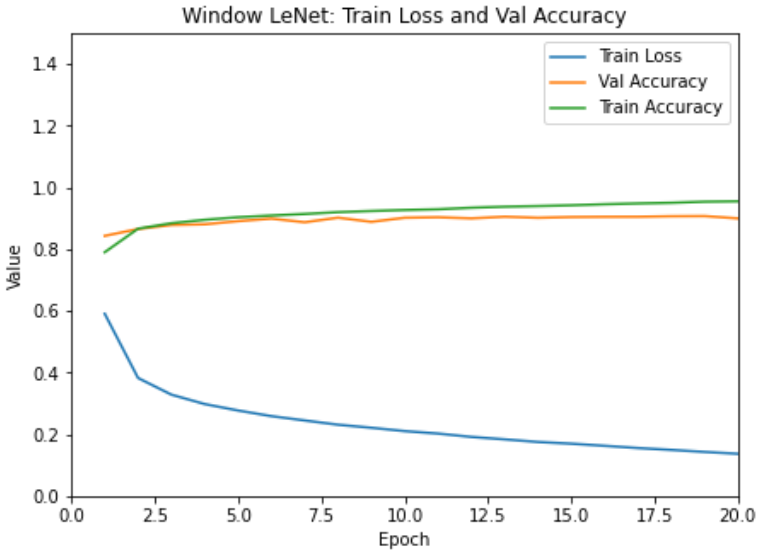
Problem 2

Multiple experiments were conducted on the MaxLeNet model from Problem 1 including adjustments to the window/kernel size, channel width, number of convolution layers, number of fully connected layers, and learning rate until the best performing models were found. The model performance metrics reported in the table below are from the corresponding models with the following adjustments to the baseline MaxLeNet model:

- MaxLeNet - Baseline model from Problem 1 (no adjustments)
- Window - Kernel size = 3
- Channels - | Conv 1 = 32 | Conv 2 = 32 | Linear 1 = 256 | Linear 2 = 64 |
- Conv Layers - | Conv 3 = 32 | Conv 4 = 64 |
- FC Layers - | Linear 1 = 256 | Linear 2 = 128 | Linear 3 = 64 | Linear 4 = 32 |
- Learning Rate - lr = 0.0001 (opposed to 0.001 for models above)

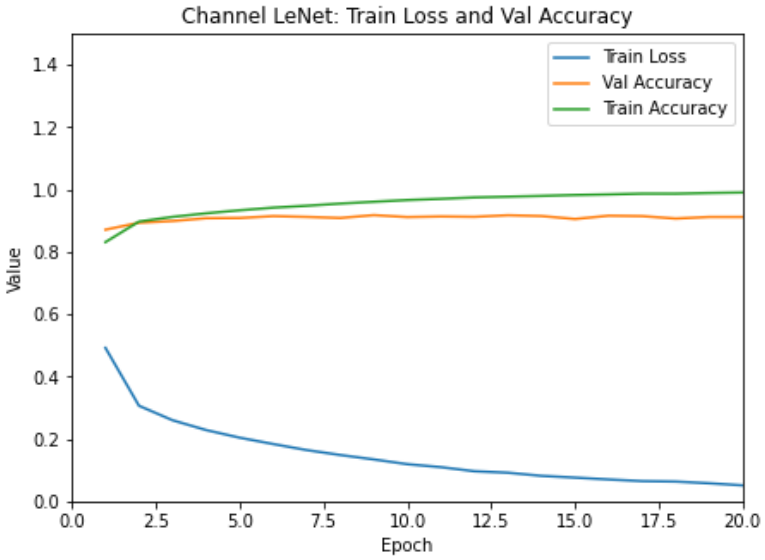
Model	**Validation Accuracy**	**Training Accuracy**	**Training Loss**	**Parameters**	**Operations**
MaxLeNet	90.3%	92.9%	0.18	61.71k	435.85k
Window	89.9%	93.1%	0.15	81.19k	299.39k
Channels	91.2%	96.5%	0.06	248.62k	3.49M
Conv Layers	90.0%	92.8%	0.19	69.45k	1.71M
FC Layers	90.6%	93.5%	0.12	148.79k	523.21k
Learning Rate	87.7%	88.9%	0.31	61.71k	435.85k

Window LeNet:



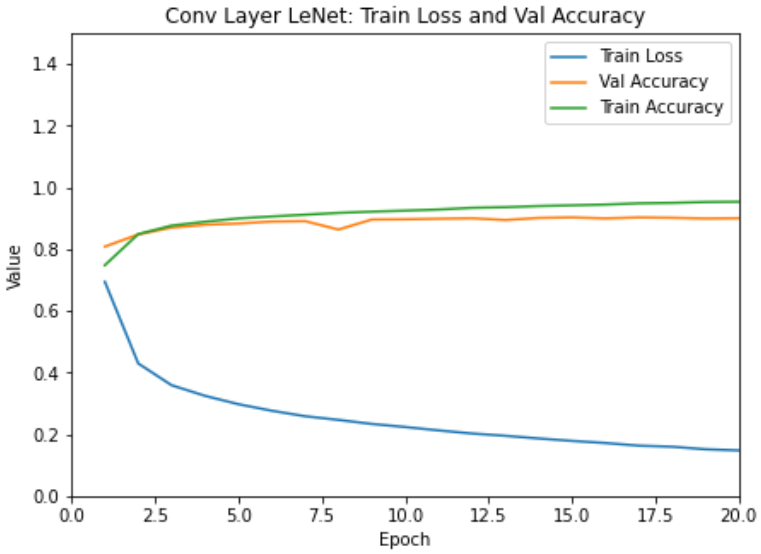

```
Epoch 15
loss: 0.21292787790298462
loss: 0.08505263179540634
Validation Accuracy: 90.4     Validation Loss:  0.27278

Epoch 16
loss: 0.0945063978433609
loss: 0.24951516091823578
Validation Accuracy: 90.47     Validation Loss:  0.2857

Epoch 17
loss: 0.18068593740463257
loss: 0.049970388412475586
Validation Accuracy: 90.49000000000001     Validation L

Epoch 18
loss: 0.18012750148773193
loss: 0.180588960647583
Validation Accuracy: 90.66     Validation Loss:  0.2852

Epoch 19
loss: 0.13082930445671082
loss: 0.22957293689250946
Validation Accuracy: 90.71000000000001     Validation L

Epoch 20
loss: 0.10809242725372314
loss: 0.21371260285377502
Validation Accuracy: 89.96     Validation Loss:  0.3274
```

Channel LeNet:



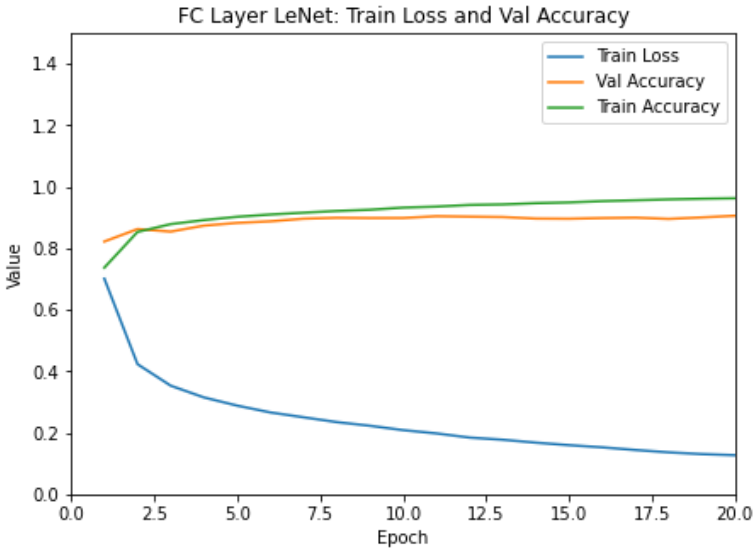

```
Epoch 15
loss: 0.00550600653514266
loss: 0.02556084655225277
Validation Accuracy: 90.53     Validation Loss:  0.3927089

Epoch 16
loss: 0.0077915857546031475
loss: 0.009563696570694447
Validation Accuracy: 91.58     Validation Loss:  0.3945212

Epoch 17
loss: 0.019824210554361343
loss: 0.11915914714336395
Validation Accuracy: 91.45     Validation Loss:  0.3854067

Epoch 18
loss: 0.07205665856599808
loss: 0.03600491210818291
Validation Accuracy: 90.67     Validation Loss:  0.4403740

Epoch 19
loss: 0.004822830203920603
loss: 0.01705688238143921
Validation Accuracy: 91.18     Validation Loss:  0.3897840

Epoch 20
loss: 0.015321574173867702
loss: 0.007182026281952858
Validation Accuracy: 91.18     Validation Loss:  0.4734119
```

Conv Layer LeNet:



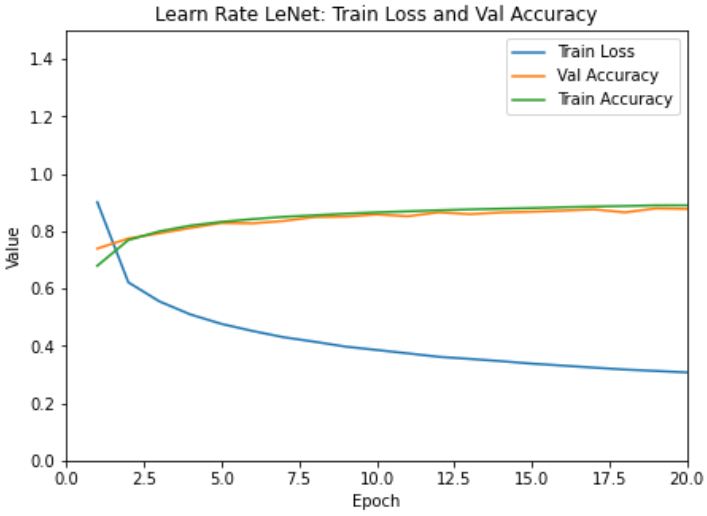

```
Epoch 15
loss: 0.512250542640686
loss: 0.2508762776851654
Validation Accuracy: 90.29     Validation Loss:  0.302850

Epoch 16
loss: 0.16260407865047455
loss: 0.22891202569007874
Validation Accuracy: 89.96     Validation Loss:  0.313734

Epoch 17
loss: 0.05506058782339096
loss: 0.1931689828634262
Validation Accuracy: 90.28     Validation Loss:  0.330059

Epoch 18
loss: 0.09002522379159927
loss: 0.23958276212215424
Validation Accuracy: 90.16     Validation Loss:  0.330501

Epoch 19
loss: 0.046834371984004974
loss: 0.12266209721565247
Validation Accuracy: 89.92     Validation Loss:  0.306237

Epoch 20
loss: 0.07435212284326553
loss: 0.08859160542488098
Validation Accuracy: 90.02     Validation Loss:  0.322594
```

FC Layer LeNet




```
Epoch 15
loss: 0.0524703748524189
loss: 0.0757688507437706
Validation Accuracy: 89.59     Validation Loss:  0.349349

Epoch 16
loss: 0.07670421898365021
loss: 0.44105902314186096
Validation Accuracy: 89.81     Validation Loss:  0.335506

Epoch 17
loss: 0.3046317398548126
loss: 0.05711526796221733
Validation Accuracy: 89.95     Validation Loss:  0.314469

Epoch 18
loss: 0.08318367600440979
loss: 0.05493469536304474
Validation Accuracy: 89.53999999999999     Validation Los

Epoch 19
loss: 0.13648349046707153
loss: 0.03826886788010597
Validation Accuracy: 90.03     Validation Loss:  0.366671

Epoch 20
loss: 0.19884093105793
loss: 0.11653818935155869
Validation Accuracy: 90.56     Validation Loss:  0.370572
```

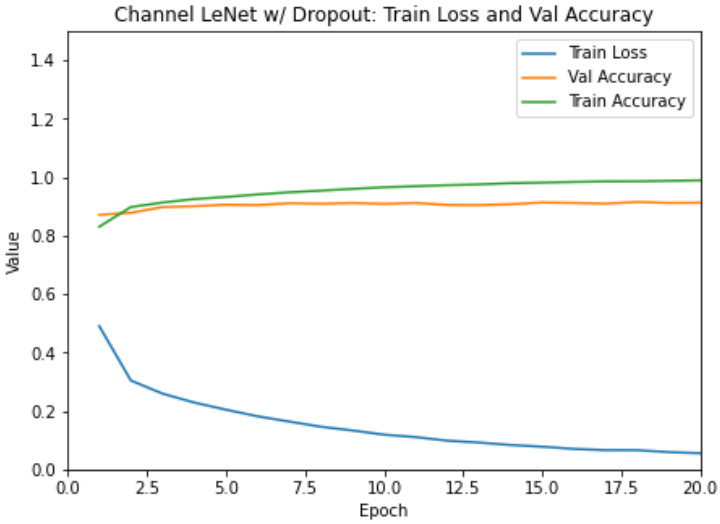
Learning Rate LeNet:




```
Epoch 15
loss: 0.4175805449485779
loss: 0.44802987575531006
Validation Accuracy: 86.76     Validation Loss:  0.364700

Epoch 16
loss: 0.43517136573791504
loss: 0.36722302436828613
Validation Accuracy: 87.12     Validation Loss:  0.359685

Epoch 17
loss: 0.15792155265808105
loss: 0.1539457142353058
Validation Accuracy: 87.59     Validation Loss:  0.350129

Epoch 18
loss: 0.387608140707016
loss: 0.3448188602924347
Validation Accuracy: 86.53     Validation Loss:  0.366545

Epoch 19
loss: 0.3941614329814911
loss: 0.3907373547554016
Validation Accuracy: 87.94     Validation Loss:  0.336039

Epoch 20
loss: 0.21067094802856445
loss: 0.40098559856414795
Validation Accuracy: 87.72999999999999     Validation Los
```

As seen in the plots above, the experiments yielded mostly similar results compared to the baseline model. The Window, Conv Layer, and FC Layer models had very similar validation accuracies to the MaxLeNet models, all bordering ~90%. Although the Learning Rate model performed the worst in terms of validation accuracy with a value of 87.7%, it had one of the lowest generalization errors in accuracy with only a 1.2% difference in validation and training accuracy. However, the best performing model was the Channel LeNet model, as it had the highest validation accuracy (91.2%) as well as the lowest training loss (0.06) out of all of the experimental models.

Problem 3




```
Epoch 15
loss: 0.09907671809196472
loss: 0.2174682468175888
Validation Accuracy: 91.34     Validation Loss:  0.357621

Epoch 16
loss: 0.0863342434167862
loss: 0.029391279444098473
Validation Accuracy: 91.18     Validation Loss:  0.357186

Epoch 17
loss: 0.018787117674946785
loss: 0.030273647978901863
Validation Accuracy: 90.96     Validation Loss:  0.409469

Epoch 18
loss: 0.09341385960578918
loss: 0.015946049243211746
Validation Accuracy: 91.51     Validation Loss:  0.416498

Epoch 19
loss: 0.01702222228050232
loss: 0.015503406524658203
Validation Accuracy: 91.19     Validation Loss:  0.441614

Epoch 20
loss: 0.15391159057617188
loss: 0.001051229308359325
Validation Accuracy: 91.25999999999999     Validation Los
```

The Channel LeNet model from Problem 2 was selected due to its higher accuracy and modified by applying dropout layers with a probability of 0.3. The Channel LeNet model with dropout showed a slight improvement in performance compared to the original Channel LeNet model, with a validation accuracy of approximately 91.26% and training loss of 0.04.

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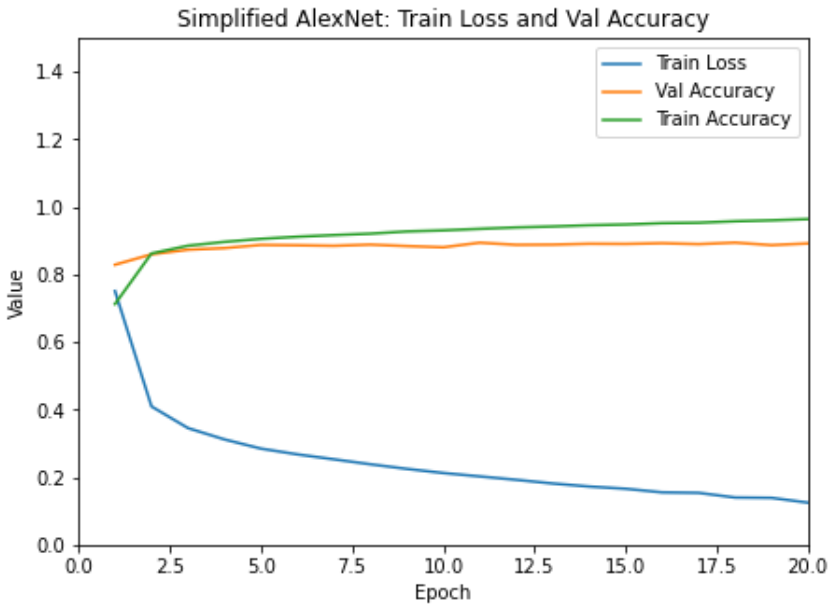
Problems 4/5

The AlexNet model was simplified by reducing kernel, stride, and layer output sizes to produce the SimpleAlexNet model. The table below shows the difference in parameter and operation counts between the original AlexNet model and SimpleAlexNet:

Model	Parameters	Operations
AlexNet	46.76M	939.85M
SimpleAlexNet	392.33k	3.26M

As seen in the table above, SimpleAlexNet requires less than 1% of AlexNet's parameter count and less than 0.5% of its operation count.



```
Epoch 15
loss: 0.32782769203186035
loss: 0.16226975619792938
Validation Accuracy: 89.03     Validation Loss:  0.338018

Epoch 16
loss: 0.18509599566459656
loss: 0.09188417345285416
Validation Accuracy: 89.24     Validation Loss:  0.379391

Epoch 17
loss: 0.13456179201602936
loss: 0.08670203387737274
Validation Accuracy: 88.97     Validation Loss:  0.407832

Epoch 18
loss: 0.16297142207622528
loss: 0.2289642095565796
Validation Accuracy: 89.41     Validation Loss:  0.386052

Epoch 19
loss: 0.07365482300519943
loss: 0.13822397589683533
Validation Accuracy: 88.67     Validation Loss:  0.440638

Epoch 20
loss: 0.05559298396110535
loss: 0.12641765177249908
Validation Accuracy: 89.17     Validation Loss:  0.386917
```

The SimpleAlexNet model performed relatively well, especially considering the reduction in computation and size from the original AlexNet model. The model reached a validation accuracy of approximately 89.17% and a train loss of approximately 0.16. Though this performance wasn't nearly as good as the Channel LeNet and Dropout Channel LeNet models from Problems 2 and 3, the model performed well with only minor signs of overfitting.

Problem 5: The accuracy value I found for AlexNet was 84.7%. Based on this accuracy value the SimpleAlexNet model was able to outperform AlexNet directly on the 28x28 images used for training while being significantly smaller and less complex in computation.