Machine Problem 3

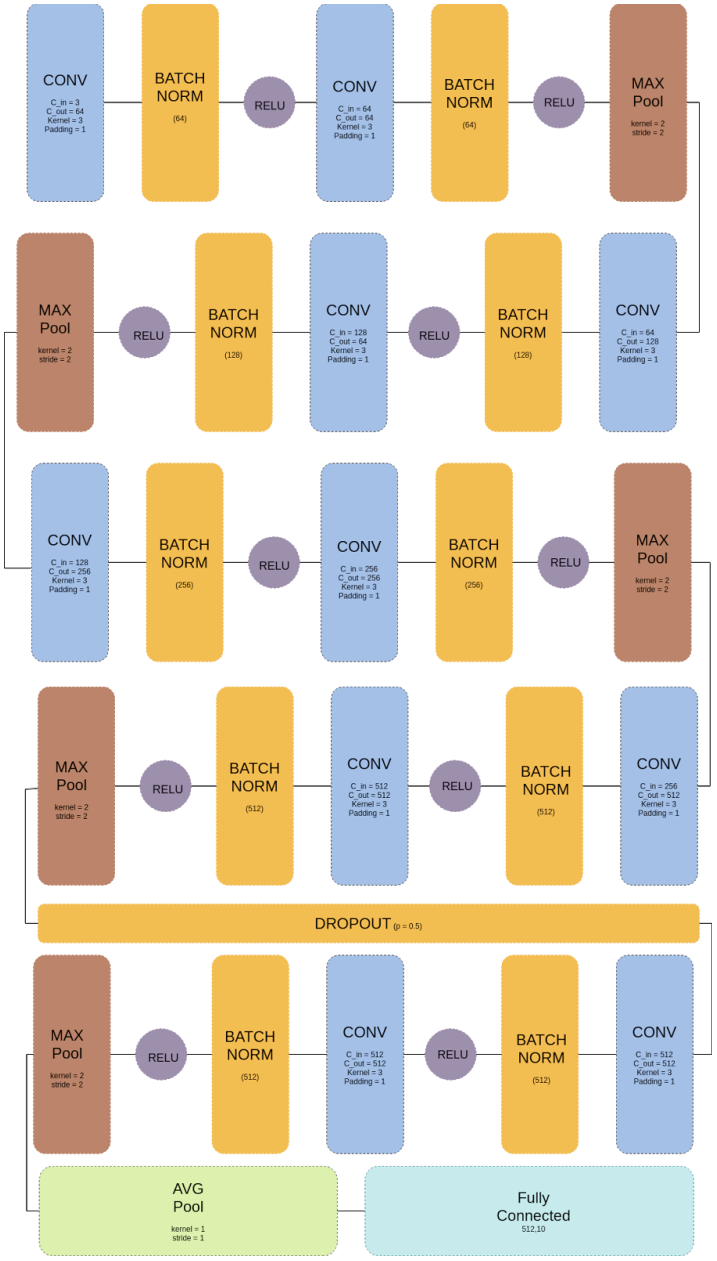
IE 534/CS 598 - Deep Learning

CIFAR 10 Classification

Naman Shukla (namans2@illinois.edu)

Implementation:

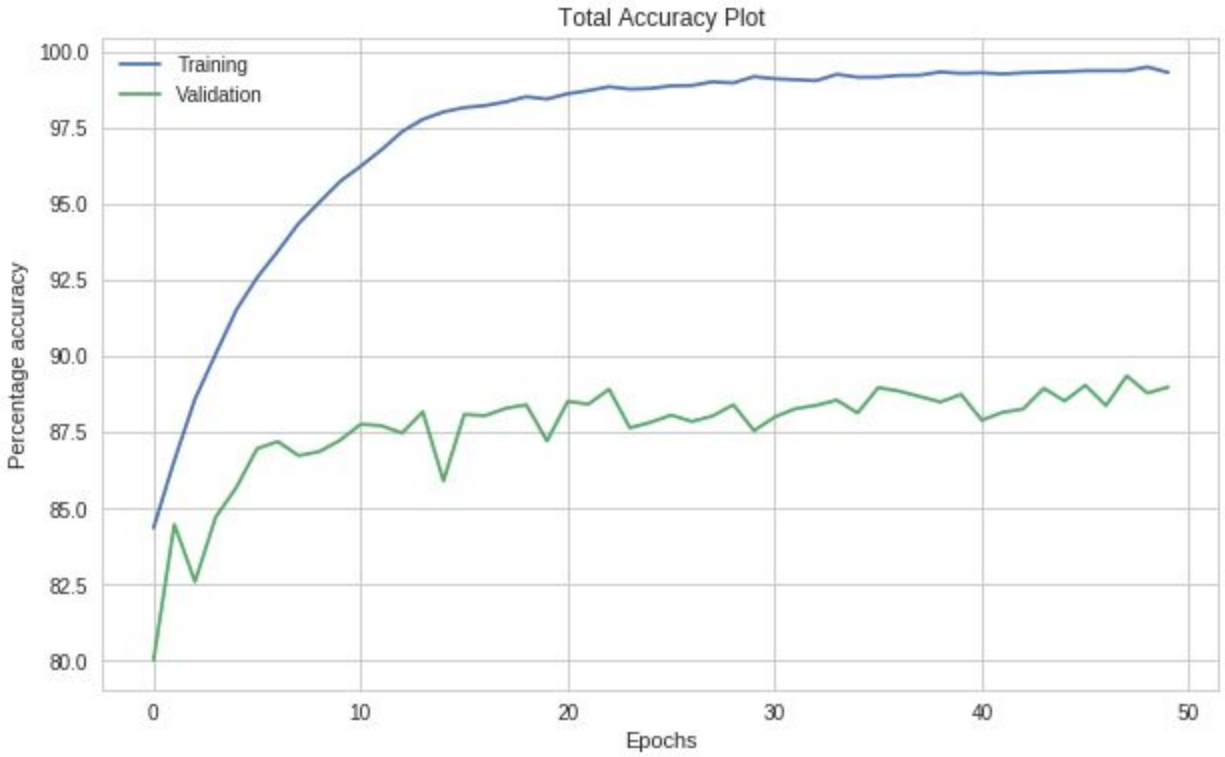
The following diagram is the network that I have implemented to gain about 89% testing accuracy on CIFAR10 dataset. This network is inspired from VGG Net13. The following flowchart contains detailed layout with hyperparameters in each layer.

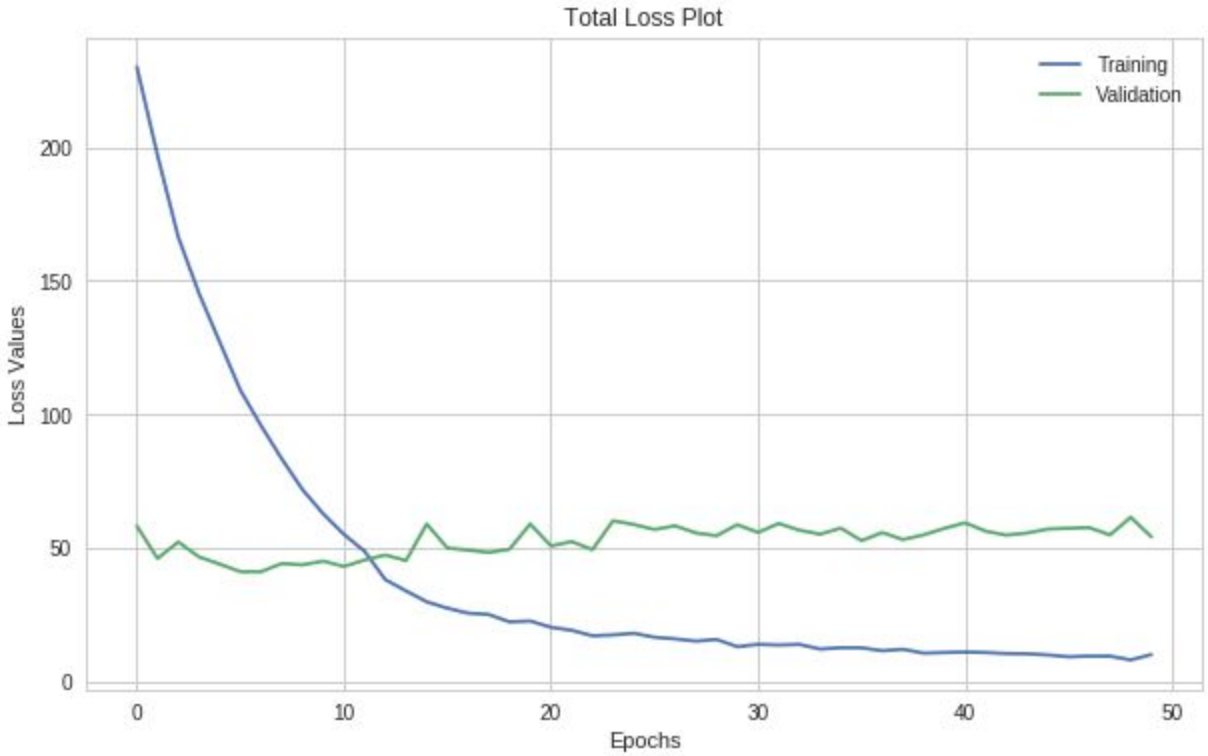


Training and Testing:
The nohup files are provided with the model for the reference output.
Output:

```
Epoch:  1, Training Loss: 230.0511, Training Acc: 84.350%, Validation Loss: 58.0886, Validation Acc: 80.010%
Epoch:  2, Training Loss: 196.8694, Training Acc: 86.558%, Validation Loss: 45.9411, Validation Acc: 84.460%
Epoch:  3, Training Loss: 166.3102, Training Acc: 88.580%, Validation Loss: 52.1074, Validation Acc: 82.580%
Epoch:  4, Training Loss: 145.2501, Training Acc: 90.058%, Validation Loss: 46.5152, Validation Acc: 84.700%
Epoch:  5, Training Loss: 127.0381, Training Acc: 91.510%, Validation Loss: 43.8055, Validation Acc: 85.680%
Epoch:  6, Training Loss: 108.9500, Training Acc: 92.566%, Validation Loss: 40.9946, Validation Acc: 86.950%
Epoch:  7, Training Loss: 95.6468, Training Acc: 93.432%, Validation Loss: 40.9985, Validation Acc: 87.180%
Epoch:  8, Training Loss: 83.2581, Training Acc: 94.338%, Validation Loss: 44.0373, Validation Acc: 86.720%
Epoch:  9, Training Loss: 71.7347, Training Acc: 95.036%, Validation Loss: 43.5541, Validation Acc: 86.850%
Epoch: 10, Training Loss: 62.6524, Training Acc: 95.716%, Validation Loss: 44.9335, Validation Acc: 87.220%
Epoch: 11, Training Loss: 54.9783, Training Acc: 96.220%, Validation Loss: 42.9432, Validation Acc: 87.750%
Epoch: 12, Training Loss: 48.6288, Training Acc: 96.758%, Validation Loss: 45.3767, Validation Acc: 87.700%
Epoch: 13, Training Loss: 37.9911, Training Acc: 97.358%, Validation Loss: 47.2240, Validation Acc: 87.460%
Epoch: 14, Training Loss: 33.7887, Training Acc: 97.762%, Validation Loss: 45.1574, Validation Acc: 88.160%
Epoch: 15, Training Loss: 29.7023, Training Acc: 98.006%, Validation Loss: 58.8487, Validation Acc: 85.890%
Epoch: 16, Training Loss: 27.3030, Training Acc: 98.146%, Validation Loss: 49.8524, Validation Acc: 88.070%
Epoch: 17, Training Loss: 25.4430, Training Acc: 98.212%, Validation Loss: 49.0694, Validation Acc: 88.030%
Epoch: 18, Training Loss: 24.9420, Training Acc: 98.334%, Validation Loss: 48.1482, Validation Acc: 88.270%
Epoch: 19, Training Loss: 22.1744, Training Acc: 98.504%, Validation Loss: 49.4116, Validation Acc: 88.390%
Epoch: 20, Training Loss: 22.4946, Training Acc: 98.428%, Validation Loss: 58.8556, Validation Acc: 87.200%
Epoch: 21, Training Loss: 20.1511, Training Acc: 98.602%, Validation Loss: 50.5998, Validation Acc: 88.500%
Epoch: 22, Training Loss: 19.0254, Training Acc: 98.704%, Validation Loss: 52.2803, Validation Acc: 88.410%
Epoch: 23, Training Loss: 16.9786, Training Acc: 98.832%, Validation Loss: 49.2047, Validation Acc: 88.900%
Epoch: 24, Training Loss: 17.2858, Training Acc: 98.754%, Validation Loss: 60.0716, Validation Acc: 87.630%
Epoch: 25, Training Loss: 17.9289, Training Acc: 98.774%, Validation Loss: 58.6494, Validation Acc: 87.810%
Epoch: 26, Training Loss: 16.4216, Training Acc: 98.860%, Validation Loss: 56.7904, Validation Acc: 88.050%
Epoch: 27, Training Loss: 15.8195, Training Acc: 98.872%, Validation Loss: 58.1613, Validation Acc: 87.840%
Epoch: 28, Training Loss: 14.9702, Training Acc: 98.994%, Validation Loss: 55.4771, Validation Acc: 88.020%
Epoch: 29, Training Loss: 15.6044, Training Acc: 98.956%, Validation Loss: 54.4586, Validation Acc: 88.390%
Epoch: 30, Training Loss: 12.8831, Training Acc: 99.166%, Validation Loss: 58.6037, Validation Acc: 87.540%
Epoch: 31, Training Loss: 13.7762, Training Acc: 99.094%, Validation Loss: 55.6829, Validation Acc: 87.990%
Epoch: 32, Training Loss: 13.5005, Training Acc: 99.062%, Validation Loss: 59.0262, Validation Acc: 88.260%
Epoch: 33, Training Loss: 13.7519, Training Acc: 99.030%, Validation Loss: 56.5374, Validation Acc: 88.370%
Epoch: 34, Training Loss: 11.9886, Training Acc: 99.240%, Validation Loss: 55.0260, Validation Acc: 88.540%
Epoch: 35, Training Loss: 12.5038, Training Acc: 99.144%, Validation Loss: 57.3083, Validation Acc: 88.120%
Epoch: 36, Training Loss: 12.4723, Training Acc: 99.148%, Validation Loss: 52.6121, Validation Acc: 88.950%
Epoch: 37, Training Loss: 11.3700, Training Acc: 99.202%, Validation Loss: 55.6453, Validation Acc: 88.840%
Epoch: 38, Training Loss: 11.9208, Training Acc: 99.210%, Validation Loss: 53.0050, Validation Acc: 88.660%
Epoch: 39, Training Loss: 10.4648, Training Acc: 99.318%, Validation Loss: 54.7718, Validation Acc: 88.480%
Epoch: 40, Training Loss: 10.7160, Training Acc: 99.270%, Validation Loss: 57.2157, Validation Acc: 88.730%
Epoch: 41, Training Loss: 10.8807, Training Acc: 99.292%, Validation Loss: 59.2818, Validation Acc: 87.880%
Epoch: 42, Training Loss: 10.7126, Training Acc: 99.250%, Validation Loss: 56.1364, Validation Acc: 88.140%
Epoch: 43, Training Loss: 10.3139, Training Acc: 99.292%, Validation Loss: 54.6872, Validation Acc: 88.250%
Epoch: 44, Training Loss: 10.2194, Training Acc: 99.310%, Validation Loss: 55.4662, Validation Acc: 88.930%
Epoch: 45, Training Loss: 9.7936, Training Acc: 99.326%, Validation Loss: 56.9781, Validation Acc: 88.510%
Epoch: 46, Training Loss: 9.1098, Training Acc: 99.356%, Validation Loss: 57.2373, Validation Acc: 89.030%
Epoch: 47, Training Loss: 9.3739, Training Acc: 99.358%, Validation Loss: 57.4847, Validation Acc: 88.360%
Epoch: 48, Training Loss: 9.3464, Training Acc: 99.356%, Validation Loss: 54.7467, Validation Acc: 89.340%
Epoch: 49, Training Loss: 7.9246, Training Acc: 99.482%, Validation Loss: 61.3772, Validation Acc: 88.770%
Epoch: 50, Training Loss: 9.9378, Training Acc: 99.298%, Validation Loss: 54.0046, Validation Acc: 88.970%
```

Graphs:


Total Accuracy Plot
Training
Validation
Percentage accuracy
100.0
97.5
95.0
92.5
90.0
87.5
85.0
82.5
80.0
0
10
20
30
40
50
Epochs


Total Loss Plot
Training
Validation
Loss Values
200
150
100
50
0
0
10
20
30
40
50
Epochs

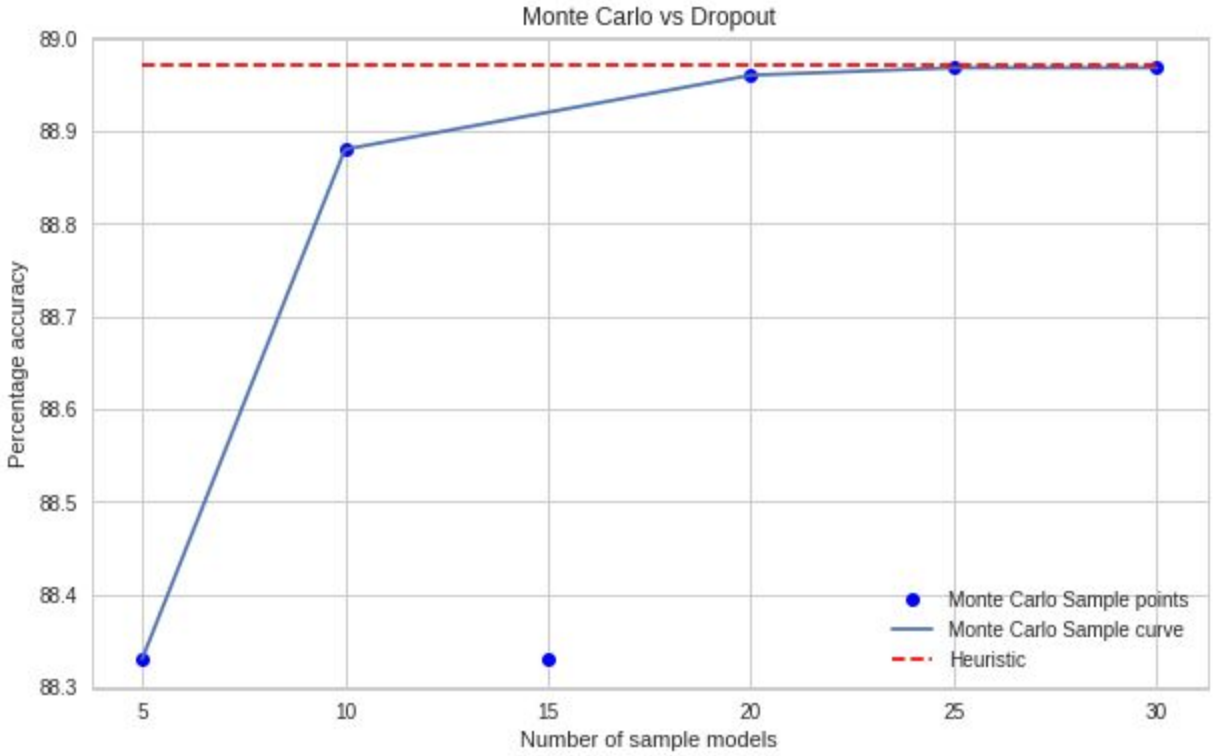
EXTRA CREDIT :

Aim : To compare dropout test accuracy (i) using the heuristic prediction rule and (ii) Monte Carlo simulation. For full credit, the model should achieve 80-90% Test Accuracy.

Note : Due to time constraints, only few samples are chosen to plot to observe the trend in the monte carlo simulation. Also, please refer to Geoffrey Hilton's original paper for the loss comparison graph.

Output: (also available in nohup file)

```
Samples:  5,  Accuracy: 88.830%
Samples:  10,  Accuracy: 88.880%
Samples:  15,  Accuracy: 88.830%
Samples:  20,  Accuracy: 88.960%
Samples:  25,  Accuracy: 88.968%
Samples:  30,  Accuracy: 88.968%
```



The dropout method proposed by Hilton is heuristic way of sampling from different models. Hence, when comparing training accuracy, as the number of models increases, the loss should tend to a stable value i.e. heuristic value. This implies that the accuracy should converge to the heuristic accuracy (dropout) when sample size is large. I have sampled 5 to 30 models with average prediction to plot the above curve. This curve confirms the convergence but we need more data points to further validate.