

Intro To Deep Learning
ECE 16:332:579

Homework 4

Name: Shounak Rangwala
Netid:snr85

The screen snapshots of the final results in the 3 cases are as follows:

1) Network without dropout/ batch normalization

```
Train Epoch: 50 [0/50000 (0%)] Loss: 1.239557
Train Epoch: 50 [1280/50000 (3%)] Loss: 1.320386
Train Epoch: 50 [2560/50000 (5%)] Loss: 1.073426
Train Epoch: 50 [3840/50000 (8%)] Loss: 1.257935
Train Epoch: 50 [5120/50000 (10%)] Loss: 1.045429
Train Epoch: 50 [6400/50000 (13%)] Loss: 1.279258
Train Epoch: 50 [7680/50000 (15%)] Loss: 0.923727
Train Epoch: 50 [8960/50000 (18%)] Loss: 1.419962
Train Epoch: 50 [10240/50000 (20%)] Loss: 1.241281
Train Epoch: 50 [11520/50000 (23%)] Loss: 1.224272
Train Epoch: 50 [12800/50000 (26%)] Loss: 1.171784
Train Epoch: 50 [14080/50000 (28%)] Loss: 1.147944
Train Epoch: 50 [15360/50000 (31%)] Loss: 1.174067
Train Epoch: 50 [16640/50000 (33%)] Loss: 1.204183
Train Epoch: 50 [17920/50000 (36%)] Loss: 1.368955
Train Epoch: 50 [19200/50000 (38%)] Loss: 1.246794
Train Epoch: 50 [20480/50000 (41%)] Loss: 1.266295
Train Epoch: 50 [21760/50000 (43%)] Loss: 1.160982
Train Epoch: 50 [23040/50000 (46%)] Loss: 1.065211
Train Epoch: 50 [24320/50000 (49%)] Loss: 1.083241
Train Epoch: 50 [25600/50000 (51%)] Loss: 1.311247
Train Epoch: 50 [26880/50000 (54%)] Loss: 1.446866
Train Epoch: 50 [28160/50000 (56%)] Loss: 1.350741
Train Epoch: 50 [29440/50000 (59%)] Loss: 1.230411
Train Epoch: 50 [30720/50000 (61%)] Loss: 1.265561
Train Epoch: 50 [32000/50000 (64%)] Loss: 1.359423
Train Epoch: 50 [33280/50000 (66%)] Loss: 1.355800
Train Epoch: 50 [34560/50000 (69%)] Loss: 1.184134
Train Epoch: 50 [35840/50000 (72%)] Loss: 1.045431
Train Epoch: 50 [37120/50000 (74%)] Loss: 1.172240
Train Epoch: 50 [38400/50000 (77%)] Loss: 1.156191
Train Epoch: 50 [39680/50000 (79%)] Loss: 1.233815
Train Epoch: 50 [40960/50000 (82%)] Loss: 1.171064
Train Epoch: 50 [42240/50000 (84%)] Loss: 1.131738
Train Epoch: 50 [43520/50000 (87%)] Loss: 1.016533
Train Epoch: 50 [44800/50000 (90%)] Loss: 1.297075
Train Epoch: 50 [46080/50000 (92%)] Loss: 1.246159
Train Epoch: 50 [47360/50000 (95%)] Loss: 1.248696
Train Epoch: 50 [48640/50000 (97%)] Loss: 1.333781
Train Epoch: 50 [31200/50000 (100%)] Loss: 0.963831

Test set: Average loss: 1.1075, Accuracy: 6248/10000 (62%)

Traning and Testing total excution time is: 2325.9632711410522 seconds
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2) Network with additional dropout layer

```
Train Epoch: 50 [0/50000 (0%)] Loss: 1.315268
Train Epoch: 50 [1280/50000 (3%)] Loss: 1.287735
Train Epoch: 50 [2560/50000 (5%)] Loss: 1.234877
Train Epoch: 50 [3840/50000 (8%)] Loss: 1.038986
Train Epoch: 50 [5120/50000 (10%)] Loss: 1.300337
Train Epoch: 50 [6400/50000 (13%)] Loss: 1.158519
Train Epoch: 50 [7680/50000 (15%)] Loss: 1.340239
Train Epoch: 50 [8960/50000 (18%)] Loss: 1.409270
Train Epoch: 50 [10240/50000 (20%)] Loss: 1.282208
Train Epoch: 50 [11520/50000 (23%)] Loss: 1.220007
Train Epoch: 50 [12800/50000 (26%)] Loss: 1.306531
Train Epoch: 50 [14080/50000 (28%)] Loss: 1.484605
Train Epoch: 50 [15360/50000 (31%)] Loss: 1.526141
Train Epoch: 50 [16640/50000 (33%)] Loss: 1.338631
Train Epoch: 50 [17920/50000 (36%)] Loss: 1.265509
Train Epoch: 50 [19200/50000 (38%)] Loss: 1.123598
Train Epoch: 50 [20480/50000 (41%)] Loss: 1.193225
Train Epoch: 50 [21760/50000 (43%)] Loss: 1.247666
Train Epoch: 50 [23040/50000 (46%)] Loss: 1.299415
Train Epoch: 50 [24320/50000 (49%)] Loss: 1.218696
Train Epoch: 50 [25600/50000 (51%)] Loss: 1.080708
Train Epoch: 50 [26880/50000 (54%)] Loss: 1.158993
Train Epoch: 50 [28160/50000 (56%)] Loss: 1.384896
Train Epoch: 50 [29440/50000 (59%)] Loss: 1.279704
Train Epoch: 50 [30720/50000 (61%)] Loss: 1.395216
Train Epoch: 50 [32000/50000 (64%)] Loss: 1.108406
Train Epoch: 50 [33280/50000 (66%)] Loss: 1.153651
Train Epoch: 50 [34560/50000 (69%)] Loss: 1.169921
Train Epoch: 50 [35840/50000 (72%)] Loss: 1.113130
Train Epoch: 50 [37120/50000 (74%)] Loss: 1.446717
Train Epoch: 50 [38400/50000 (77%)] Loss: 1.262444
Train Epoch: 50 [39680/50000 (79%)] Loss: 1.289180
Train Epoch: 50 [40960/50000 (82%)] Loss: 1.280956
Train Epoch: 50 [42240/50000 (84%)] Loss: 1.280873
Train Epoch: 50 [43520/50000 (87%)] Loss: 1.206315
Train Epoch: 50 [44800/50000 (90%)] Loss: 1.066622
Train Epoch: 50 [46080/50000 (92%)] Loss: 1.212352
Train Epoch: 50 [47360/50000 (95%)] Loss: 1.294498
Train Epoch: 50 [48640/50000 (97%)] Loss: 1.203302
Train Epoch: 50 [31200/50000 (100%)] Loss: 1.341009

Test set: Average loss: 1.1034, Accuracy: 6205/10000 (62%)

Training and Testing total execution time is: 1786.100849866867 seconds
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3) Network with additional batch normalization

```
Train Epoch: 50 [0/50000 (0%)] Loss: 1.471429
Train Epoch: 50 [1280/50000 (3%)] Loss: 1.645628
Train Epoch: 50 [2560/50000 (5%)] Loss: 1.550724
Train Epoch: 50 [3840/50000 (8%)] Loss: 1.520625
Train Epoch: 50 [5120/50000 (10%)] Loss: 1.426219
Train Epoch: 50 [6400/50000 (13%)] Loss: 1.507372
Train Epoch: 50 [7680/50000 (15%)] Loss: 1.373160
Train Epoch: 50 [8960/50000 (18%)] Loss: 1.648814
Train Epoch: 50 [10240/50000 (20%)] Loss: 1.565533
Train Epoch: 50 [11520/50000 (23%)] Loss: 1.372894
Train Epoch: 50 [12800/50000 (26%)] Loss: 1.336424
Train Epoch: 50 [14080/50000 (28%)] Loss: 1.559218
Train Epoch: 50 [15360/50000 (31%)] Loss: 1.580400
Train Epoch: 50 [16640/50000 (33%)] Loss: 1.494160
Train Epoch: 50 [17920/50000 (36%)] Loss: 1.440488
Train Epoch: 50 [19200/50000 (38%)] Loss: 1.429951
Train Epoch: 50 [20480/50000 (41%)] Loss: 1.510176
Train Epoch: 50 [21760/50000 (43%)] Loss: 1.609476
Train Epoch: 50 [23040/50000 (46%)] Loss: 1.413746
Train Epoch: 50 [24320/50000 (49%)] Loss: 1.517002
Train Epoch: 50 [25600/50000 (51%)] Loss: 1.397030
Train Epoch: 50 [26880/50000 (54%)] Loss: 1.559407
Train Epoch: 50 [28160/50000 (56%)] Loss: 1.402797
Train Epoch: 50 [29440/50000 (59%)] Loss: 1.440210
Train Epoch: 50 [30720/50000 (61%)] Loss: 1.499036
Train Epoch: 50 [32000/50000 (64%)] Loss: 1.522069
Train Epoch: 50 [33280/50000 (66%)] Loss: 1.441083
Train Epoch: 50 [34560/50000 (69%)] Loss: 1.533419
Train Epoch: 50 [35840/50000 (72%)] Loss: 1.485122
Train Epoch: 50 [37120/50000 (74%)] Loss: 1.726954
Train Epoch: 50 [38400/50000 (77%)] Loss: 1.437079
Train Epoch: 50 [39680/50000 (79%)] Loss: 1.664803
Train Epoch: 50 [40960/50000 (82%)] Loss: 1.571459
Train Epoch: 50 [42240/50000 (84%)] Loss: 1.553619
Train Epoch: 50 [43520/50000 (87%)] Loss: 1.377157
Train Epoch: 50 [44800/50000 (90%)] Loss: 1.528979
Train Epoch: 50 [46080/50000 (92%)] Loss: 1.477032
Train Epoch: 50 [47360/50000 (95%)] Loss: 1.452484
Train Epoch: 50 [48640/50000 (97%)] Loss: 1.533763
Train Epoch: 50 [31200/50000 (100%)] Loss: 1.457028

Test set: Average loss: 1.4029, Accuracy: 5352/10000 (54%)

Training and Testing total execution time is: 2513.147794008255 seconds
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