

# Deep Neural Networks

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## 1 Assignment-2

### 1.1 Gradient Descent with Tensorflow

- Implemented with a subset of training data (100K) and varying number of iterations

SubsetSize: 5000 NumSteps: 500 TimeElapsed: 13.93 Test accuracy: 80.7%  
SubsetSize: 5000 NumSteps: 1000 TimeElapsed: 27.49 Test accuracy: 81.5%  
SubsetSize: 5000 NumSteps: 1500 TimeElapsed: 41.05 Test accuracy: 81.8%  
SubsetSize: 5000 NumSteps: 2000 TimeElapsed: 54.59 Test accuracy: 81.8%  
SubsetSize: 5000 NumSteps: 2500 TimeElapsed: 68.15 Test accuracy: 82.0%  
SubsetSize: 5000 NumSteps: 3000 TimeElapsed: 82.06 Test accuracy: 82.0%  
SubsetSize: 5000 NumSteps: 3500 TimeElapsed: 95.65 Test accuracy: 81.9%  
SubsetSize: 5000 NumSteps: 4000 TimeElapsed: 109.39 Test accuracy: 82.0%  
SubsetSize: 5000 NumSteps: 4500 TimeElapsed: 123.09 Test accuracy: 82.1%

SubsetSize: 10000 NumSteps: 500 TimeElapsed: 26.82 Test accuracy: 82.2%  
SubsetSize: 10000 NumSteps: 1000 TimeElapsed: 53.17 Test accuracy: 83.0%  
SubsetSize: 10000 NumSteps: 1500 TimeElapsed: 79.68 Test accuracy: 83.5%  
SubsetSize: 10000 NumSteps: 2000 TimeElapsed: 105.96 Test accuracy: 83.9%  
SubsetSize: 10000 NumSteps: 2500 TimeElapsed: 132.19 Test accuracy: 84.1%  
SubsetSize: 10000 NumSteps: 3000 TimeElapsed: 158.45 Test accuracy: 84.3%  
SubsetSize: 10000 NumSteps: 3500 TimeElapsed: 184.82 Test accuracy: 84.4%  
SubsetSize: 10000 NumSteps: 4000 TimeElapsed: 211.10 Test accuracy: 84.4%  
SubsetSize: 10000 NumSteps: 4500 TimeElapsed: 237.34 Test accuracy: 84.5%

SubsetSize: 15000 NumSteps: 500 TimeElapsed: 40.75 Test accuracy: 82.4%  
SubsetSize: 15000 NumSteps: 1000 TimeElapsed: 80.88 Test accuracy: 83.3%  
SubsetSize: 15000 NumSteps: 1500 TimeElapsed: 123.19 Test accuracy: 83.9%  
SubsetSize: 15000 NumSteps: 2000 TimeElapsed: 163.38 Test accuracy: 84.1%  
SubsetSize: 15000 NumSteps: 2500 TimeElapsed: 203.56 Test accuracy: 84.4%  
SubsetSize: 15000 NumSteps: 3000 TimeElapsed: 243.67 Test accuracy: 84.7%  
SubsetSize: 15000 NumSteps: 3500 TimeElapsed: 284.50 Test accuracy: 84.9%  
SubsetSize: 15000 NumSteps: 4000 TimeElapsed: 324.80 Test accuracy: 85.2%  
SubsetSize: 15000 NumSteps: 4500 TimeElapsed: 365.15 Test accuracy: 85.3%

SubsetSize: 20000 NumSteps: 500 TimeElapsed: 54.14 Test accuracy: 82.3%  
SubsetSize: 20000 NumSteps: 1000 TimeElapsed: 107.58 Test accuracy: 83.2%  
SubsetSize: 20000 NumSteps: 1500 TimeElapsed: 167.59 Test accuracy: 83.9%  
SubsetSize: 20000 NumSteps: 2000 TimeElapsed: 221.55 Test accuracy: 84.2%  
SubsetSize: 20000 NumSteps: 2500 TimeElapsed: 274.99 Test accuracy: 84.7%  
SubsetSize: 20000 NumSteps: 3000 TimeElapsed: 328.04 Test accuracy: 84.9%  
SubsetSize: 20000 NumSteps: 3500 TimeElapsed: 381.22 Test accuracy: 85.1%  
SubsetSize: 20000 NumSteps: 4000 TimeElapsed: 434.55 Test accuracy: 85.3%  
SubsetSize: 20000 NumSteps: 4500 TimeElapsed: 488.82 Test accuracy: 85.4%

SubsetSize: 25000 NumSteps: 500 TimeElapsed: 67.05 Test accuracy: 82.5%  
SubsetSize: 25000 NumSteps: 1000 TimeElapsed: 133.22 Test accuracy: 83.5%  
SubsetSize: 25000 NumSteps: 1500 TimeElapsed: 199.75 Test accuracy: 84.0%

SubsetSize: 25000 NumSteps: 2000 TimeElapsed: 266.00 Test accuracy: 84.3%  
 SubsetSize: 25000 NumSteps: 2500 TimeElapsed: 332.50 Test accuracy: 84.6%  
 SubsetSize: 25000 NumSteps: 3000 TimeElapsed: 401.35 Test accuracy: 85.0%  
 SubsetSize: 25000 NumSteps: 3500 TimeElapsed: 471.72 Test accuracy: 85.3%  
 SubsetSize: 25000 NumSteps: 4000 TimeElapsed: 548.04 Test accuracy: 85.5%  
 SubsetSize: 25000 NumSteps: 4500 TimeElapsed: 621.31 Test accuracy: 85.7%

SubsetSize: 30000 NumSteps: 500 TimeElapsed: 81.26 Test accuracy: 82.7%  
 SubsetSize: 30000 NumSteps: 1000 TimeElapsed: 168.11 Test accuracy: 83.7%  
 SubsetSize: 30000 NumSteps: 1500 TimeElapsed: 248.38 Test accuracy: 84.5%  
 SubsetSize: 30000 NumSteps: 2000 TimeElapsed: 328.91 Test accuracy: 85.1%  
 SubsetSize: 30000 NumSteps: 2500 TimeElapsed: 416.95 Test accuracy: 85.4%  
 SubsetSize: 30000 NumSteps: 3000 TimeElapsed: 500.80 Test accuracy: 85.7%  
 SubsetSize: 30000 NumSteps: 3500 TimeElapsed: 585.57 Test accuracy: 85.9%  
 SubsetSize: 30000 NumSteps: 4000 TimeElapsed: 666.61 Test accuracy: 86.2%  
 SubsetSize: 30000 NumSteps: 4500 TimeElapsed: 747.29 Test accuracy: 86.4%

- On an average it takes 450s to get a test accuracy of 84.9%

## 1.2 Stochastic Gradient Descent with TensorFlow

- Implemented with varying batch size

BatchSize: 64 NumSteps: 500 TimeElapsed: 0.81 Test accuracy: 82.2%  
 BatchSize: 64 NumSteps: 1000 TimeElapsed: 1.33 Test accuracy: 83.6%  
 BatchSize: 64 NumSteps: 1500 TimeElapsed: 1.84 Test accuracy: 83.8%  
 BatchSize: 64 NumSteps: 2000 TimeElapsed: 2.37 Test accuracy: 83.5%  
 BatchSize: 64 NumSteps: 2500 TimeElapsed: 2.89 Test accuracy: 84.8%  
 BatchSize: 64 NumSteps: 3000 TimeElapsed: 3.41 Test accuracy: 83.7%  
 BatchSize: 64 NumSteps: 3500 TimeElapsed: 3.92 Test accuracy: 85.0%  
 BatchSize: 64 NumSteps: 4000 TimeElapsed: 4.45 Test accuracy: 84.8%  
 BatchSize: 64 NumSteps: 4500 TimeElapsed: 4.96 Test accuracy: 86.1%

BatchSize: 128 NumSteps: 500 TimeElapsed: 1.01 Test accuracy: 82.9%  
 BatchSize: 128 NumSteps: 1000 TimeElapsed: 1.80 Test accuracy: 83.5%  
 BatchSize: 128 NumSteps: 1500 TimeElapsed: 2.59 Test accuracy: 84.4%  
 BatchSize: 128 NumSteps: 2000 TimeElapsed: 3.38 Test accuracy: 84.0%  
 BatchSize: 128 NumSteps: 2500 TimeElapsed: 4.17 Test accuracy: 85.6%  
 BatchSize: 128 NumSteps: 3000 TimeElapsed: 4.97 Test accuracy: 85.0%  
 BatchSize: 128 NumSteps: 3500 TimeElapsed: 5.75 Test accuracy: 86.2%  
 BatchSize: 128 NumSteps: 4000 TimeElapsed: 6.55 Test accuracy: 86.3%  
 BatchSize: 128 NumSteps: 4500 TimeElapsed: 7.35 Test accuracy: 86.6%

BatchSize: 256 NumSteps: 500 TimeElapsed: 1.53 Test accuracy: 82.7%  
 BatchSize: 256 NumSteps: 1000 TimeElapsed: 2.82 Test accuracy: 83.8%  
 BatchSize: 256 NumSteps: 1500 TimeElapsed: 4.11 Test accuracy: 84.5%  
 BatchSize: 256 NumSteps: 2000 TimeElapsed: 5.40 Test accuracy: 85.2%  
 BatchSize: 256 NumSteps: 2500 TimeElapsed: 6.69 Test accuracy: 85.7%  
 BatchSize: 256 NumSteps: 3000 TimeElapsed: 7.98 Test accuracy: 86.1%  
 BatchSize: 256 NumSteps: 3500 TimeElapsed: 9.27 Test accuracy: 86.3%  
 BatchSize: 256 NumSteps: 4000 TimeElapsed: 10.56 Test accuracy: 86.2%  
 BatchSize: 256 NumSteps: 4500 TimeElapsed: 11.84 Test accuracy: 86.5%

BatchSize: 512 NumSteps: 500 TimeElapsed: 2.51 Test accuracy: 82.5%  
 BatchSize: 512 NumSteps: 1000 TimeElapsed: 4.74 Test accuracy: 83.7%  
 BatchSize: 512 NumSteps: 1500 TimeElapsed: 6.98 Test accuracy: 84.4%  
 BatchSize: 512 NumSteps: 2000 TimeElapsed: 9.22 Test accuracy: 84.9%  
 BatchSize: 512 NumSteps: 2500 TimeElapsed: 11.45 Test accuracy: 85.3%

BatchSize: 512 NumSteps: 3000 TimeElapsed: 13.70 Test accuracy: 86.0%  
BatchSize: 512 NumSteps: 3500 TimeElapsed: 15.93 Test accuracy: 86.2%  
BatchSize: 512 NumSteps: 4000 TimeElapsed: 18.17 Test accuracy: 86.4%  
BatchSize: 512 NumSteps: 4500 TimeElapsed: 20.40 Test accuracy: 86.4%

BatchSize: 1024 NumSteps: 500 TimeElapsed: 4.30 Test accuracy: 82.5%  
BatchSize: 1024 NumSteps: 1000 TimeElapsed: 8.35 Test accuracy: 83.8%  
BatchSize: 1024 NumSteps: 1500 TimeElapsed: 12.39 Test accuracy: 84.4%  
BatchSize: 1024 NumSteps: 2000 TimeElapsed: 16.44 Test accuracy: 85.2%  
BatchSize: 1024 NumSteps: 2500 TimeElapsed: 20.48 Test accuracy: 85.6%  
BatchSize: 1024 NumSteps: 3000 TimeElapsed: 25.14 Test accuracy: 86.2%  
BatchSize: 1024 NumSteps: 3500 TimeElapsed: 29.67 Test accuracy: 86.4%  
BatchSize: 1024 NumSteps: 4000 TimeElapsed: 34.03 Test accuracy: 86.7%  
BatchSize: 1024 NumSteps: 4500 TimeElapsed: 38.60 Test accuracy: 86.9%

BatchSize: 2048 NumSteps: 500 TimeElapsed: 8.14 Test accuracy: 82.9%  
BatchSize: 2048 NumSteps: 1000 TimeElapsed: 16.21 Test accuracy: 83.9%  
BatchSize: 2048 NumSteps: 1500 TimeElapsed: 24.39 Test accuracy: 84.7%  
BatchSize: 2048 NumSteps: 2000 TimeElapsed: 32.00 Test accuracy: 85.3%  
BatchSize: 2048 NumSteps: 2500 TimeElapsed: 39.43 Test accuracy: 85.8%  
BatchSize: 2048 NumSteps: 3000 TimeElapsed: 46.82 Test accuracy: 86.1%  
BatchSize: 2048 NumSteps: 3500 TimeElapsed: 54.28 Test accuracy: 86.5%  
BatchSize: 2048 NumSteps: 4000 TimeElapsed: 61.88 Test accuracy: 86.8%  
BatchSize: 2048 NumSteps: 4500 TimeElapsed: 69.37 Test accuracy: 87.0%

- **Optimizing using SGD can achieve 86%+ accuracy using a batch size of 128 in just 7.35s**
- SGD is way faster than batch GD.

### 1.3 Neural Network

- 1 hidden layer, 1024 nodes, 128 batch size
- Achieves 88.3% test accuracy in around 50s