

# Homework Assignment - 1

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**Problem Statement.** Implement and train a neural network from scratch in Python for the MNIST dataset (no PyTorch). The neural network should be trained on the Training Set using stochastic gradient descent. It should achieve 97-98% accuracy on the Test Set. For full credit, submit via Compass (1) the code and (2) a paragraph (in a PDF document) which states the Test Accuracy and briefly describes the implementation.

**Approach.** A single-layer neural network has been implemented using the NumPy library on Python 3.

- **Input Dimension** -  $28*28 = 784$
- **Hidden Units** - 100
- **Output Dimension** - 10 (MNIST digits)
- **Epochs** - 30
- **ReLU** non-linear activation on the hidden layer.
- Stochastic Gradient Descent (**SGD**) for parameter updates.
- Network trained on **Cross-Entropy loss**.
- Decaying schedule used for the learning rate. (Starting from **1e-2** to **1e-5**)

**Results on MNIST.** After 30 epochs, accuracy on test data - **98.11%**.

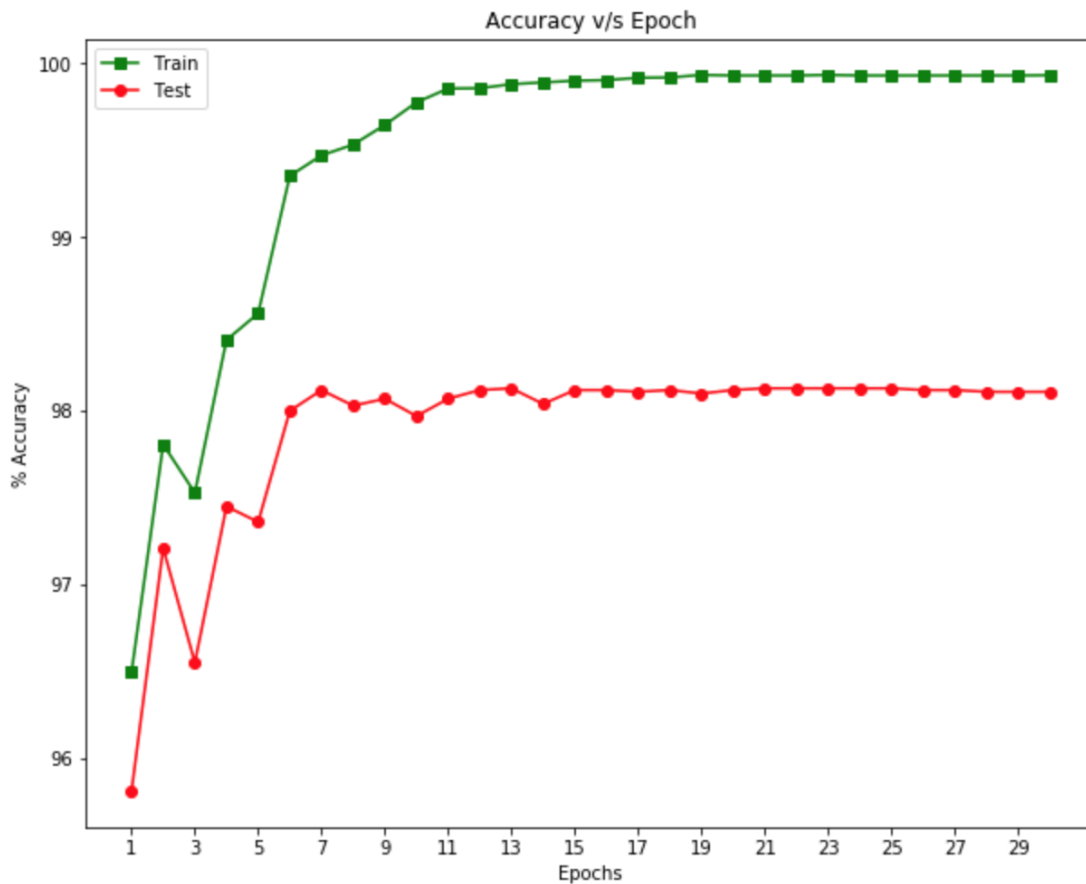
It can be seen through the below summary that the network converges after roughly 20 epochs.

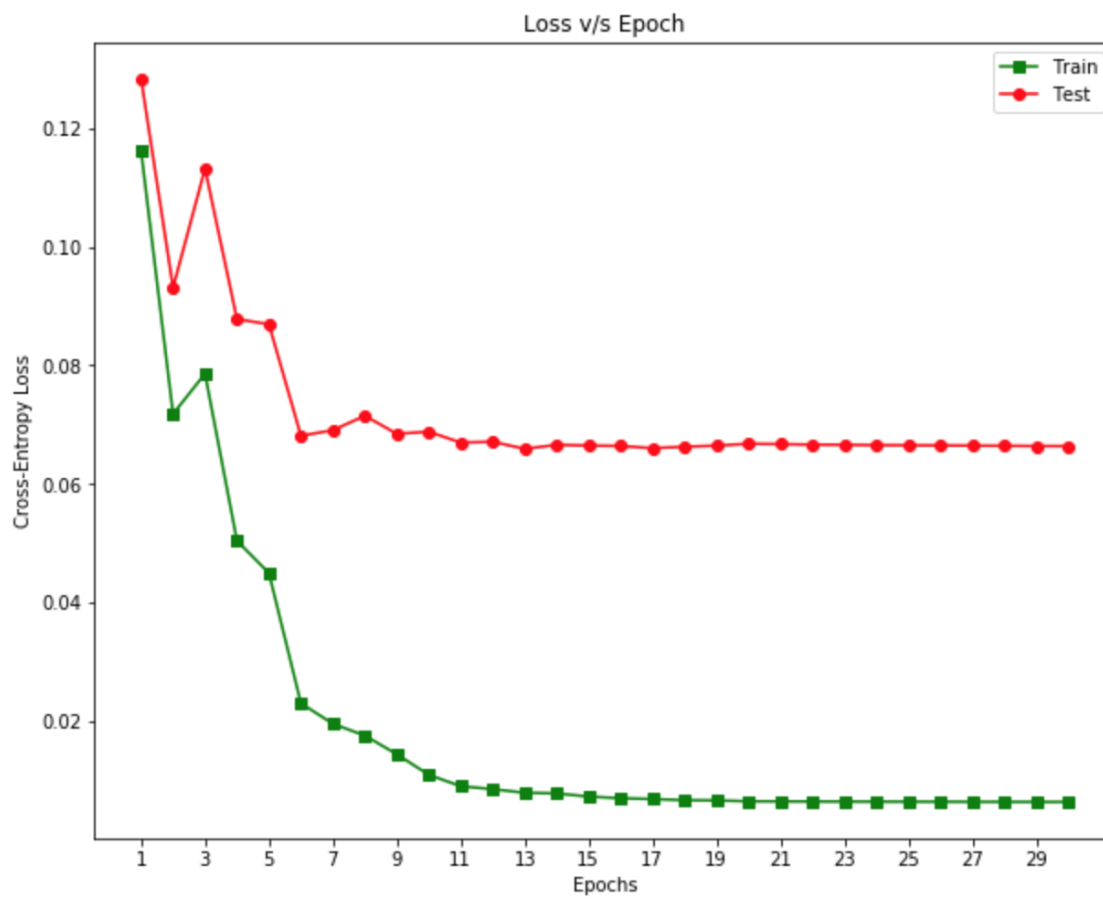
Time taken for the training - **22 minutes**.

Please scroll to the **next page** for loss and accuracy curves.

Epoch 1 - 95.81% test accuracy, 0.1284 test loss, 96.50% train accuracy, 0.1162 train loss.  
Epoch 2 - 97.21% test accuracy, 0.0931 test loss, 97.81% train accuracy, 0.0718 train loss.  
Epoch 3 - 96.55% test accuracy, 0.1132 test loss, 97.53% train accuracy, 0.0786 train loss.  
Epoch 4 - 97.45% test accuracy, 0.0878 test loss, 98.41% train accuracy, 0.0504 train loss.  
Epoch 5 - 97.36% test accuracy, 0.0870 test loss, 98.56% train accuracy, 0.0450 train loss.  
Epoch 6 - 98.00% test accuracy, 0.0681 test loss, 99.35% train accuracy, 0.0230 train loss.  
Epoch 7 - 98.12% test accuracy, 0.0691 test loss, 99.47% train accuracy, 0.0195 train loss.  
Epoch 8 - 98.03% test accuracy, 0.0715 test loss, 99.53% train accuracy, 0.0175 train loss.  
Epoch 9 - 98.07% test accuracy, 0.0685 test loss, 99.65% train accuracy, 0.0144 train loss.  
Epoch 10 - 97.97% test accuracy, 0.0688 test loss, 99.78% train accuracy, 0.0109 train loss.  
Epoch 11 - 98.07% test accuracy, 0.0670 test loss, 99.86% train accuracy, 0.0090 train loss.  
Epoch 12 - 98.12% test accuracy, 0.0671 test loss, 99.86% train accuracy, 0.0085 train loss.  
Epoch 13 - 98.13% test accuracy, 0.0659 test loss, 99.88% train accuracy, 0.0079 train loss.  
Epoch 14 - 98.04% test accuracy, 0.0666 test loss, 99.89% train accuracy, 0.0078 train loss.  
Epoch 15 - 98.12% test accuracy, 0.0665 test loss, 99.90% train accuracy, 0.0072 train loss.  
Epoch 16 - 98.12% test accuracy, 0.0664 test loss, 99.91% train accuracy, 0.0070 train loss.  
Epoch 17 - 98.11% test accuracy, 0.0660 test loss, 99.92% train accuracy, 0.0068 train loss.  
Epoch 18 - 98.12% test accuracy, 0.0663 test loss, 99.92% train accuracy, 0.0066 train loss.  
Epoch 19 - 98.10% test accuracy, 0.0665 test loss, 99.94% train accuracy, 0.0066 train loss.  
Epoch 20 - 98.12% test accuracy, 0.0668 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 21 - 98.13% test accuracy, 0.0667 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 22 - 98.13% test accuracy, 0.0666 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 23 - 98.13% test accuracy, 0.0666 test loss, 99.94% train accuracy, 0.0064 train loss.  
Epoch 24 - 98.13% test accuracy, 0.0666 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 25 - 98.13% test accuracy, 0.0665 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 26 - 98.12% test accuracy, 0.0665 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 27 - 98.12% test accuracy, 0.0665 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 28 - 98.11% test accuracy, 0.0664 test loss, 99.93% train accuracy, 0.0064 train loss.  
Epoch 29 - 98.11% test accuracy, 0.0664 test loss, 99.93% train accuracy, 0.0063 train loss.  
Epoch 30 - 98.11% test accuracy, 0.0664 test loss, 99.93% train accuracy, 0.0063 train loss.

Time taken for 30 epochs - 1298.218 seconds





End of HW - 1

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