**Critical Thinking 2**

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CSC580: Applying Machine Learning and Neural Networks - Capstone

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# MNIST Multi-Layer Perceptron (MLP) – Assignment Report

## Introduction

This report documents my experiments training a multi-layer perceptron (MLP) on the MNIST dataset using TensorFlow. I follow the assignment’s pipeline (flattened 28×28 inputs, one-hot labels, ReLU, softmax cross-entropy, SGD) and vary key hyperparameters.

**Single baseline run**

python mnist\_mlp\_tf1\_compat.py --epochs 20 --batch\_size 100 --learning\_rate 0.5 --hidden\_nodes 512

Outputs saved under outputs/hn512\_hn20\_lr0.5\_bs100\_ep20\_seed42/:

* metrics.json (includes final test accuracy)
* misclassified\_grid.png and several sample\_misclassified\_\*.png

**Grid of experiments**

python experiments\_grid.py

Results go to experiments/results.csv, and each run has its own folder under experiments/runs/. The script also prints the best accuracy configuration.

**View a run’s misclassifications**

python visualize\_misclassifications.py --run\_dir experiments/runs/<your\_run\_folder>

**Information gathered from results.csv:**

## Accuracy of the Model

Final test accuracy across runs ranged from 91.5% to 98.5%. The best configuration achieved 98.48% accuracy.

## Misclassified Images

In the best model (98.48% accuracy), 152 test images were misclassified. Typical errors included confusions such as 4 vs 9, 5 vs 3, and 7 vs 1.

## Hyperparameter Studies

### Hidden Neurons

- 128 nodes → avg accuracy: 96.50%  
- 512 nodes → avg accuracy: 96.96%  
Conclusion: More neurons improved performance slightly.

### Learning Rate

- 0.01 → 94.37%  
- 0.05 → 96.91%  
- 0.1 → 97.51%  
- 0.5 → 98.13%  
Conclusion: Higher learning rates (0.1–0.5) produced the best results within 15 epochs.

### Adding a Second Hidden Layer

- Single layer (hn2=0) → avg accuracy: 96.40%  
- Two layers (hn2=256) → avg accuracy: 97.06%  
Conclusion: Adding a second hidden layer improved accuracy by ~0.6%.

### Batch Size Variations

- 64 → 97.36%  
- 100 → 96.91%  
- 256 → 95.92%  
Conclusion: Smaller batches improved generalization; larger batches reduced accuracy slightly.

## Best Accuracy Achieved

The best accuracy achieved was 98.48% with configuration:  
- Hidden layer 1: 512 nodes  
- Hidden layer 2: 256 nodes  
- Learning rate: 0.5  
- Batch size: 64  
- Epochs: 15  
This run misclassified 152 test images.