

# Hyperparameter Tuning

---

## What Hyperparameters Were Explored

The tuning process explored the following key hyperparameters:

### 1. Units (Neurons) in Fully Connected Layers:

- The tuner's search space for each layer's neurons was **constrained to a range around values** derived from the digits of the user's unique ID.
- **Ranges:**
  - Layer 1: **40 – 80** (centered around the fixed 57 neurons)
  - Layer 2: **70 – 120** (centered around the fixed 93 neurons)
  - Layer 3: **35 – 65** (centered around the fixed 50 neurons)
  - Layer 4: **15 – 30** (centered around the fixed 22 neurons)

### 2. Dropout Rates:

- Explored for each fully connected layer within the range of **0.1** to **0.4** in steps of 0.1.

### 3. Learning Rates:

- Discrete choices: **[0.01, 0.001, 0.0001]**.

### 4. Training Epochs:

- Fixed at **10** epochs for all trials.
- 

## Search Process: Hyperband Algorithm

### Number of Trials

The tuner was configured to explore the search space over multiple trials, with each trial representing a unique combination of hyperparameter values. The following parameters were configured:

- **Max Trials:** 30.
- **Max Epochs per Trial:** 10.
- **Factor:** 3 (reducing the resources allocated to less promising configurations).

A total of **30 trials** were **executed**, during which the tuner evaluated each hyperparameter combination on a validation split of the training data.

## Trials & Epochs Details

30 Trials completion with the best hyperparameters found:

```
Trial 30 Complete [00h 01m 35s]
val_accuracy: 0.9674999713897705

Best val_accuracy So Far: 0.9713333249092102
Total elapsed time: 00h 20m 23s
Best hyperparameters:
units_0: 68
dropout_0: 0.2
units_1: 78
dropout_1: 0.2
units_2: 59
dropout_2: 0.1
units_3: 18
dropout_3: 0.1
learning_rate: 0.001
tuner/epochs: 10
tuner/initial_epoch: 4
tuner/bracket: 1
tuner/round: 1
tuner/trial_id: 0020
Epoch 1/10
1500/1500 ————— 12s 6ms/step - accuracy: 0.6997 - loss: 0.9821 - val_accuracy: 0.9443 - val_loss: 0.1857
Epoch 2/10
1500/1500 ————— 9s 5ms/step - accuracy: 0.9011 - loss: 0.3396 - val_accuracy: 0.9572 - val_loss: 0.1476
Epoch 3/10
1500/1500 ————— 10s 5ms/step - accuracy: 0.9228 - loss: 0.2694 - val_accuracy: 0.9625 - val_loss: 0.1320
Epoch 4/10
1500/1500 ————— 8s 5ms/step - accuracy: 0.9300 - loss: 0.2427 - val_accuracy: 0.9647 - val_loss: 0.1228
Epoch 5/10
1500/1500 ————— 7s 5ms/step - accuracy: 0.9387 - loss: 0.2147 - val_accuracy: 0.9675 - val_loss: 0.1099
Epoch 6/10
1500/1500 ————— 10s 4ms/step - accuracy: 0.9411 - loss: 0.2007 - val_accuracy: 0.9679 - val_loss: 0.1107
Epoch 7/10
1500/1500 ————— 10s 5ms/step - accuracy: 0.9434 - loss: 0.1915 - val_accuracy: 0.9712 - val_loss: 0.1013
Epoch 8/10
1500/1500 ————— 8s 5ms/step - accuracy: 0.9503 - loss: 0.1692 - val_accuracy: 0.9707 - val_loss: 0.0982
Epoch 9/10
1500/1500 ————— 9s 4ms/step - accuracy: 0.9523 - loss: 0.1669 - val_accuracy: 0.9702 - val_loss: 0.1002
Epoch 10/10
1500/1500 ————— 8s 5ms/step - accuracy: 0.9535 - loss: 0.1588 - val_accuracy: 0.9722 - val_loss: 0.0975
313/313 ————— 1s 2ms/step - accuracy: 0.9685 - loss: 0.1020
Best model test loss: 0.0919
Best model test accuracy: 0.9726
```

Time taken for the tuner to finish executing: **20 mins**

## Results

The hyperparameters found (near-optimal) by the tuner are:

- **Units (Neurons):**
  - Layer 1: **68**
  - Layer 2: **78**
  - Layer 3: **59**
  - Layer 4: **18**
- **Dropout Rates:**
  - Layer 1: **0.2**
  - Layer 2: **0.2**
  - Layer 3: **0.1**
  - Layer 4: **0.1**
- **Learning Rate: 0.001**

---

## Conclusion

The hyperparameter tuning process successfully identified a configuration that **significantly enhanced the model's performance**. The best model achieved a **test accuracy of 97.26%** and a **test loss of 9.19%**, demonstrating strong generalization and effective learning. By **balancing the ID-based neuron configuration with optimal dropout rates and learning rates**, the final architecture maintained interpretability while maximizing performance.

These optimized hyperparameters **were integrated into the final model** (in `Osama_Ghaliah_ex2.ipynb`), ensuring that the design leverages the best possible configuration for the MNIST classification task.

---