

Importing libraries

```
In [22]: import os
import sys
import torch
import importlib

current_dir = os.getcwd()
project_root = os.path.dirname(current_dir)
sys.path.append(project_root)

# Import our custom modules
import src.utils as utils
import src.plots as plots
import src.flexible_nn as nn_flexible

from src.utils import load_transform_split_mnist, per_class_accuracy
from src.plots import plot_train_val_curves, plot_confusion_matrix, plot_per_class_acc
from src.flexible_nn import FlexibleNN
```

Load Data loaders

```
In [19]: # Using the same utility from Part A, but loading all classes
train_loader, val_loader, test_loader, _, _, _, _ = load_transform_split_mnist(
    val_size=0.2,
    classes=None, # None means all 10 classes
    batch_size=64
)

print("Data loaders created successfully.")
```

Data loaders created successfully.

Initialize and Train Model

```
In [7]: # B1: Define flexible architecture
# We just pass a list of layer sizes to my FlexibleNN
layer_sizes = [
    28 * 28, # 784 Input
    128,     # Hidden 1
    64,      # Hidden 2
    10       # Output
]

# B2: Set training configuration
LEARNING_RATE = 0.01
EPOCHS = 20 # Using 30 epochs as in your notebook
N_RUNS = 5 # Number of runs for error bars

# List to store the history from all runs
all_histories = []

print(f"Starting {N_RUNS} training runs (for error bars)...")
print("#" * 60)

for i in range(N_RUNS):
    print(f"\n--- Starting Run {i+1}/{N_RUNS} ---")

    # Set a different seed for each run for different weight initializations
    torch.manual_seed(i)

    # B1: Initialize my FlexibleNN model
    model = FlexibleNN(layer_sizes)

    # B2: Call the custom training loop.
    # Note: My `fit` method saves history internally.
    model.fit(train_loader, val_loader, epochs=EPOCHS, lr=LEARNING_RATE)

    # Save the history from this run
    all_histories.append(model.history)
    print(f"Run {i+1} complete.")

print("#" * 60)
print("All training runs complete!")
```

Starting 5 training runs (for error bars)...

#####

--- Starting Run 1/5 ---

Epoch	1/20		Train Loss: 0.8404,	Train Acc: 77.82%		Val Loss: 0.4265,	Val Acc: 88.51%
Epoch	2/20		Train Loss: 0.3688,	Train Acc: 89.72%		Val Loss: 0.3341,	Val Acc: 90.73%
Epoch	3/20		Train Loss: 0.3042,	Train Acc: 91.33%		Val Loss: 0.2909,	Val Acc: 91.68%
Epoch	4/20		Train Loss: 0.2695,	Train Acc: 92.26%		Val Loss: 0.2622,	Val Acc: 92.59%
Epoch	5/20		Train Loss: 0.2453,	Train Acc: 92.98%		Val Loss: 0.2444,	Val Acc: 93.14%
Epoch	6/20		Train Loss: 0.2264,	Train Acc: 93.55%		Val Loss: 0.2309,	Val Acc: 93.41%
Epoch	7/20		Train Loss: 0.2102,	Train Acc: 93.97%		Val Loss: 0.2177,	Val Acc: 93.75%
Epoch	8/20		Train Loss: 0.1968,	Train Acc: 94.44%		Val Loss: 0.2101,	Val Acc: 93.95%
Epoch	9/20		Train Loss: 0.1850,	Train Acc: 94.74%		Val Loss: 0.1991,	Val Acc: 94.37%
Epoch	10/20		Train Loss: 0.1747,	Train Acc: 95.05%		Val Loss: 0.1893,	Val Acc: 94.50%
Epoch	11/20		Train Loss: 0.1655,	Train Acc: 95.29%		Val Loss: 0.1811,	Val Acc: 94.83%
Epoch	12/20		Train Loss: 0.1573,	Train Acc: 95.50%		Val Loss: 0.1741,	Val Acc: 94.97%
Epoch	13/20		Train Loss: 0.1497,	Train Acc: 95.75%		Val Loss: 0.1689,	Val Acc: 95.08%
Epoch	14/20		Train Loss: 0.1432,	Train Acc: 95.93%		Val Loss: 0.1644,	Val Acc: 95.40%
Epoch	15/20		Train Loss: 0.1369,	Train Acc: 96.14%		Val Loss: 0.1595,	Val Acc: 95.47%
Epoch	16/20		Train Loss: 0.1312,	Train Acc: 96.25%		Val Loss: 0.1551,	Val Acc: 95.59%
Epoch	17/20		Train Loss: 0.1260,	Train Acc: 96.42%		Val Loss: 0.1515,	Val Acc: 95.64%
Epoch	18/20		Train Loss: 0.1211,	Train Acc: 96.58%		Val Loss: 0.1484,	Val Acc: 95.83%
Epoch	19/20		Train Loss: 0.1167,	Train Acc: 96.70%		Val Loss: 0.1446,	Val Acc: 95.95%
Epoch	20/20		Train Loss: 0.1125,	Train Acc: 96.87%		Val Loss: 0.1404,	Val Acc: 96.07%

Run 1 complete.

--- Starting Run 2/5 ---

Epoch	1/20		Train Loss: 0.8973,	Train Acc: 76.61%		Val Loss: 0.4476,	Val Acc: 87.96%
Epoch	2/20		Train Loss: 0.3872,	Train Acc: 89.11%		Val Loss: 0.3463,	Val Acc: 90.37%
Epoch	3/20		Train Loss: 0.3216,	Train Acc: 90.86%		Val Loss: 0.3047,	Val Acc: 91.27%
Epoch	4/20		Train Loss: 0.2856,	Train Acc: 91.84%		Val Loss: 0.2800,	Val Acc: 91.97%
Epoch	5/20		Train Loss: 0.2604,	Train Acc: 92.59%		Val Loss: 0.2599,	Val Acc: 92.61%
Epoch	6/20		Train Loss: 0.2400,	Train Acc: 93.15%		Val Loss: 0.2424,	Val Acc: 93.08%
Epoch	7/20		Train Loss: 0.2237,	Train Acc: 93.60%		Val Loss: 0.2289,	Val Acc: 93.60%
Epoch	8/20		Train Loss: 0.2092,	Train Acc: 93.95%		Val Loss: 0.2161,	Val Acc: 93.95%
Epoch	9/20		Train Loss: 0.1964,	Train Acc: 94.33%		Val Loss: 0.2086,	Val Acc: 94.08%
Epoch	10/20		Train Loss: 0.1857,	Train Acc: 94.66%		Val Loss: 0.1978,	Val Acc: 94.56%
Epoch	11/20		Train Loss: 0.1754,	Train Acc: 94.95%		Val Loss: 0.1898,	Val Acc: 94.61%
Epoch	12/20		Train Loss: 0.1663,	Train Acc: 95.19%		Val Loss: 0.1815,	Val Acc: 94.94%
Epoch	13/20		Train Loss: 0.1580,	Train Acc: 95.47%		Val Loss: 0.1740,	Val Acc: 95.10%
Epoch	14/20		Train Loss: 0.1503,	Train Acc: 95.63%		Val Loss: 0.1715,	Val Acc: 95.29%
Epoch	15/20		Train Loss: 0.1433,	Train Acc: 95.85%		Val Loss: 0.1622,	Val Acc: 95.48%
Epoch	16/20		Train Loss: 0.1368,	Train Acc: 96.09%		Val Loss: 0.1573,	Val Acc: 95.62%
Epoch	17/20		Train Loss: 0.1307,	Train Acc: 96.27%		Val Loss: 0.1527,	Val Acc: 95.67%
Epoch	18/20		Train Loss: 0.1254,	Train Acc: 96.48%		Val Loss: 0.1501,	Val Acc: 95.71%
Epoch	19/20		Train Loss: 0.1204,	Train Acc: 96.59%		Val Loss: 0.1443,	Val Acc: 95.93%
Epoch	20/20		Train Loss: 0.1154,	Train Acc: 96.73%		Val Loss: 0.1406,	Val Acc: 96.06%

Run 2 complete.

--- Starting Run 3/5 ---

Epoch	1/20		Train Loss: 0.8846,	Train Acc: 76.89%		Val Loss: 0.4458,	Val Acc: 87.81%
Epoch	2/20		Train Loss: 0.3825,	Train Acc: 89.30%		Val Loss: 0.3435,	Val Acc: 90.34%
Epoch	3/20		Train Loss: 0.3177,	Train Acc: 91.12%		Val Loss: 0.3012,	Val Acc: 91.47%
Epoch	4/20		Train Loss: 0.2845,	Train Acc: 91.88%		Val Loss: 0.2806,	Val Acc: 91.91%
Epoch	5/20		Train Loss: 0.2607,	Train Acc: 92.54%		Val Loss: 0.2588,	Val Acc: 92.60%
Epoch	6/20		Train Loss: 0.2422,	Train Acc: 93.12%		Val Loss: 0.2441,	Val Acc: 93.00%
Epoch	7/20		Train Loss: 0.2272,	Train Acc: 93.46%		Val Loss: 0.2292,	Val Acc: 93.58%
Epoch	8/20		Train Loss: 0.2136,	Train Acc: 93.84%		Val Loss: 0.2187,	Val Acc: 93.78%
Epoch	9/20		Train Loss: 0.2018,	Train Acc: 94.18%		Val Loss: 0.2098,	Val Acc: 94.18%
Epoch	10/20		Train Loss: 0.1909,	Train Acc: 94.51%		Val Loss: 0.2042,	Val Acc: 94.11%
Epoch	11/20		Train Loss: 0.1813,	Train Acc: 94.82%		Val Loss: 0.1946,	Val Acc: 94.54%
Epoch	12/20		Train Loss: 0.1723,	Train Acc: 95.06%		Val Loss: 0.1900,	Val Acc: 94.77%
Epoch	13/20		Train Loss: 0.1644,	Train Acc: 95.30%		Val Loss: 0.1811,	Val Acc: 95.02%
Epoch	14/20		Train Loss: 0.1564,	Train Acc: 95.57%		Val Loss: 0.1760,	Val Acc: 95.08%
Epoch	15/20		Train Loss: 0.1495,	Train Acc: 95.74%		Val Loss: 0.1699,	Val Acc: 95.24%
Epoch	16/20		Train Loss: 0.1433,	Train Acc: 95.93%		Val Loss: 0.1665,	Val Acc: 95.36%
Epoch	17/20		Train Loss: 0.1373,	Train Acc: 96.10%		Val Loss: 0.1619,	Val Acc: 95.47%
Epoch	18/20		Train Loss: 0.1321,	Train Acc: 96.22%		Val Loss: 0.1562,	Val Acc: 95.66%
Epoch	19/20		Train Loss: 0.1265,	Train Acc: 96.36%		Val Loss: 0.1520,	Val Acc: 95.64%
Epoch	20/20		Train Loss: 0.1220,	Train Acc: 96.57%		Val Loss: 0.1489,	Val Acc: 95.72%

Run 3 complete.

--- Starting Run 4/5 ---

Epoch	1/20		Train Loss: 0.9114,	Train Acc: 76.31%		Val Loss: 0.4344,	Val Acc: 88.33%
Epoch	2/20		Train Loss: 0.3729,	Train Acc: 89.61%		Val Loss: 0.3314,	Val Acc: 90.73%
Epoch	3/20		Train Loss: 0.3085,	Train Acc: 91.23%		Val Loss: 0.2921,	Val Acc: 91.71%
Epoch	4/20		Train Loss: 0.2747,	Train Acc: 92.15%		Val Loss: 0.2689,	Val Acc: 92.30%
Epoch	5/20		Train Loss: 0.2514,	Train Acc: 92.80%		Val Loss: 0.2507,	Val Acc: 92.95%
Epoch	6/20		Train Loss: 0.2324,	Train Acc: 93.39%		Val Loss: 0.2353,	Val Acc: 93.38%
Epoch	7/20		Train Loss: 0.2172,	Train Acc: 93.77%		Val Loss: 0.2213,	Val Acc: 93.88%
Epoch	8/20		Train Loss: 0.2038,	Train Acc: 94.20%		Val Loss: 0.2114,	Val Acc: 94.03%
Epoch	9/20		Train Loss: 0.1924,	Train Acc: 94.47%		Val Loss: 0.2019,	Val Acc: 94.45%
Epoch	10/20		Train Loss: 0.1822,	Train Acc: 94.81%		Val Loss: 0.1953,	Val Acc: 94.53%
Epoch	11/20		Train Loss: 0.1731,	Train Acc: 95.06%		Val Loss: 0.1838,	Val Acc: 94.83%
Epoch	12/20		Train Loss: 0.1647,	Train Acc: 95.32%		Val Loss: 0.1792,	Val Acc: 95.03%
Epoch	13/20		Train Loss: 0.1572,	Train Acc: 95.42%		Val Loss: 0.1733,	Val Acc: 95.15%
Epoch	14/20		Train Loss: 0.1502,	Train Acc: 95.73%		Val Loss: 0.1676,	Val Acc: 95.25%

Epoch 15/20	Train Loss: 0.1439, Train Acc: 95.85%	Val Loss: 0.1646, Val Acc: 95.28%
Epoch 16/20	Train Loss: 0.1380, Train Acc: 96.06%	Val Loss: 0.1585, Val Acc: 95.53%
Epoch 17/20	Train Loss: 0.1324, Train Acc: 96.26%	Val Loss: 0.1564, Val Acc: 95.47%
Epoch 18/20	Train Loss: 0.1275, Train Acc: 96.36%	Val Loss: 0.1506, Val Acc: 95.71%
Epoch 19/20	Train Loss: 0.1226, Train Acc: 96.53%	Val Loss: 0.1469, Val Acc: 95.73%
Epoch 20/20	Train Loss: 0.1181, Train Acc: 96.64%	Val Loss: 0.1454, Val Acc: 95.80%

Run 4 complete.

--- Starting Run 5/5 ---

Epoch 1/20	Train Loss: 0.8775, Train Acc: 76.74%	Val Loss: 0.4384, Val Acc: 88.08%
Epoch 2/20	Train Loss: 0.3736, Train Acc: 89.60%	Val Loss: 0.3362, Val Acc: 90.31%
Epoch 3/20	Train Loss: 0.3062, Train Acc: 91.33%	Val Loss: 0.2915, Val Acc: 91.68%
Epoch 4/20	Train Loss: 0.2701, Train Acc: 92.33%	Val Loss: 0.2656, Val Acc: 92.51%
Epoch 5/20	Train Loss: 0.2453, Train Acc: 93.03%	Val Loss: 0.2465, Val Acc: 92.97%
Epoch 6/20	Train Loss: 0.2257, Train Acc: 93.53%	Val Loss: 0.2289, Val Acc: 93.39%
Epoch 7/20	Train Loss: 0.2100, Train Acc: 93.96%	Val Loss: 0.2156, Val Acc: 93.91%
Epoch 8/20	Train Loss: 0.1966, Train Acc: 94.34%	Val Loss: 0.2052, Val Acc: 94.17%
Epoch 9/20	Train Loss: 0.1852, Train Acc: 94.75%	Val Loss: 0.1954, Val Acc: 94.46%
Epoch 10/20	Train Loss: 0.1749, Train Acc: 95.01%	Val Loss: 0.1868, Val Acc: 94.63%
Epoch 11/20	Train Loss: 0.1656, Train Acc: 95.29%	Val Loss: 0.1791, Val Acc: 94.88%
Epoch 12/20	Train Loss: 0.1574, Train Acc: 95.44%	Val Loss: 0.1756, Val Acc: 94.96%
Epoch 13/20	Train Loss: 0.1501, Train Acc: 95.69%	Val Loss: 0.1683, Val Acc: 95.17%
Epoch 14/20	Train Loss: 0.1431, Train Acc: 95.89%	Val Loss: 0.1655, Val Acc: 95.36%
Epoch 15/20	Train Loss: 0.1370, Train Acc: 96.06%	Val Loss: 0.1569, Val Acc: 95.58%
Epoch 16/20	Train Loss: 0.1311, Train Acc: 96.24%	Val Loss: 0.1531, Val Acc: 95.61%
Epoch 17/20	Train Loss: 0.1258, Train Acc: 96.41%	Val Loss: 0.1513, Val Acc: 95.71%
Epoch 18/20	Train Loss: 0.1209, Train Acc: 96.50%	Val Loss: 0.1456, Val Acc: 95.93%
Epoch 19/20	Train Loss: 0.1161, Train Acc: 96.64%	Val Loss: 0.1431, Val Acc: 95.99%
Epoch 20/20	Train Loss: 0.1119, Train Acc: 96.76%	Val Loss: 0.1384, Val Acc: 96.14%

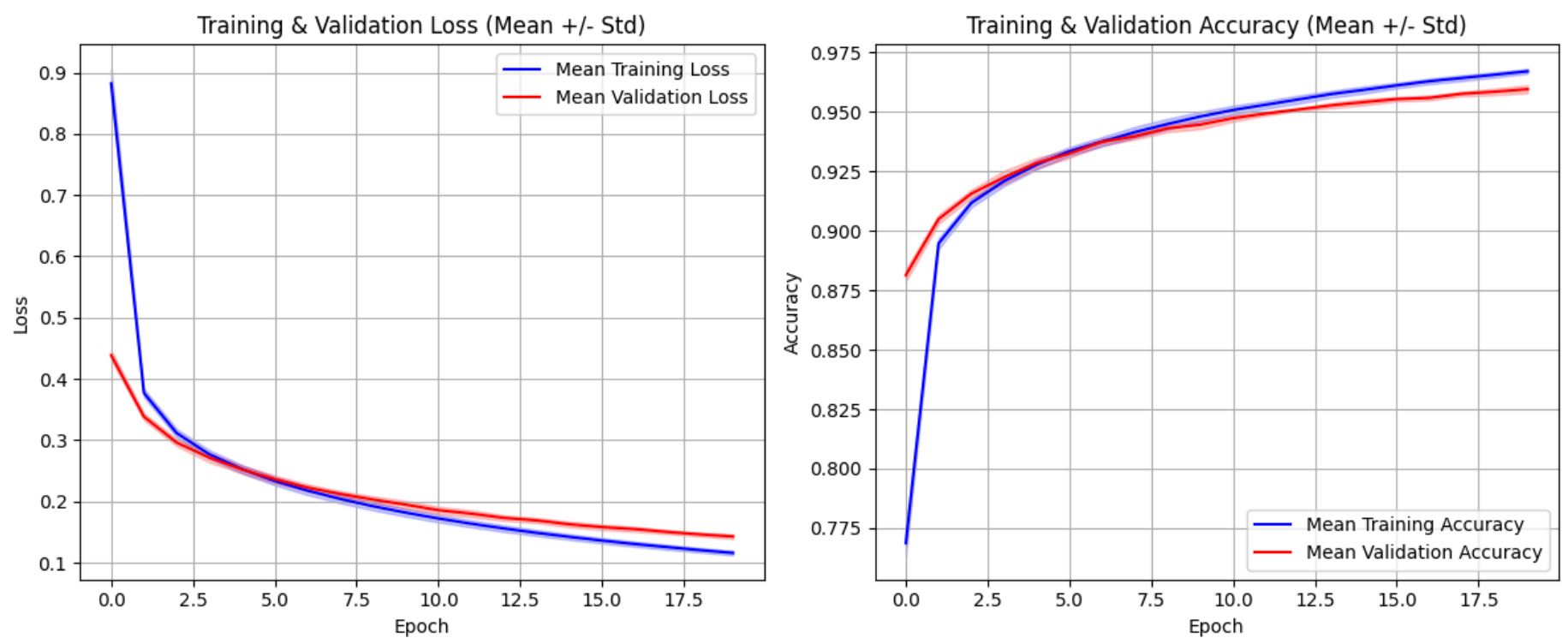
Run 5 complete.

#####

All training runs complete!

Performance Visualization

```
In [23]: importlib.reload(plots)
from src.plots import plot_learning_curves_with_error_bars
plot_learning_curves_with_error_bars(all_histories)
```



Test Set Evaluation

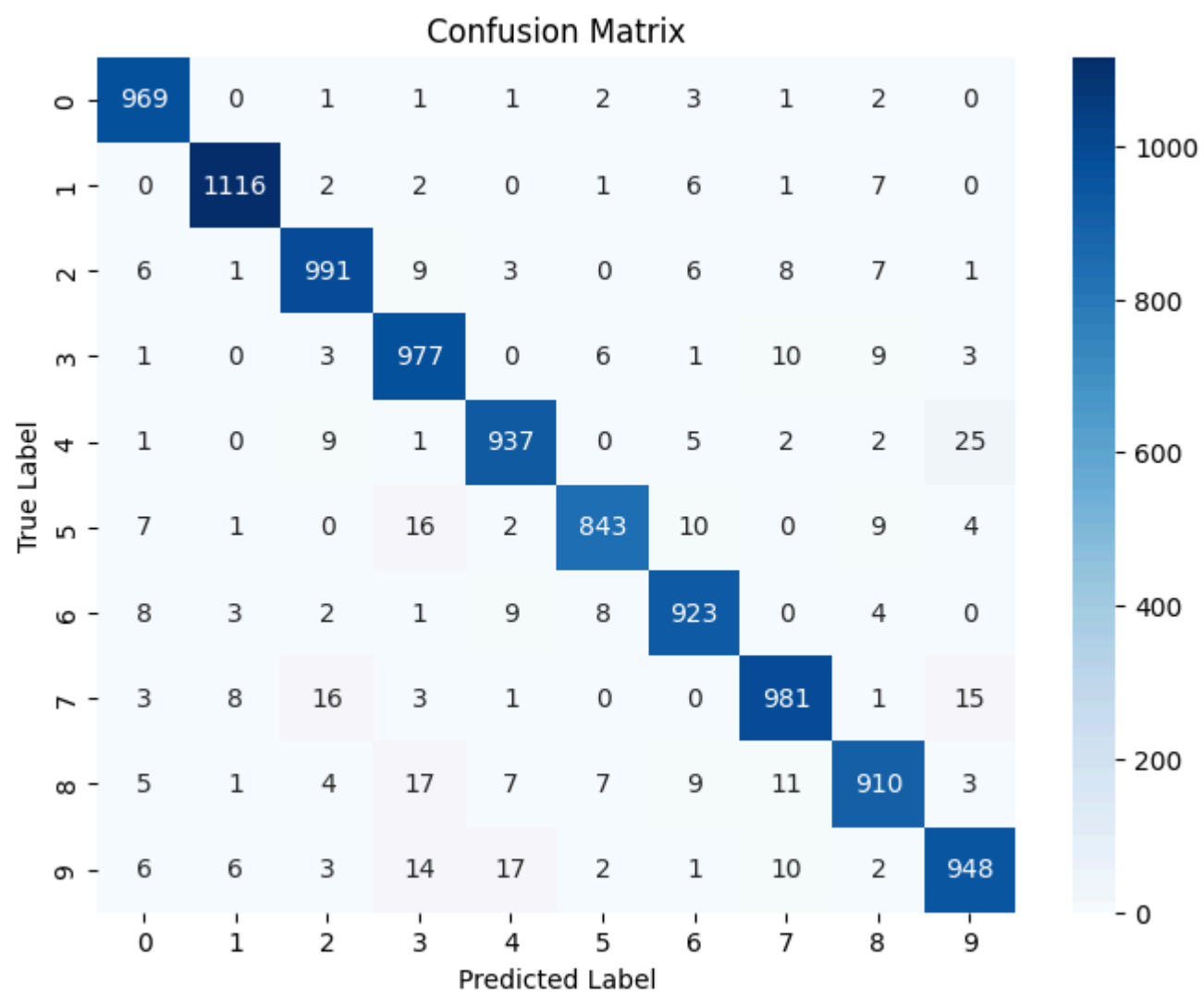
```
In [24]: import numpy as np
# Get predictions for the entire test set
y_test = []
y_pred_test = []

model.eval()
with torch.no_grad():
    for X, y in test_loader:
        preds = model.predict(X)
        y_test.extend(y.numpy())
        y_pred_test.extend(preds.numpy())

print("Generating Confusion Matrix for Test Set (from last run)...")
cm = plot_confusion_matrix(y_test, y_pred_test)

print("\nGenerating Per-Class Accuracy for Test Set (from last run)...")
df_acc = per_class_accuracy(cm)
plot_per_class_acc(df_acc)
```

Generating Confusion Matrix for Test Set (from last run)...



Generating Per-Class Accuracy for Test Set (from last run)...

	Class	Accuracy
0	0	0.988776
1	1	0.983260
2	2	0.960271
3	3	0.967327
4	4	0.954175
5	5	0.945067
6	6	0.963466
7	7	0.954280
8	8	0.934292
9	9	0.939544

