visualize

December 12, 2025

1 CNN Custom Framework vs PyTorch — Visualization Notebook

This notebook: - Runs comparable experiments in our NumPy-based CNN framework and PyTorch - Logs training dynamics (loss, accuracy, gradient norms, time, memory) - Generates plots for: - Custom vs PyTorch (same optimizer) - SGD vs Adam (2x2 optimizer grid) - Detailed diagnostics for selected runs

[1]:
```
from pathlib import Path
from helper import ExperimentConfig, run_pair, run_optimizer_grid,␣
 ↪visualize_pair, visualize_optimizer_grid, visualize_diagnostics
import visuals

LOG_DIR = Path("./logs")
```

1.1 1. Training and Logging

[2]:
```
# === Baseline pair: Custom vs Torch, Adam ===

base_cfg = ExperimentConfig(
    optimizer_type="Adam",
    num_epochs=5,
    batch_size=64,
    lr=1e-3,
    model_out_channels=8,
    model_kernel_size=3,
    model_hidden_dim=128,
    log_name="k3_c8_h128_Adam_lr0.001",
    log_path=str(LOG_DIR),
)

custom_log_adam, torch_log_adam = run_pair(base_cfg)
print("Custom Adam log:", custom_log_adam)
print("Torch   Adam log:", torch_log_adam)
```

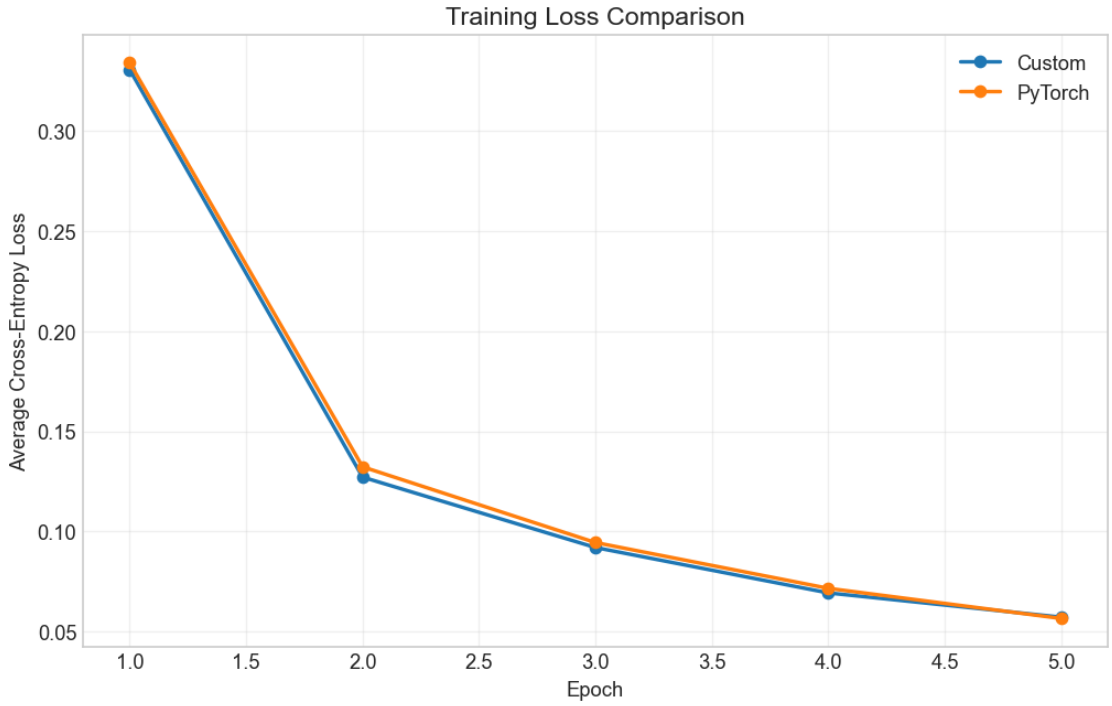
```
>>> Running Custom framework with Adam …
[INFO] Training Start | Optimizer: Adam | Epochs: 5
[INFO] Training log saved to:
```

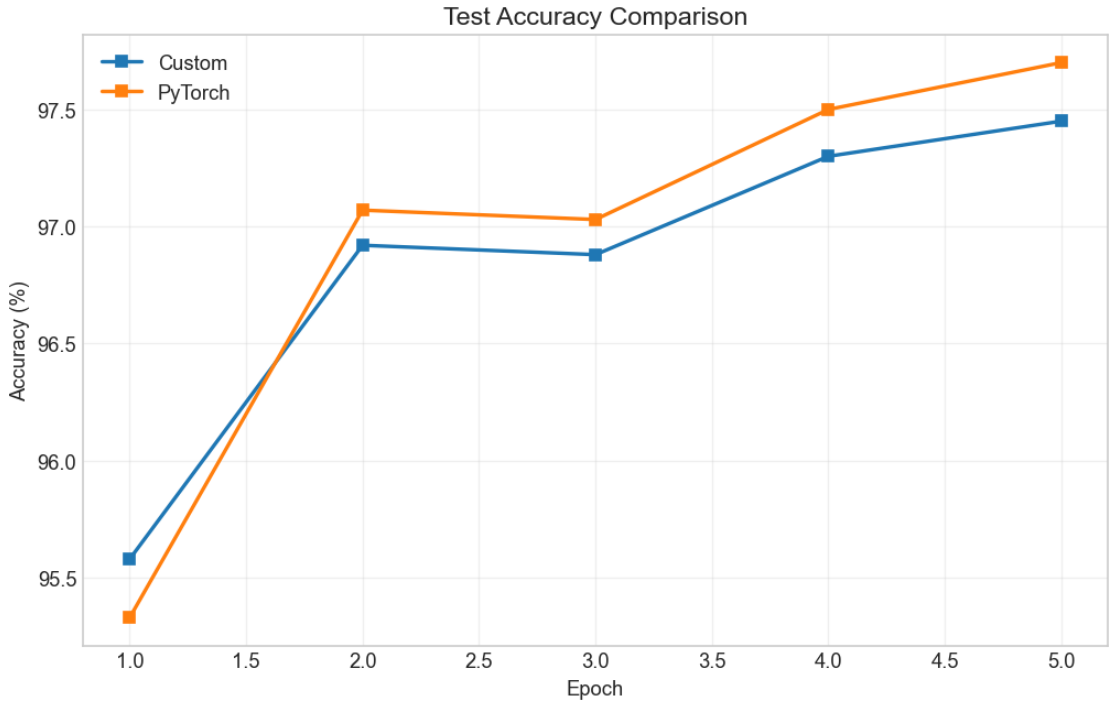
```
logs/CNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.001_20251212_165612.json
Custom log saved at:
logs/CNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.001_20251212_165612.json
>>> Running PyTorch baseline with Adam …
[INFO-TORCH] Training Start | Opt: Adam | Device: cpu
Training log saved to: logs/TorchCNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0
.001_20251212_165830.json
Torch log saved at: logs/TorchCNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.00
1_20251212_165830.json
Custom Adam log:
logs/CNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.001_20251212_165612.json
Torch   Adam log: logs/TorchCNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.001_
20251212_165830.json
```

1.2 2. Baseline Comparison: Custom vs PyTorch

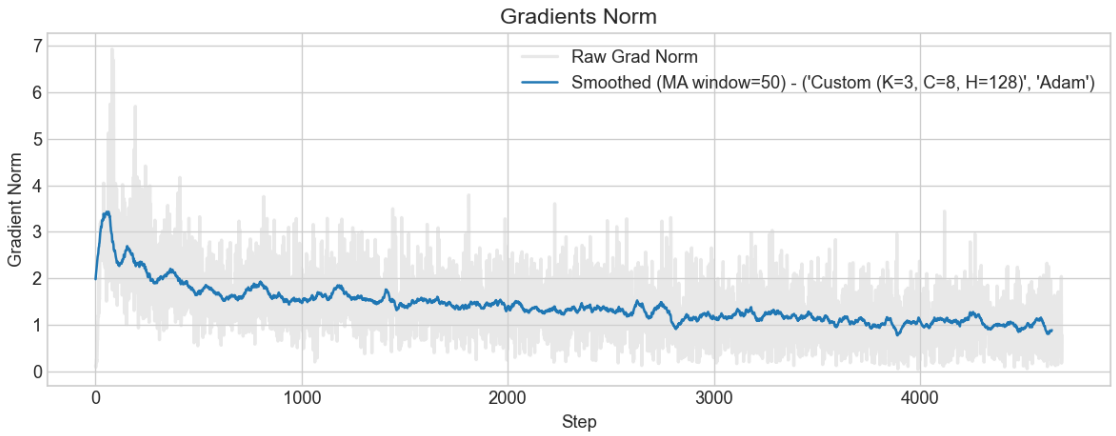
[3]:
```
# === Visualize baseline pair: Custom vs Torch (Adam) ===

visualize_pair(custom_log_adam, torch_log_adam)
visuals.plot_detailed_loss(custom_log_adam, window=50)
visuals.plot_detailed_loss(torch_log_adam, window=50)
```

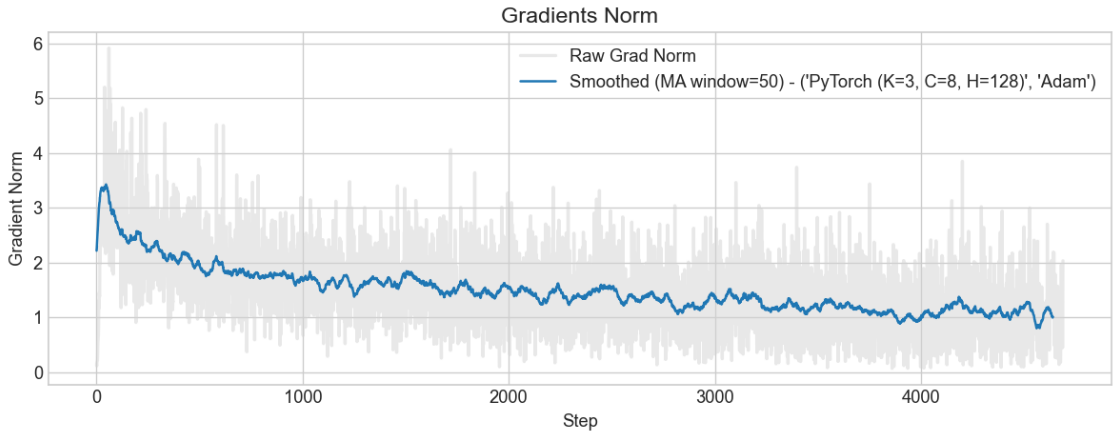
```
Custom vs PyTorch: Convergence & Generalization
```



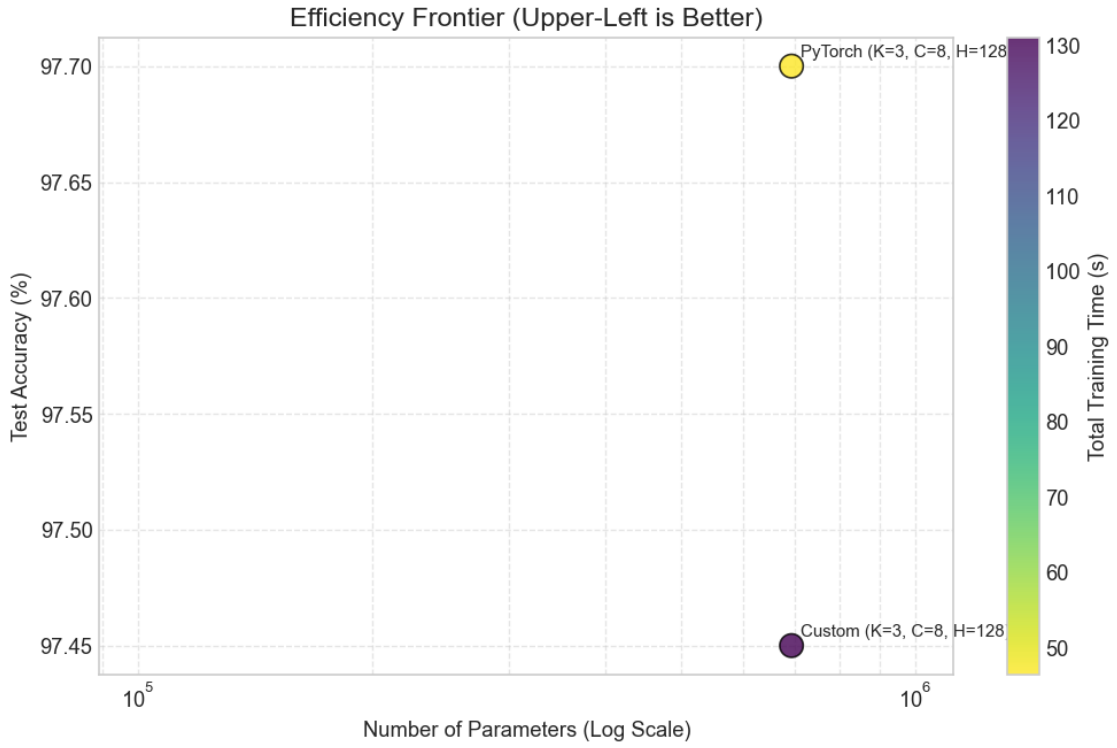


Training Stability: Gradient Norms

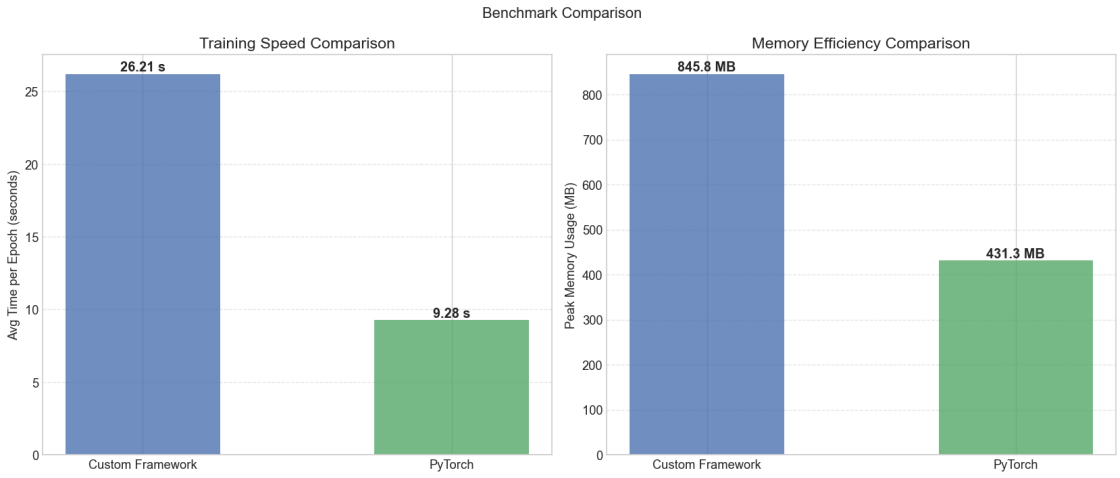


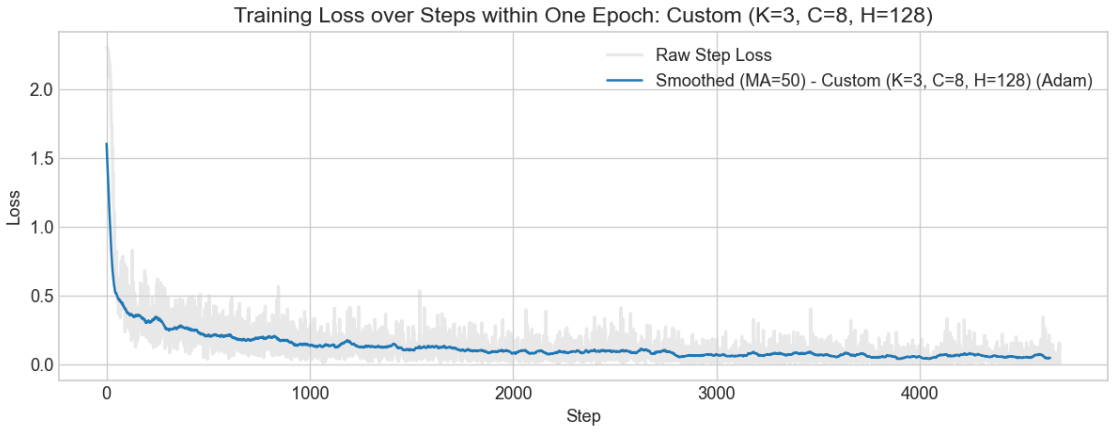


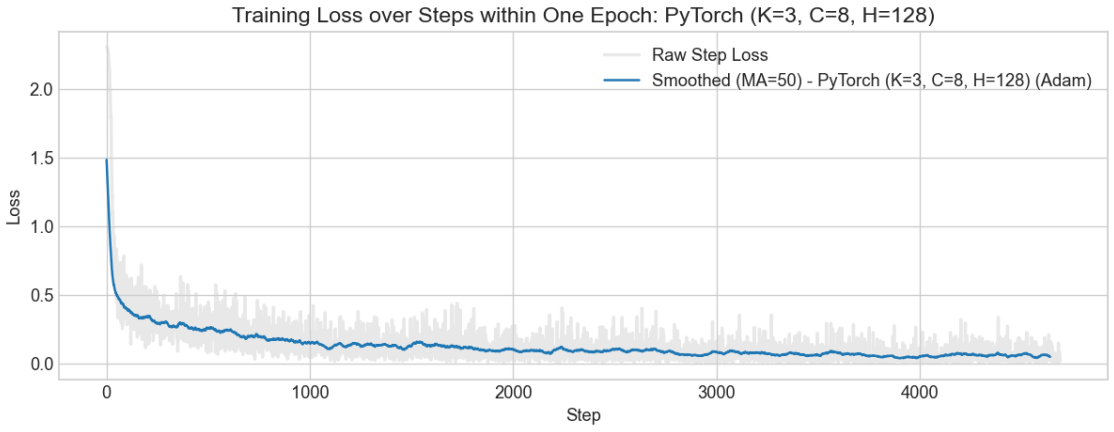
Efficiency Frontier: Time vs Memory



System Benchmark (Param count, time, memory)


Benchmark Comparison
Training Speed Comparison
Avg Time per Epoch (seconds)
26.21 s
9.28 s
Custom Framework
PyTorch
Memory Efficiency Comparison
Peak Memory Usage (MB)
845.8 MB
431.3 MB
Custom Framework
PyTorch

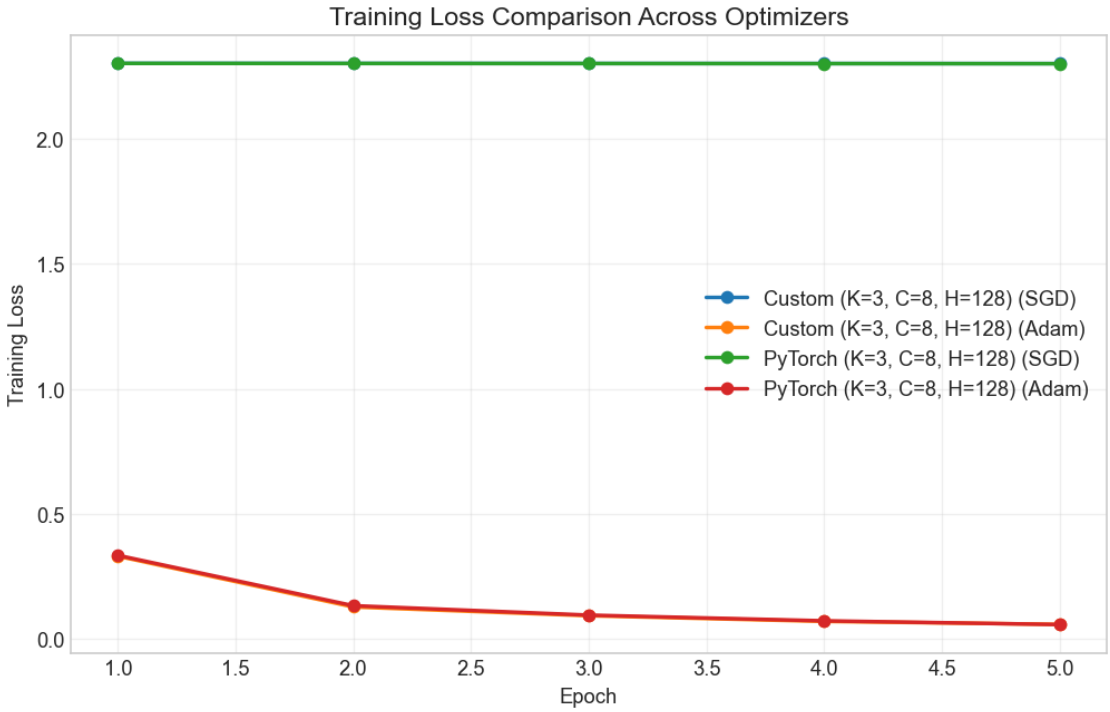

Training Loss over Steps within One Epoch: Custom (K=3, C=8, H=128)
Raw Step Loss
Smoothed (MA=50) - Custom (K=3, C=8, H=128) (Adam)
Loss
Step

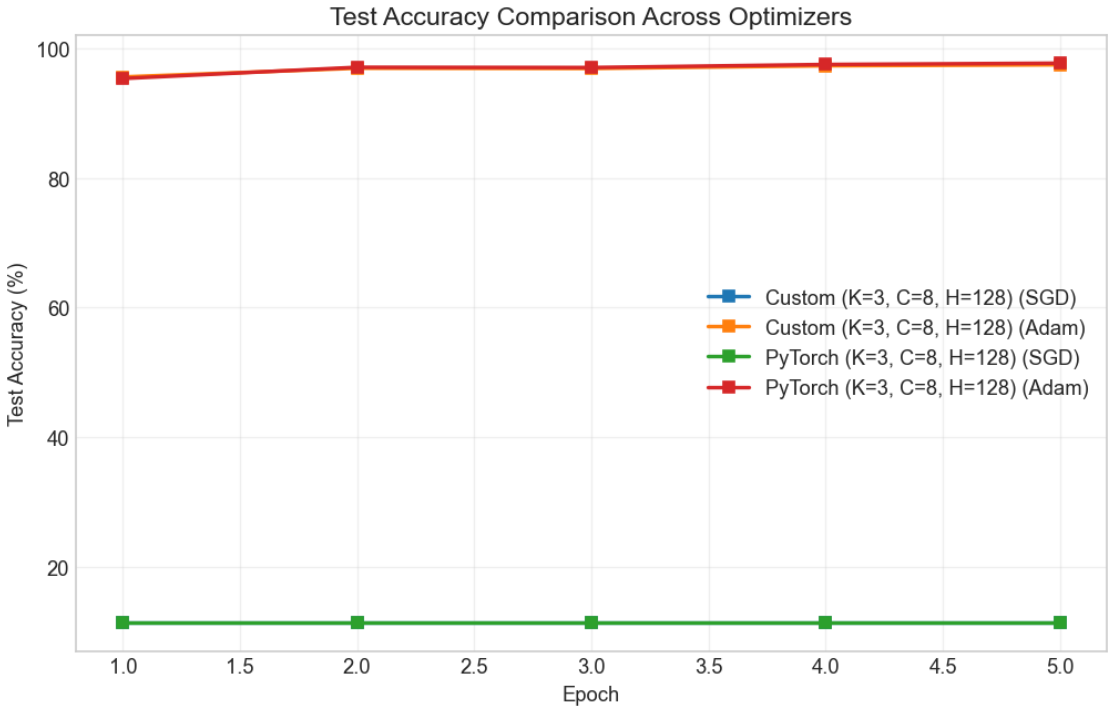

Training Loss over Steps within One Epoch: PyTorch (K=3, C=8, H=128)
Raw Step Loss
Smoothed (MA=50) - PyTorch (K=3, C=8, H=128) (Adam)
Loss
Step

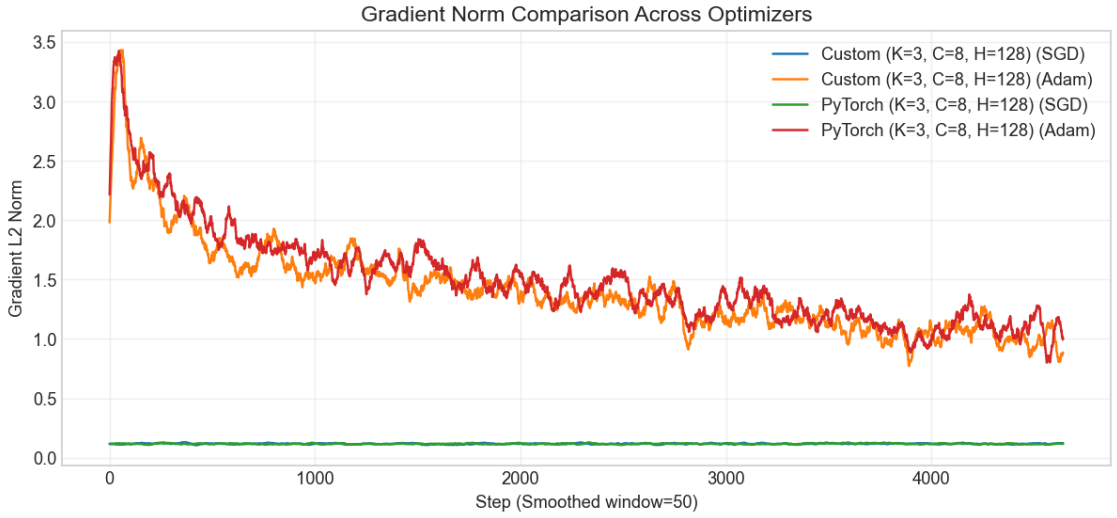
1.3 3. Optimizer Comparison: SGD vs Adam

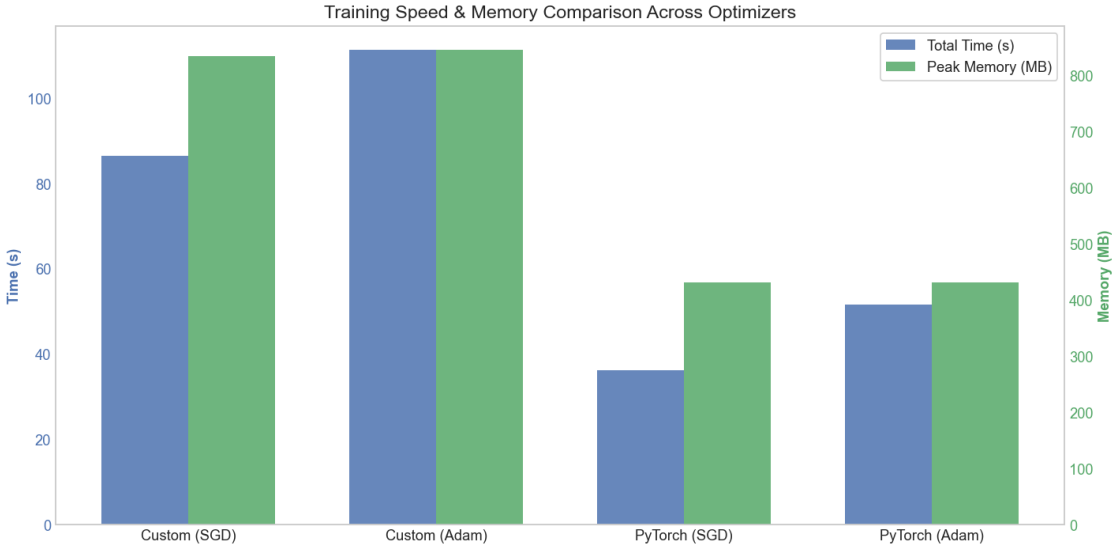
[2]:
```
# === Run 2x2 optimizer grid: [Custom, Torch] x [SGD, Adam] ===

grid_cfg = ExperimentConfig(
    num_epochs=5,
    batch_size=64,
    lr=1e-3,
    model_out_channels=8,
    model_kernel_size=3,
    model_hidden_dim=128,
    log_path=str(LOG_DIR),
)

logs_grid = run_optimizer_grid(grid_cfg)

# === Visualize optimizer x framework grid ===

visualize_optimizer_grid(logs_grid)
```

```
>>> Running Custom framework with SGD …
[INFO] Training Start | Optimizer: SGD | Epochs: 5
[INFO] Training log saved to:
logs/CNN_k3_c8_h128_SGD_lr0.001_k3_c8_h128_SGD_lr0.001_20251212_230535.json
Custom log saved at:
logs/CNN_k3_c8_h128_SGD_lr0.001_k3_c8_h128_SGD_lr0.001_20251212_230535.json
>>> Running Custom framework with Adam …
[INFO] Training Start | Optimizer: Adam | Epochs: 5
[INFO] Training log saved to:
logs/CNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.001_20251212_230706.json
Custom log saved at:
logs/CNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.001_20251212_230706.json
>>> Running PyTorch baseline with SGD …
[INFO-TORCH] Training Start | Opt: SGD | Device: cpu
Training log saved to:
logs/TorchCNN_k3_c8_h128_SGD_lr0.001_k3_c8_h128_SGD_lr0.001_20251212_230904.json
Torch log saved at:
logs/TorchCNN_k3_c8_h128_SGD_lr0.001_k3_c8_h128_SGD_lr0.001_20251212_230904.json
>>> Running PyTorch baseline with Adam …
[INFO-TORCH] Training Start | Opt: Adam | Device: cpu
Training log saved to: logs/TorchCNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0
.001_20251212_230945.json
Torch log saved at: logs/TorchCNN_k3_c8_h128_Adam_lr0.001_k3_c8_h128_Adam_lr0.00
1_20251212_230945.json

  Generating 4-Set Comparative Visualization (Optimizers x Frameworks)…
```


Training Loss Comparison Across Optimizers
Training Loss
Epoch
Custom (K=3, C=8, H=128) (SGD)
Custom (K=3, C=8, H=128) (Adam)
PyTorch (K=3, C=8, H=128) (SGD)
PyTorch (K=3, C=8, H=128) (Adam)


Test Accuracy Comparison Across Optimizers
Test Accuracy (%)
Epoch
Custom (K=3, C=8, H=128) (SGD)
Custom (K=3, C=8, H=128) (Adam)
PyTorch (K=3, C=8, H=128) (SGD)
PyTorch (K=3, C=8, H=128) (Adam)

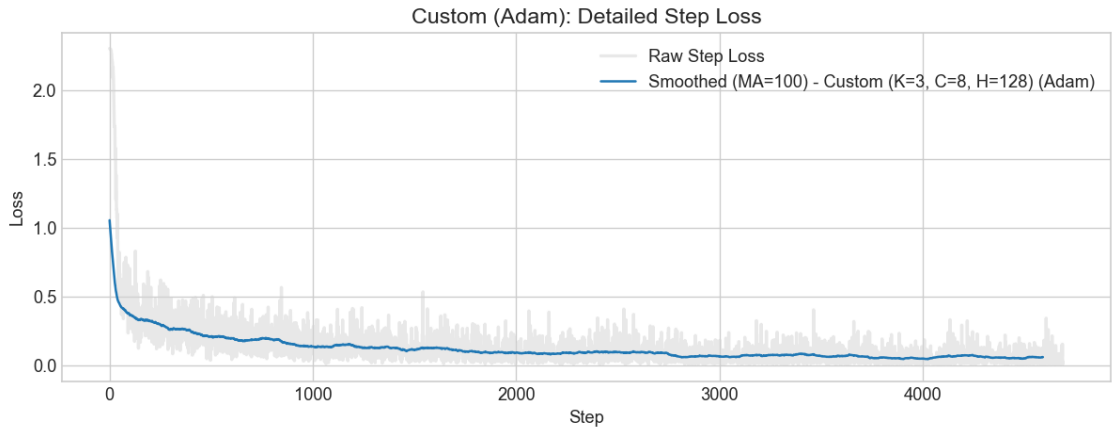




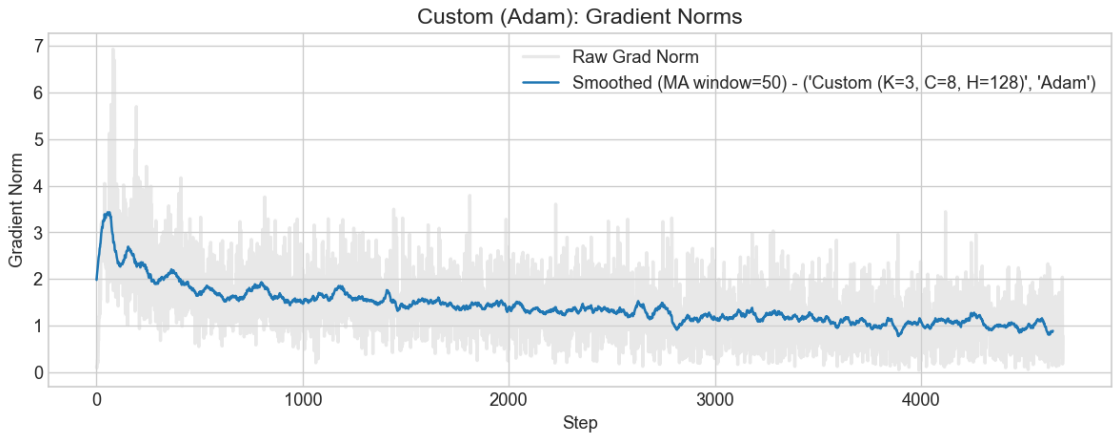
1.4 4. Detailed Diagnostics for Selected Runs

[3]:
```
# === Optional: detailed diagnostics for a single run ===

visualize_diagnostics(logs_grid["custom_adam"], title_prefix="Custom (Adam)")
visualize_diagnostics(logs_grid["custom_sgd"], title_prefix="Custom (SGD)")
visualize_diagnostics(logs_grid["torch_adam"], title_prefix="PyTorch (Adam)")
visualize_diagnostics(logs_grid["torch_sgd"], title_prefix="PyTorch (SGD)")
```

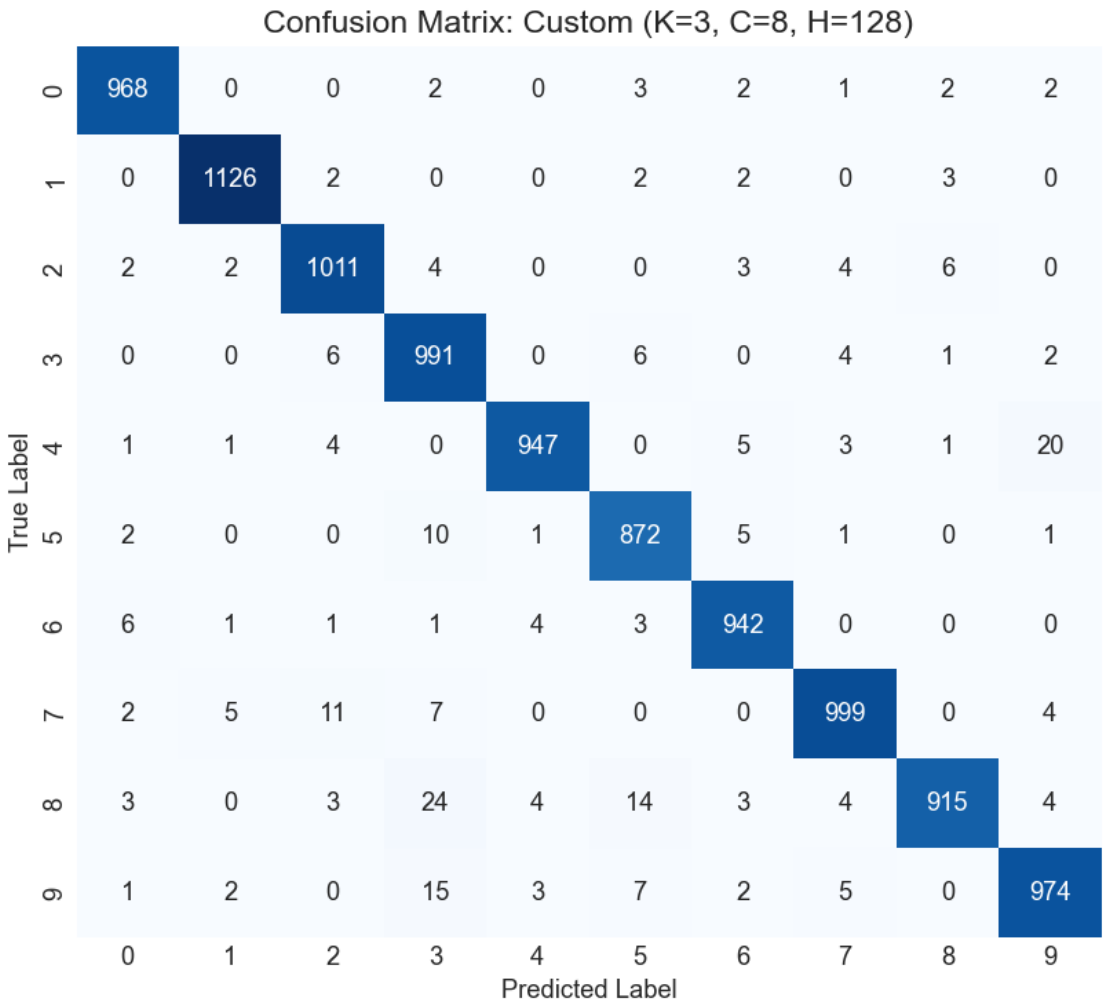
```
Detailed Training Dynamics for Custom (Adam)
```



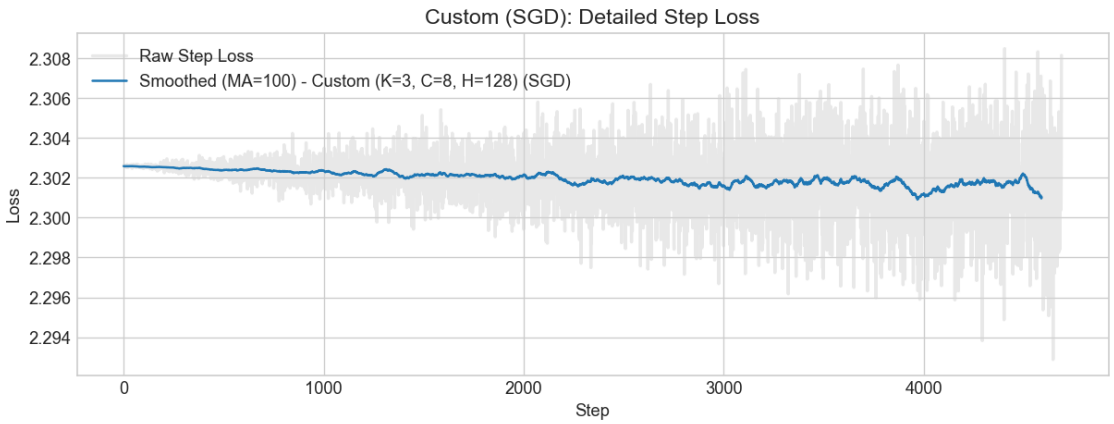
Gradient Norm Stability for Custom (Adam)



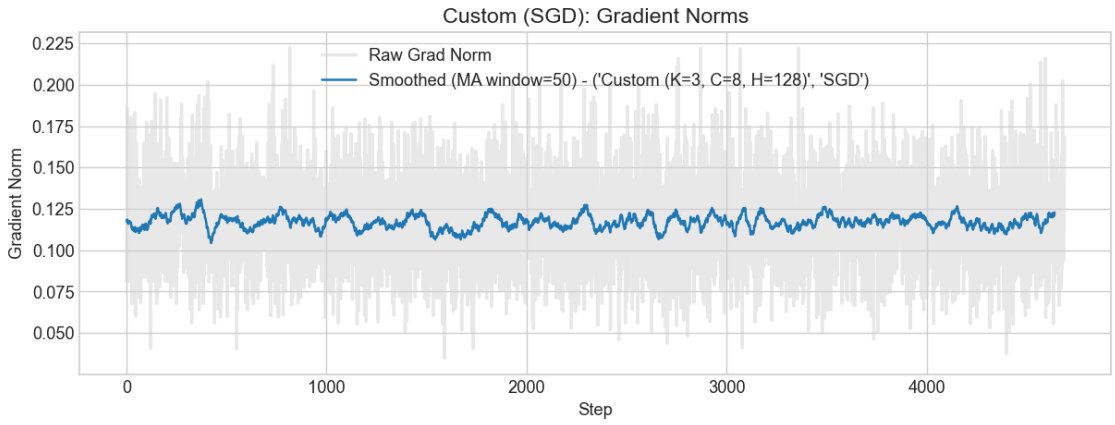
Confusion Matrix for Custom (Adam)



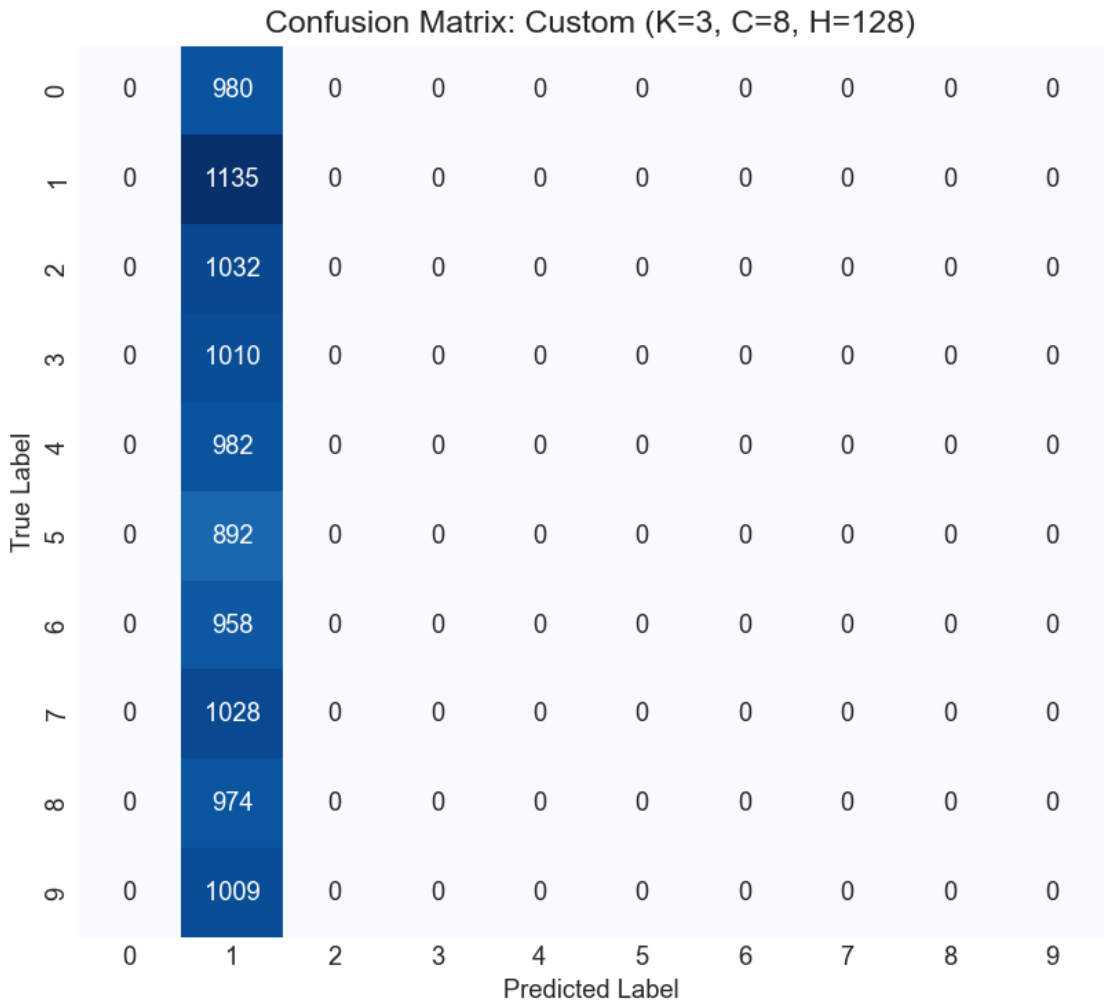
Detailed Training Dynamics for Custom (SGD)



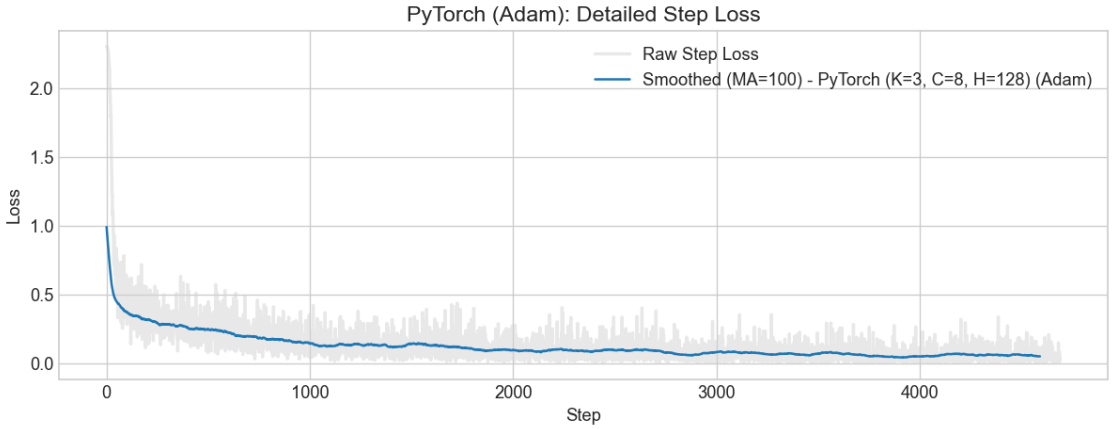
Gradient Norm Stability for Custom (SGD)



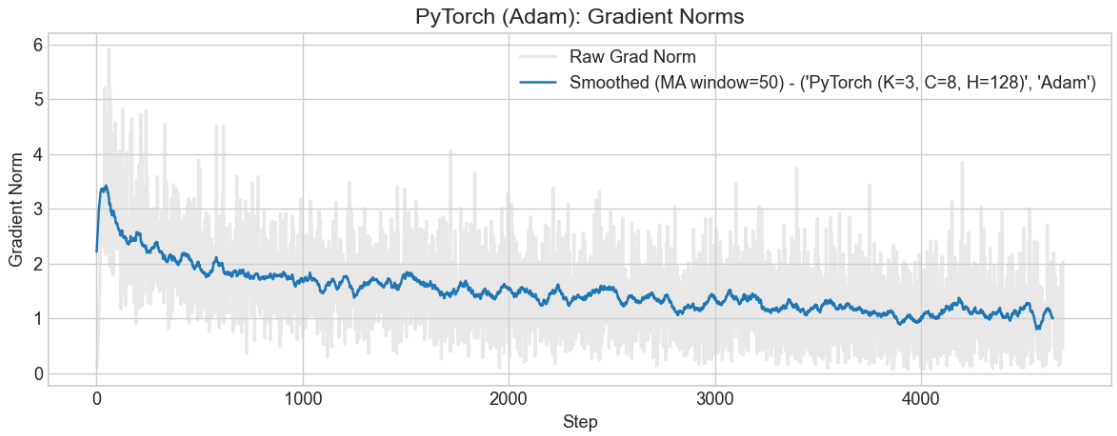
Confusion Matrix for Custom (SGD)



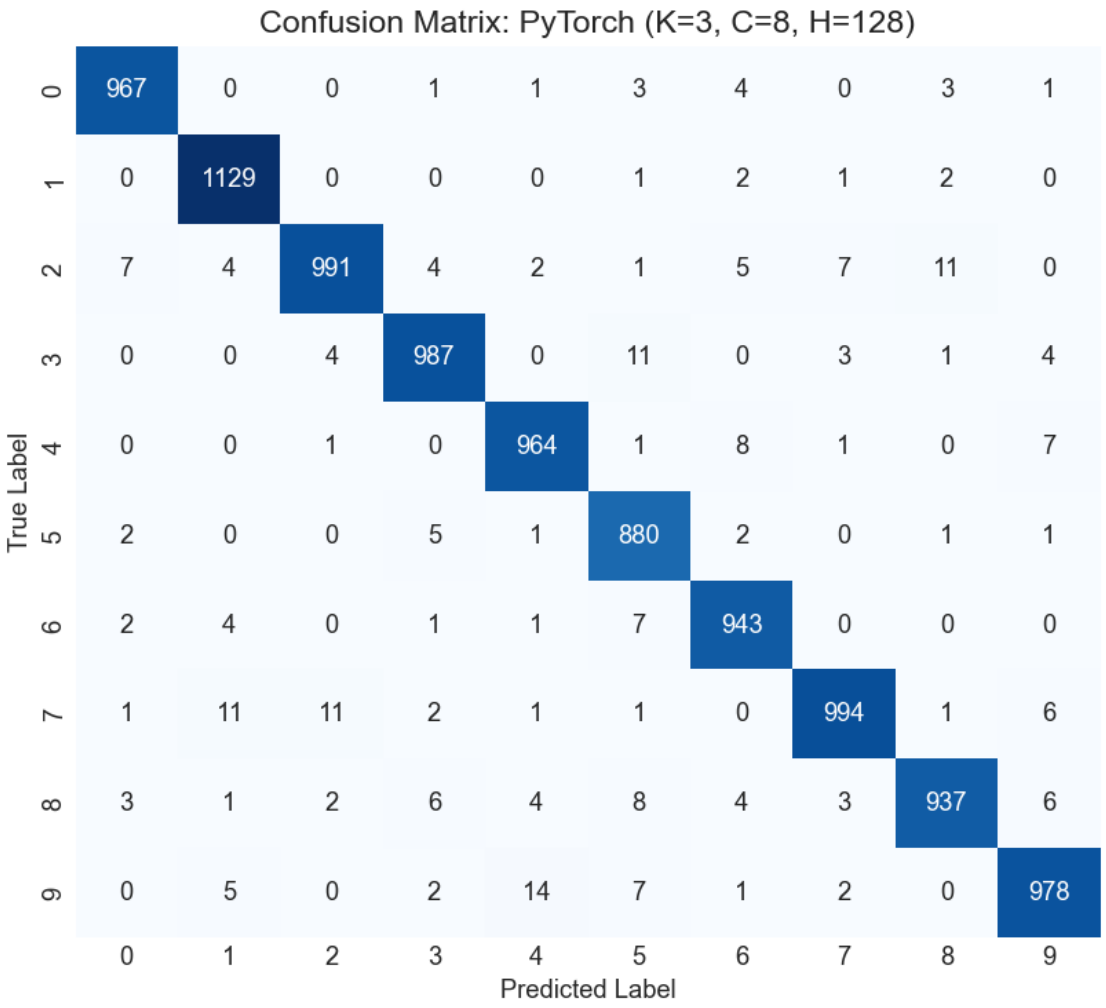
Detailed Training Dynamics for PyTorch (Adam)



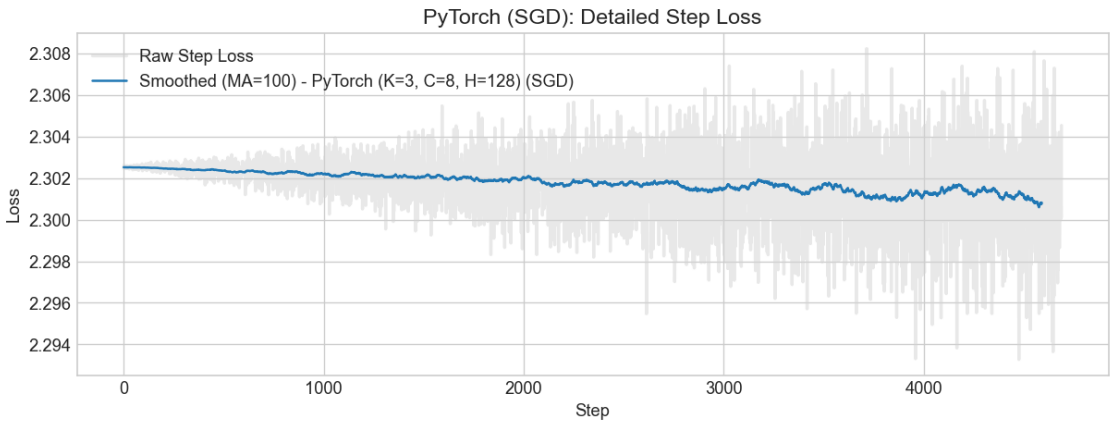
Gradient Norm Stability for PyTorch (Adam)



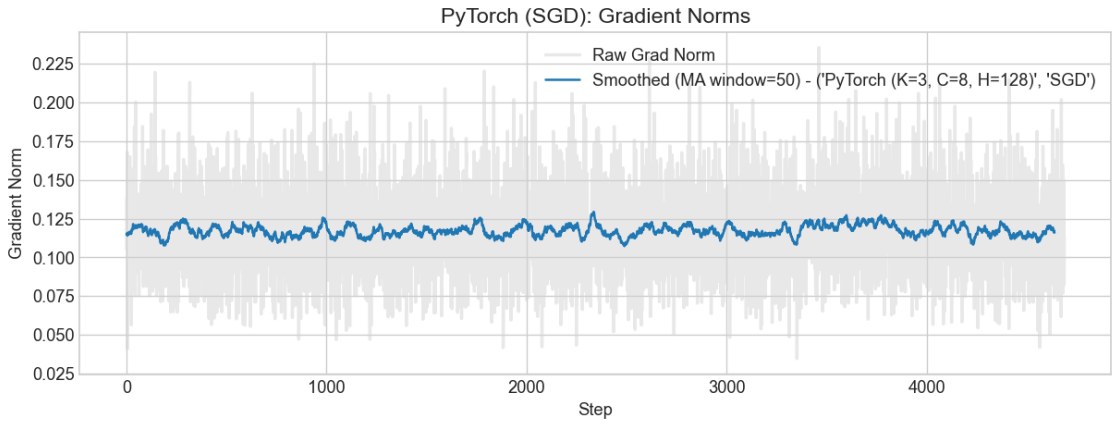
Confusion Matrix for PyTorch (Adam)



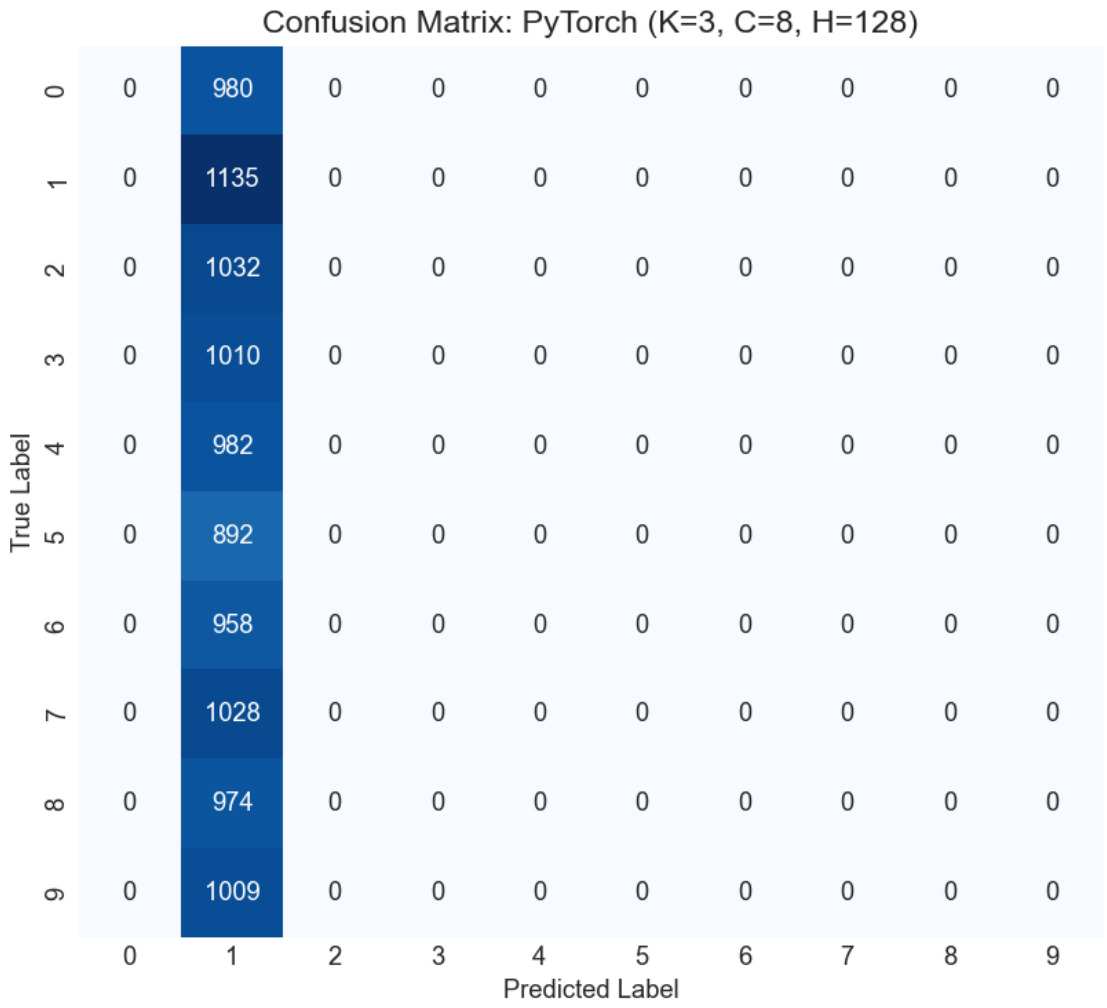
Detailed Training Dynamics for PyTorch (SGD)



Gradient Norm Stability for PyTorch (SGD)



Confusion Matrix for PyTorch (SGD)


Confusion Matrix: PyTorch (K=3, C=8, H=128)
True Label
Predicted Label
0 0 980 0 0 0 0 0 0 0 0
1 0 1135 0 0 0 0 0 0 0 0
2 0 1032 0 0 0 0 0 0 0 0
3 0 1010 0 0 0 0 0 0 0 0
4 0 982 0 0 0 0 0 0 0 0
5 0 892 0 0 0 0 0 0 0 0
6 0 958 0 0 0 0 0 0 0 0
7 0 1028 0 0 0 0 0 0 0 0
8 0 974 0 0 0 0 0 0 0 0
9 0 1009 0 0 0 0 0 0 0 0
0 1 2 3 4 5 6 7 8 9

[ ]: