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[1]:

```python
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, Dropout
import matplotlib.pyplot as plt
import numpy as np
```

```
2025-09-23 02:36:14.532797: I tensorflow/core/util/port.cc:153] oneDNN custom
operations are on. You may see slightly different numerical results due to
floating-point round-off errors from different computation orders. To turn them
off, set the environment variable `TF_ENABLE_ONEDNN_OPTS=0`.
2025-09-23 02:36:14.539931: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:467] Unable to register
cuFFT factory: Attempting to register factory for plugin cuFFT when one has
already been registered
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
E0000 00:00:1758575174.549042   23081 cuda_dnn.cc:8579] Unable to register cuDNN
factory: Attempting to register factory for plugin cuDNN when one has already
been registered
E0000 00:00:1758575174.551732   23081 cuda_blas.cc:1407] Unable to register
cuBLAS factory: Attempting to register factory for plugin cuBLAS when one has
already been registered
W0000 00:00:1758575174.558264   23081 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1758575174.558274   23081 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1758575174.558275   23081 computation_placer.cc:177] computation
placer already registered. Please check linkage and avoid linking the same
target more than once.
W0000 00:00:1758575174.558276   23081 computation_placer.cc:177] computation
```

```
placer already registered. Please check linkage and avoid linking the same
target more than once.
2025-09-23 02:36:14.560621: I tensorflow/core/platform/cpu_feature_guard.cc:210]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: AVX2 AVX_VNNI FMA, in other operations,
rebuild TensorFlow with the appropriate compiler flags.
```

[2]:

```python
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

[3]:

```python
x_train = x_train.astype('float32') / 255.0
x_test = x_test.astype('float32') / 255.0
```

[4]:

```python
print(f"Training data shape: {x_train.shape}")
print(f"Test data shape: {x_test.shape}")
```

```
Training data shape: (60000, 28, 28)
Test data shape: (10000, 28, 28)
```

[5]:

```python
# 2. Define the Neural Network Architecture
def create_model():
    model = Sequential([
        Flatten(input_shape=(28, 28)),
        Dense(128, activation='relu'),
        Dropout(0.2),
        Dense(10, activation='softmax')
    ])
    return model
```

[6]:

```python
# 3. List of Optimizers to Compare
optimizers = {
    'SGD': keras.optimizers.SGD(),
    'SGD with Momentum': keras.optimizers.SGD(momentum=0.9),
    'Adagrad': keras.optimizers.Adagrad(),
    'RMSProp': keras.optimizers.RMSprop(),
    'AdaDelta': keras.optimizers.Adadelta(),
    'Adam': keras.optimizers.Adam(),
}
```

```
I0000 00:00:1758575176.208290   23081 gpu_device.cc:2019] Created device
/job:localhost/replica:0/task:0/device:GPU:0 with 9351 MB memory:  -> device: 0,
name: NVIDIA GeForce RTX 4070 SUPER, pci bus id: 0000:01:00.0, compute
capability: 8.9
```

[7]:

```python
# Dictionary to store the history of each optimizer
history_dict = {}

# 4. Train the model with each optimizer
```

```
EPOCHS = 10
BATCH_SIZE = 128
```

[8]:

```
for name, optimizer in optimizers.items():
    print(f"\n--- Training with {name} ---")
    model = create_model()
    model.compile(optimizer=optimizer,
                  loss='sparse_categorical_crossentropy',
                  metrics=['accuracy'])

    history = model.fit(x_train, y_train,
                        batch_size=BATCH_SIZE,
                        epochs=EPOCHS,
                        validation_data=(x_test, y_test),
                        verbose=0) # Set to 1 to see epoch-by-epoch progress

    history_dict[name] = history

    # Evaluate and print final accuracy
    score = model.evaluate(x_test, y_test, verbose=0)
    print(f"Optimizer: {name}, Test Loss: {score[0]:.4f}, Test Accuracy:␣
 ↪{score[1]:.4f}")
```

```
--- Training with SGD ---

/home/smayan/Desktop/AI-ML-DS/AI-and-ML-Course/.conda/lib/python3.11/site-
packages/keras/src/layers/reshaping/flatten.py:37: UserWarning: Do not pass an
`input_shape`/`input_dim` argument to a layer. When using Sequential models,
prefer using an `Input(shape)` object as the first layer in the model instead.
  super().__init__(**kwargs)
WARNING: All log messages before absl::InitializeLog() is called are written to
STDERR
I0000 00:00:1758575176.850476   23247 service.cc:152] XLA service 0x7f0164005450
initialized for platform CUDA (this does not guarantee that XLA will be used).
Devices:
I0000 00:00:1758575176.850488   23247 service.cc:160]   StreamExecutor device
(0): NVIDIA GeForce RTX 4070 SUPER, Compute Capability 8.9
2025-09-23 02:36:16.857740: I
tensorflow/compiler/mlir/tensorflow/utils/dump_mlir_util.cc:269] disabling MLIR
crash reproducer, set env var `MLIR_CRASH_REPRODUCER_DIRECTORY` to enable.
I0000 00:00:1758575176.877219   23247 cuda_dnn.cc:529] Loaded cuDNN version
91300
2025-09-23 02:36:17.981693: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 584 bytes spill stores, 488 bytes spill loads
```

```
2025-09-23 02:36:17.982932: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 672 bytes spill stores, 544 bytes spill loads

I0000 00:00:1758575178.582284   23247 device_compiler.h:188] Compiled cluster
using XLA!  This line is logged at most once for the lifetime of the process.
2025-09-23 02:36:19.771064: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 124 bytes spill stores, 124 bytes spill loads

2025-09-23 02:36:19.771134: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 188 bytes spill stores, 188 bytes spill loads

2025-09-23 02:36:19.815125: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_544', 24 bytes spill stores, 24 bytes spill loads

2025-09-23 02:36:19.961083: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 844 bytes spill stores, 844 bytes spill loads

2025-09-23 02:36:20.007324: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 560 bytes spill stores, 560 bytes spill loads

2025-09-23 02:36:20.013978: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 672 bytes spill stores, 544 bytes spill loads

2025-09-23 02:36:20.028757: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_528', 444 bytes spill stores, 412 bytes spill loads

2025-09-23 02:36:20.886042: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_34', 4 bytes spill stores, 4 bytes spill loads

2025-09-23 02:36:25.257353: I
```

```
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_34', 4 bytes spill stores, 4 bytes spill loads


Optimizer: SGD, Test Loss: 0.2729, Test Accuracy: 0.9250

--- Training with SGD with Momentum ---
Optimizer: SGD with Momentum, Test Loss: 0.0993, Test Accuracy: 0.9714

--- Training with Adagrad ---
```

```
2025-09-23 02:36:33.695249: I
external/local_xla/xla/stream_executor/cuda/subprocess_compilation.cc:346] ptxas
warning : Registers are spilled to local memory in function
'gemm_fusion_dot_548', 24 bytes spill stores, 24 bytes spill loads
```

```
Optimizer: Adagrad, Test Loss: 0.4523, Test Accuracy: 0.8917

--- Training with RMSProp ---
Optimizer: RMSProp, Test Loss: 0.0731, Test Accuracy: 0.9769

--- Training with AdaDelta ---
Optimizer: AdaDelta, Test Loss: 1.7640, Test Accuracy: 0.6089

--- Training with Adam ---
Optimizer: Adam, Test Loss: 0.0724, Test Accuracy: 0.9786
```

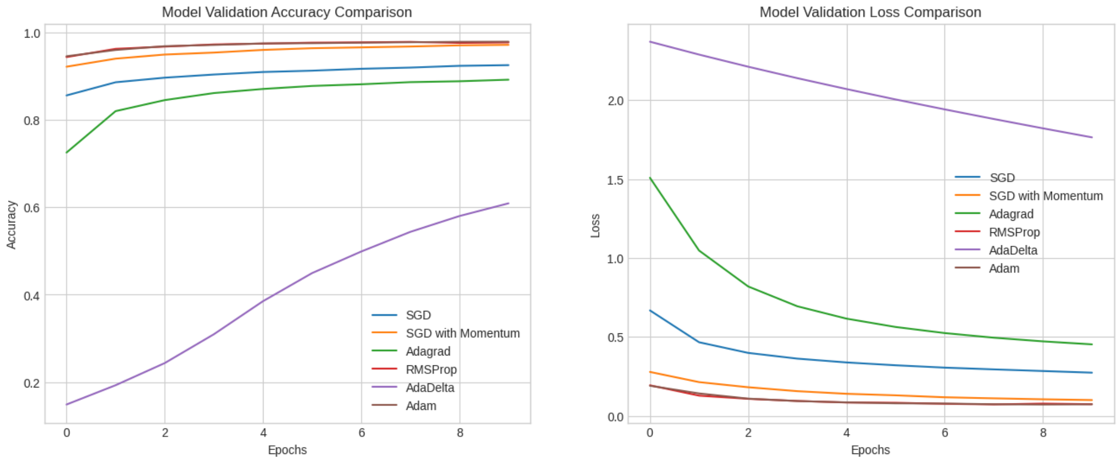
[9]:

```python
# 5. Plot and Compare Results
plt.style.use('seaborn-v0_8-whitegrid')
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(16, 6))

for name, history in history_dict.items():
    ax1.plot(history.history['val_accuracy'], label=name)
ax1.set_title('Model Validation Accuracy Comparison')
ax1.set_xlabel('Epochs')
ax1.set_ylabel('Accuracy')
ax1.legend()

for name, history in history_dict.items():
    ax2.plot(history.history['val_loss'], label=name)
ax2.set_title('Model Validation Loss Comparison')
ax2.set_xlabel('Epochs')
ax2.set_ylabel('Loss')
ax2.legend()

plt.show()
```


Model Validation Accuracy Comparison
Accuracy
1.0
0.8
0.6
0.4
0.2
0
2
4
6
8
Epochs
SGD
SGD with Momentum
Adagrad
RMSProp
AdaDelta
Adam
Model Validation Loss Comparison
Loss
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
Epochs
SGD
SGD with Momentum
Adagrad
RMSProp
AdaDelta
Adam

[ ]: