Experiment 6 - MNSIT Digit Classification Using Keras

Problem Statement:

To perform Convolutional Neural Networks for Image Classification on MNIST Dataset.

GitHub & Colab Link:

GitHub Link: https://github.com/piyush-gambhir/ncu-lab-manual-and-end-semester-projects/blob/main/NCU-CSL312%20-%20DL%20-%20Lab%20Manual/Experiment%206/Experiment%206.ipynb

Google Colab Link:

CO Open in Colab

Installing Dependencies:

In [ ]:

```
! pip install tabulate, numpy, pandas, matplotlib, seaborn
```

```
ERROR: Invalid requirement: 'tabulate,'
```

Code

In [ ]:

```
# Task 1: Import Libraries
# Import necessary libraries for data handling and visualization
import tensorflow as tf
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
from sklearn.metrics import confusion_matrix
import os
```

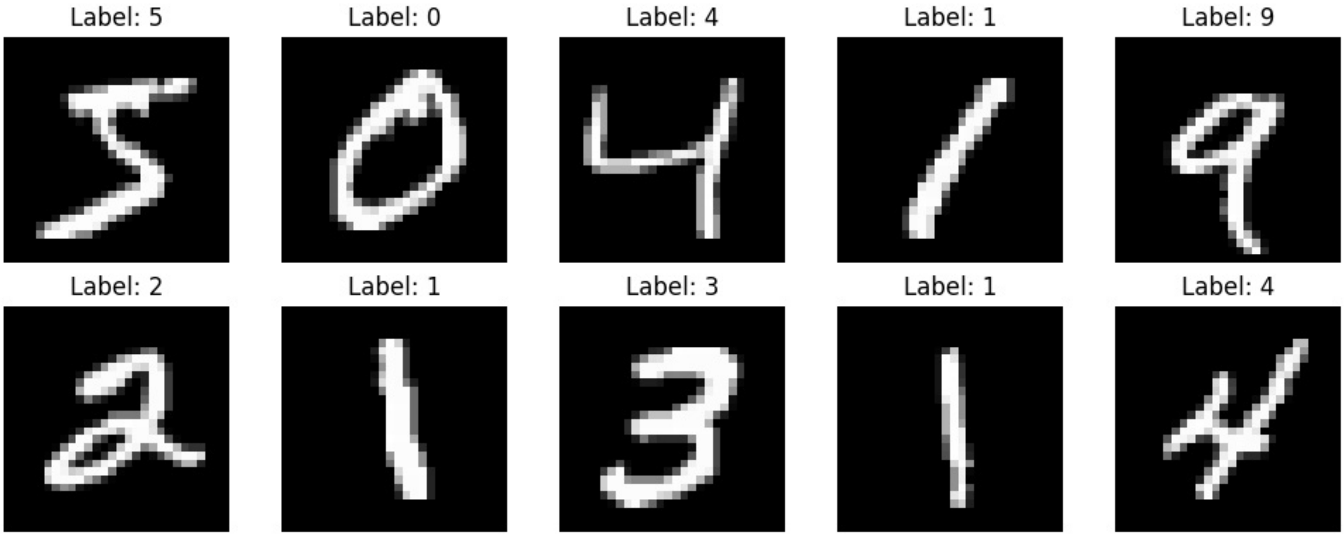
In [ ]:

```
# Task 2: Load and Preprocess Data
# Load MNIST data and normalize to facilitate efficient training
mnist = tf.keras.datasets.mnist
(x_train, y_train), (x_test, y_test) = mnist.load_data()
x_train = x_train.reshape(60000, 28*28).astype("float32") / 255
x_test = x_test.reshape(10000, 28*28).astype("float32") / 255
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.npz
11490434/11490434 ━━━━━━━━━━━━━━━━━━━━ 2s 0us/step
```

In [ ]:

```
# Task 3: Visualize the Data
# Display the first 10 images from the dataset to understand the data better
plt.figure(figsize=(10, 4))
for i in range(10):
    plt.subplot(2, 5, i + 1)
    plt.imshow(x_train[i].reshape(28, 28), cmap='gray')
    plt.title(f"Label: {y_train[i]}")
    plt.axis('off')
plt.tight_layout()
plt.show()
```



In [ ]:

```
# Task 4: Define and Compile the Model
# Set up the neural network structure and compile the model
model = tf.keras.Sequential([
    tf.keras.layers.Dense(512, activation="relu", input_shape=(28*28,)),
    tf.keras.layers.Dense(10, activation="softmax")
])
model.compile(optimizer="rmsprop", loss="sparse_categorical_crossentropy", metrics=["accuracy"])
model.summary()
```

```
c:\Users\mainp\AppData\Local\Programs\Python\Python311\Lib\site-packages\keras\src\layers\core\dense.py:86: User
Warning: Do not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer usin
g an `Input(shape)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)
```

```
Model: "sequential"

┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━━━━━━━┓
┃ Layer (type)                       ┃ Output Shape            ┃        Param # ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━━━━━━━┩
│ dense (Dense)                      │ (None, 512)             │        401,920 │
├────────────────────────────────────┼─────────────────────────┼────────────────┤
│ dense_1 (Dense)                    │ (None, 10)              │          5,130 │
└────────────────────────────────────┴─────────────────────────┴────────────────┘

 Total params: 407,050 (1.55 MB)

 Trainable params: 407,050 (1.55 MB)

 Non-trainable params: 0 (0.00 B)
```

In [ ]:

```
# Task 5: Train the Model
# Train the model using the training data and validate using part of it
history = model.fit(x_train, y_train, epochs=5, batch_size=128, validation_split=0.1)
```

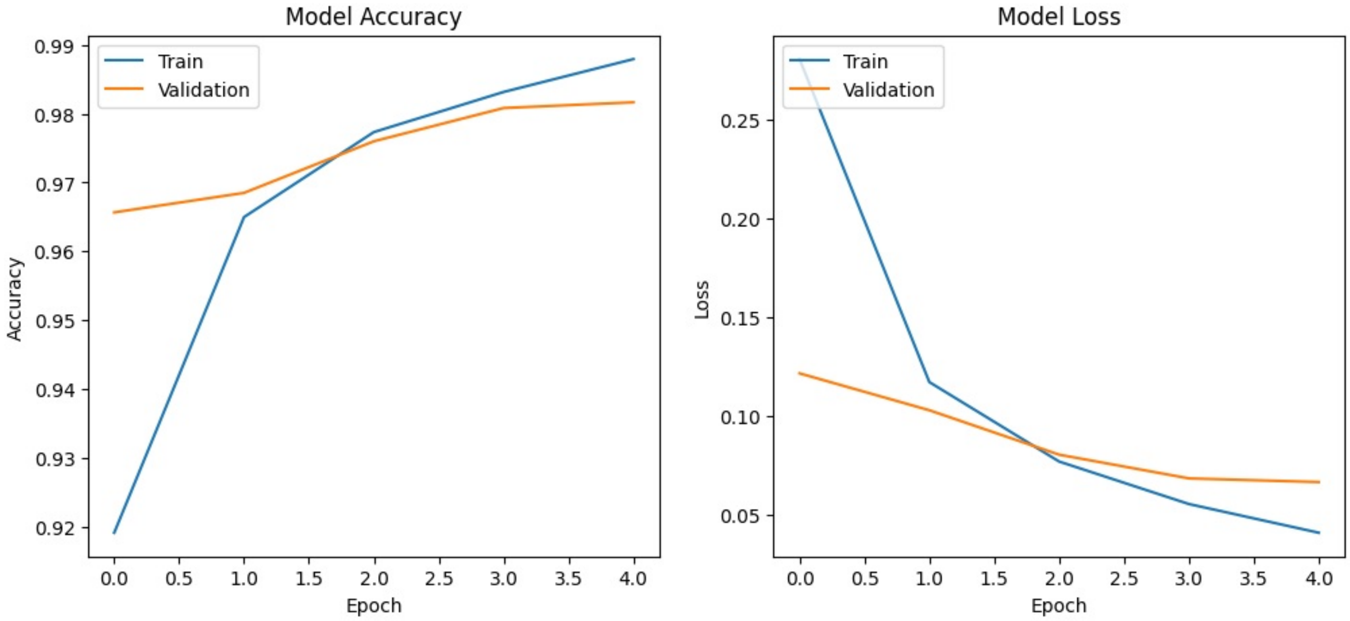
```
Epoch 1/5
422/422 ━━━━━━━━━━━━━━━━━━━━ 4s 8ms/step - accuracy: 0.8686 - loss: 0.4597 - val_accuracy: 0.9657 - val_loss: 0.
1218
Epoch 2/5
422/422 ━━━━━━━━━━━━━━━━━━━━ 3s 8ms/step - accuracy: 0.9604 - loss: 0.1304 - val_accuracy: 0.9685 - val_loss: 0.
1031
Epoch 3/5
422/422 ━━━━━━━━━━━━━━━━━━━━ 3s 6ms/step - accuracy: 0.9778 - loss: 0.0771 - val_accuracy: 0.9760 - val_loss: 0.
0806
Epoch 4/5
422/422 ━━━━━━━━━━━━━━━━━━━━ 3s 7ms/step - accuracy: 0.9835 - loss: 0.0564 - val_accuracy: 0.9808 - val_loss: 0.
0686
Epoch 5/5
422/422 ━━━━━━━━━━━━━━━━━━━━ 3s 7ms/step - accuracy: 0.9888 - loss: 0.0390 - val_accuracy: 0.9817 - val_loss: 0.
0668
```

In [ ]:

```
# Task 6: Evaluate Model Performance
# Plot accuracy and loss graphs to review the training and validation performance
plt.figure(figsize=(12, 5))
plt.subplot(1, 2, 1)
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model Accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')

plt.subplot(1, 2, 2)
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('Model Loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()

# Evaluate the model on test data and print the test accuracy
test_loss, test_acc = model.evaluate(x_test, y_test)
print(f"Test accuracy: {test_acc}")
```

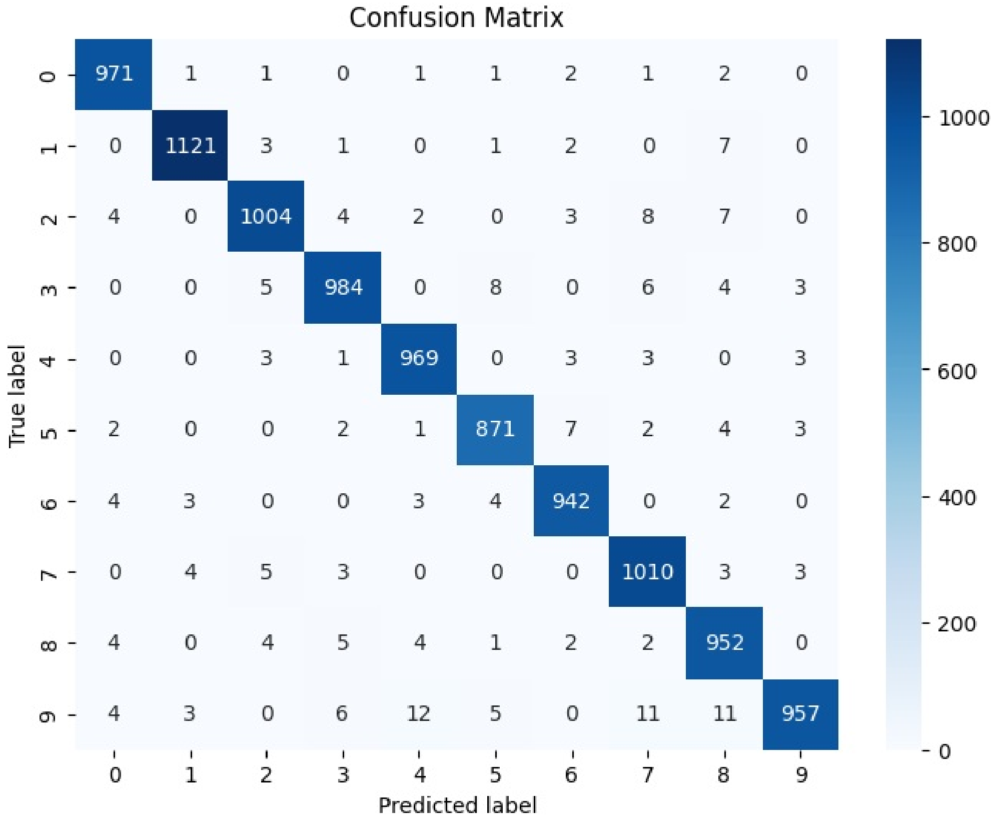


```
313/313 ━━━━━━━━━━━━━━━━━━━━ 0s 1ms/step - accuracy: 0.9754 - loss: 0.0796
Test accuracy: 0.9781000018119812
```

In [ ]:

```
# Task 7: Analyze Errors with a Confusion Matrix
# Generate predictions, calculate the confusion matrix, and visualize it
preds = model.predict(x_test)
pred_classes = np.argmax(preds, axis=1)
cm = confusion_matrix(y_test, pred_classes)
plt.figure(figsize=(8, 6))
sns.heatmap(cm, annot=True, fmt="d", cmap='Blues')
plt.title('Confusion Matrix')
plt.ylabel('True label')
plt.xlabel('Predicted label')
plt.show()
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 1s 2ms/step
```

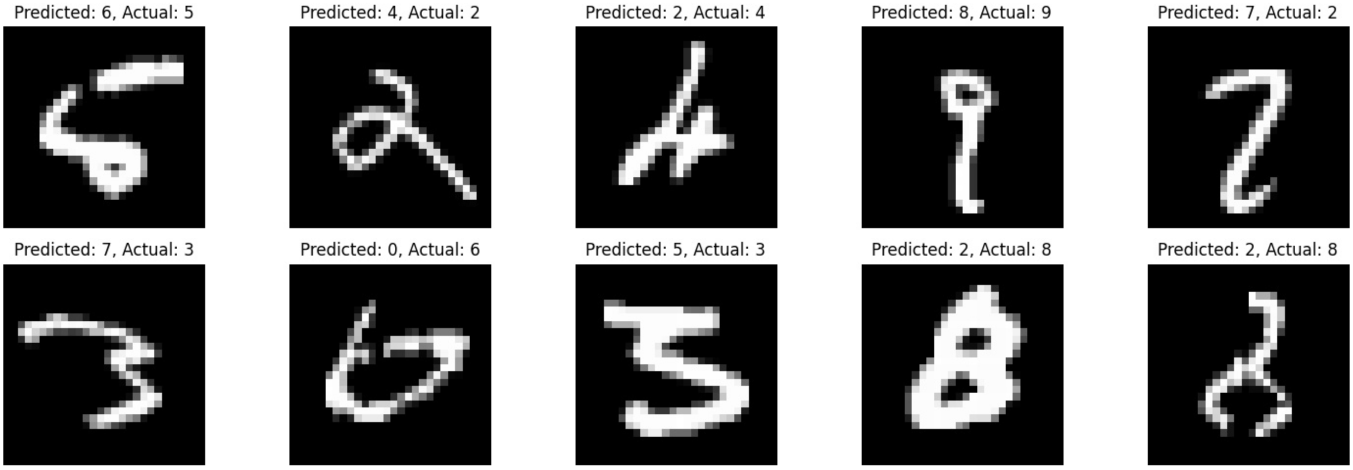


	0	1	2	3	4	5	6	7	8	9
0	971	1	1	0	1	1	2	1	2	0
1	0	1121	3	1	0	1	2	0	7	0
2	4	0	1004	4	2	0	3	8	7	0
3	0	0	5	984	0	8	0	6	4	3
4	0	0	3	1	969	0	3	3	0	3
5	2	0	0	2	1	871	7	2	4	3
6	4	3	0	0	3	4	942	0	2	0
7	0	4	5	3	0	0	0	1010	3	3
8	4	0	4	5	4	1	2	2	952	0
9	4	3	0	6	12	5	0	11	11	957

In [ ]:

```
# Task 8: Visualize Misclassifications
```

```python
# Display images that were misclassified to analyze potential reasons
misclassified_idxs = np.where(pred_classes != y_test)[0]
plt.figure(figsize=(15, 5))
for i, mis_idx in enumerate(misclassified_idxs[:10]):
    plt.subplot(2, 5, i + 1)
    plt.imshow(x_test[mis_idx].reshape(28, 28), cmap='gray')
    plt.title(f"Predicted: {pred_classes[mis_idx]}, Actual: {y_test[mis_idx]}")
    plt.axis('off')
plt.tight_layout()
plt.show()
```



Predicted: 6, Actual: 5

Predicted: 4, Actual: 2

Predicted: 2, Actual: 4

Predicted: 8, Actual: 9

Predicted: 7, Actual: 2

Predicted: 7, Actual: 3

Predicted: 0, Actual: 6

Predicted: 5, Actual: 3

Predicted: 2, Actual: 8

Predicted: 2, Actual: 8

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