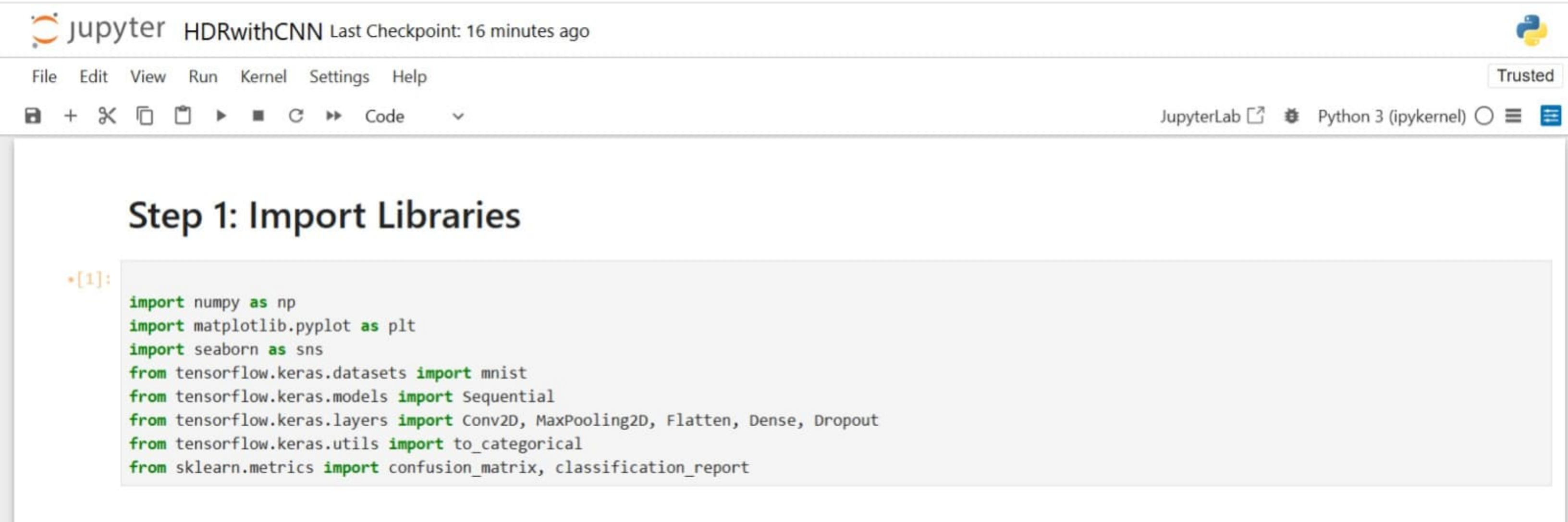
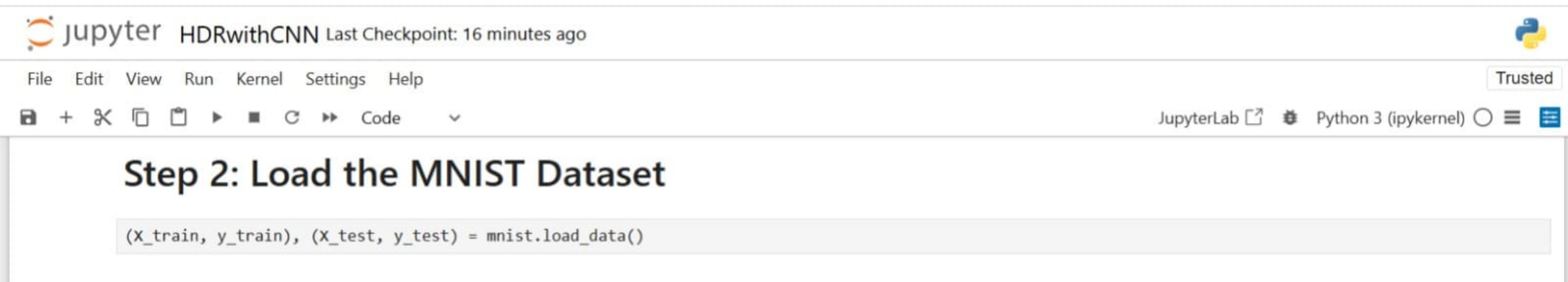


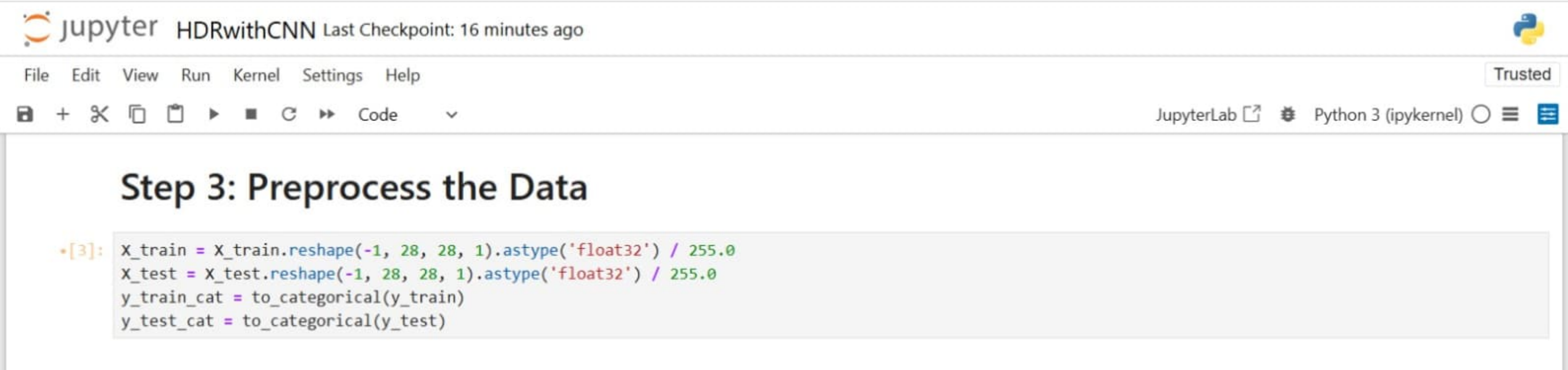
Step 1: Import Libraries

```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from tensorflow.keras.datasets import mnist
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense, Dropout
from tensorflow.keras.utils import to_categorical
from sklearn.metrics import confusion_matrix, classification_report
```



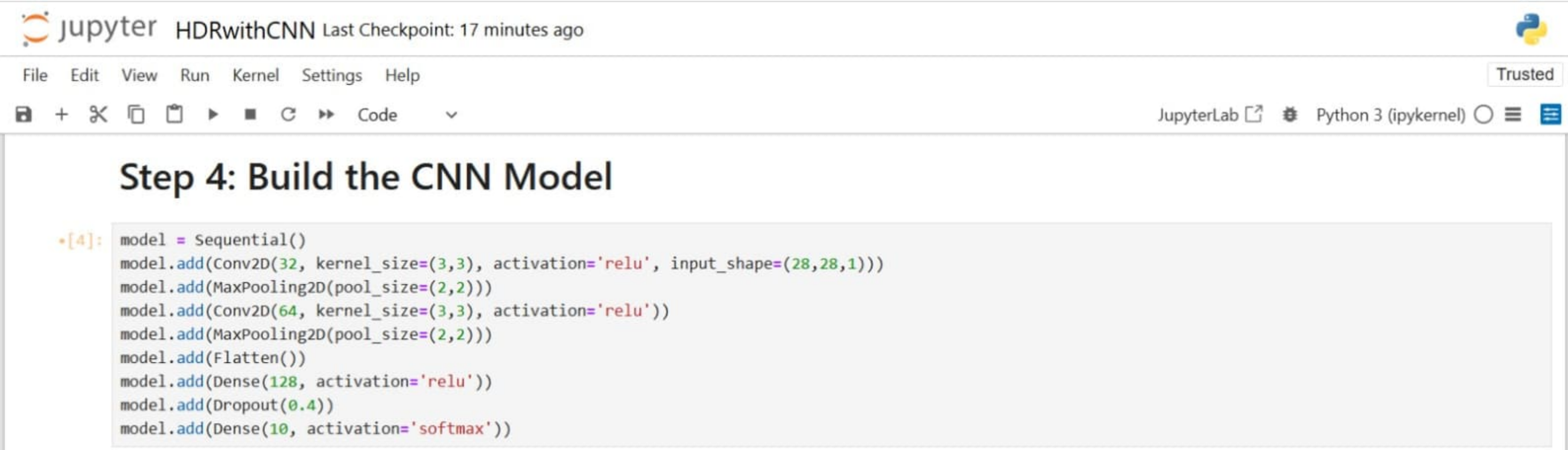
Step 2: Load the MNIST Dataset

```
(X_train, y_train), (X_test, y_test) = mnist.load_data()
```



Step 3: Preprocess the Data

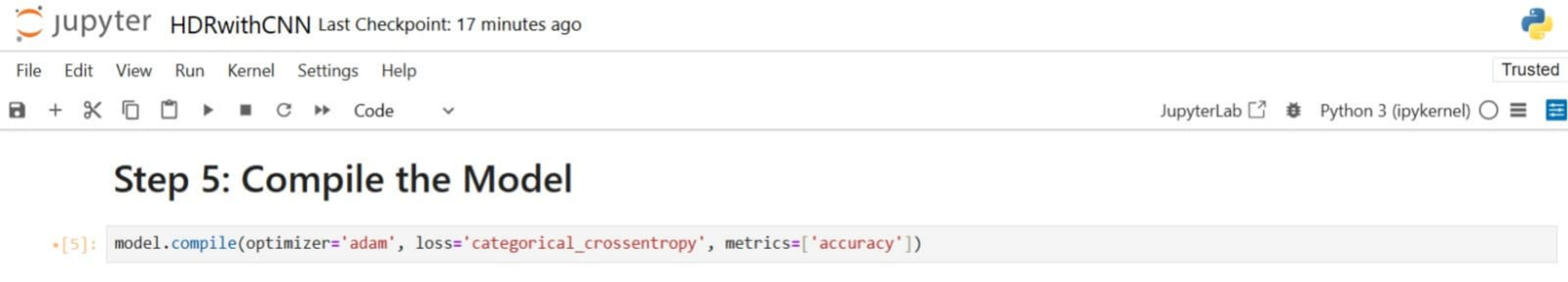
```
X_train = X_train.reshape(-1, 28, 28, 1).astype('float32') / 255.0
X_test = X_test.reshape(-1, 28, 28, 1).astype('float32') / 255.0
y_train_cat = to_categorical(y_train)
y_test_cat = to_categorical(y_test)
```



Step 4: Build the CNN Model

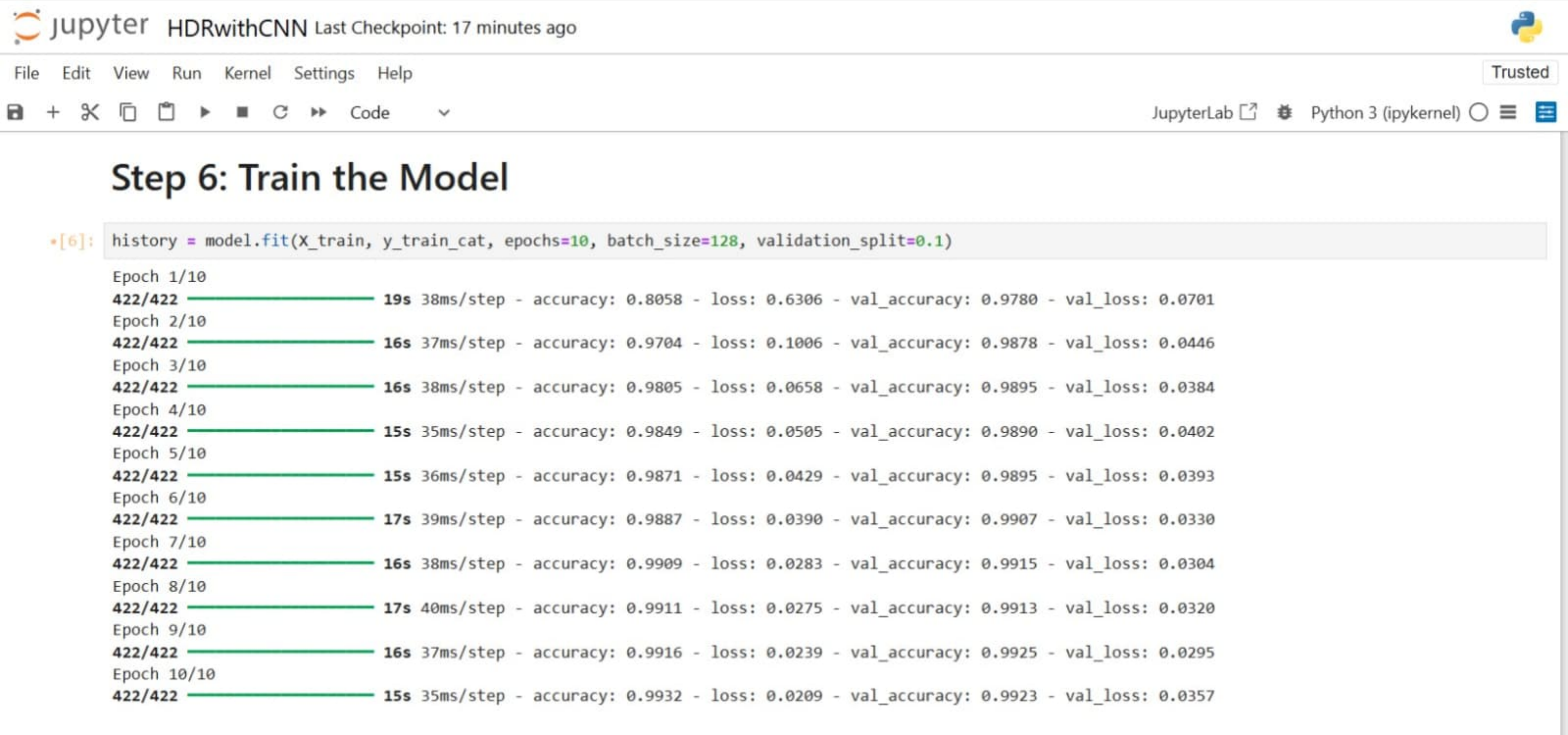
[4]:

```
model = Sequential()
model.add(Conv2D(32, kernel_size=(3,3), activation='relu', input_shape=(28,28,1)))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Conv2D(64, kernel_size=(3,3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.4))
model.add(Dense(10, activation='softmax'))
```



Step 5: Compile the Model

```
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```

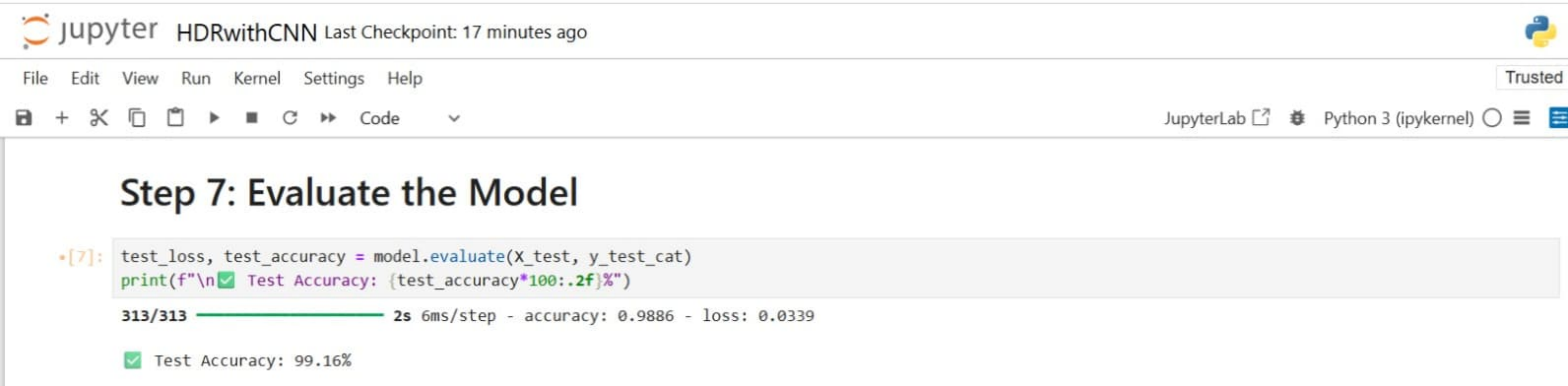


Step 6: Train the Model

[6]:

```
history = model.fit(X_train, y_train_cat, epochs=10, batch_size=128, validation_split=0.1)
```

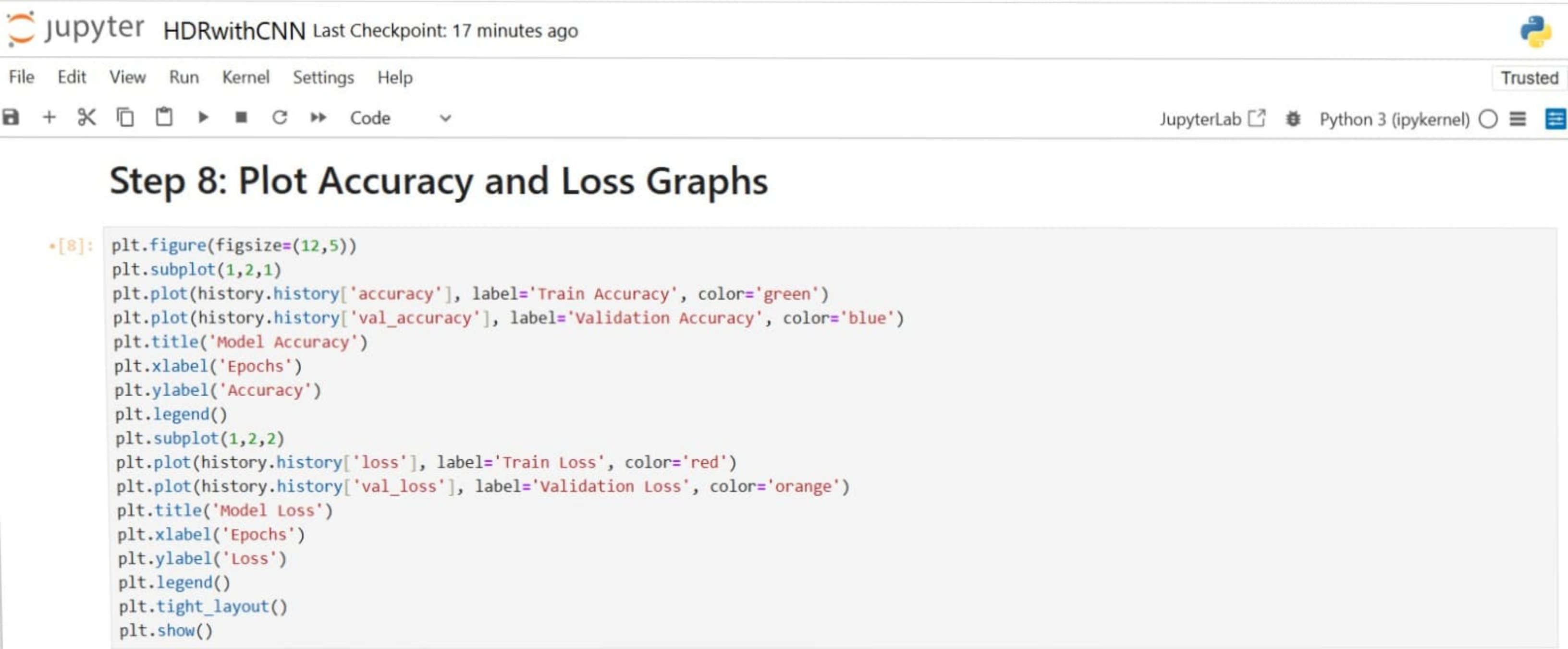
```
Epoch 1/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 19s 38ms/step - accuracy: 0.8058 - loss: 0.6306 - val_accuracy: 0.9780 - val_loss: 0.0701
Epoch 2/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 16s 37ms/step - accuracy: 0.9704 - loss: 0.1006 - val_accuracy: 0.9878 - val_loss: 0.0446
Epoch 3/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 16s 38ms/step - accuracy: 0.9805 - loss: 0.0658 - val_accuracy: 0.9895 - val_loss: 0.0384
Epoch 4/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 15s 35ms/step - accuracy: 0.9849 - loss: 0.0505 - val_accuracy: 0.9890 - val_loss: 0.0402
Epoch 5/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 15s 36ms/step - accuracy: 0.9871 - loss: 0.0429 - val_accuracy: 0.9895 - val_loss: 0.0393
Epoch 6/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 17s 39ms/step - accuracy: 0.9887 - loss: 0.0390 - val_accuracy: 0.9907 - val_loss: 0.0330
Epoch 7/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 16s 38ms/step - accuracy: 0.9909 - loss: 0.0283 - val_accuracy: 0.9915 - val_loss: 0.0304
Epoch 8/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 17s 40ms/step - accuracy: 0.9911 - loss: 0.0275 - val_accuracy: 0.9913 - val_loss: 0.0320
Epoch 9/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 16s 37ms/step - accuracy: 0.9916 - loss: 0.0239 - val_accuracy: 0.9925 - val_loss: 0.0295
Epoch 10/10
422/422 ━━━━━━━━━━━━━━━━━━━━ 15s 35ms/step - accuracy: 0.9932 - loss: 0.0209 - val_accuracy: 0.9923 - val_loss: 0.0357
```



Step 7: Evaluate the Model

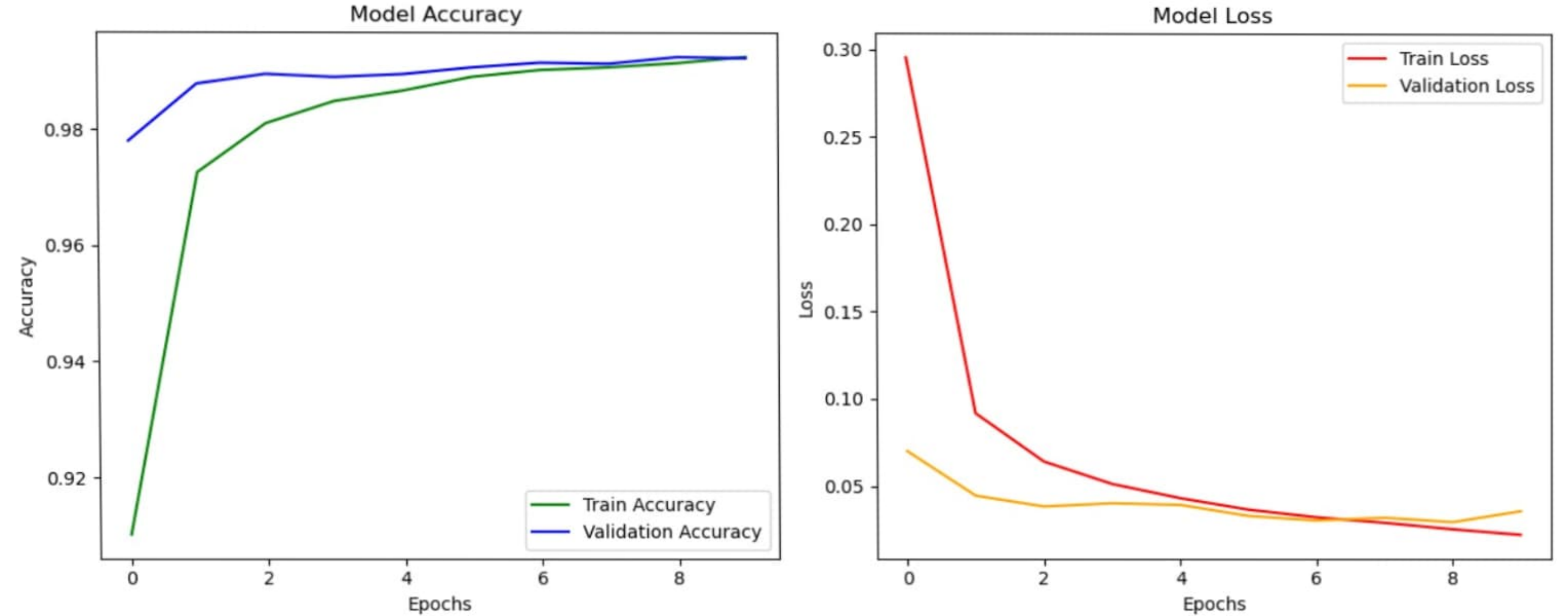
```
[7]: test_loss, test_accuracy = model.evaluate(X_test, y_test_cat)
     print(f"\n✅ Test Accuracy: {test_accuracy*100:.2f}%")
```

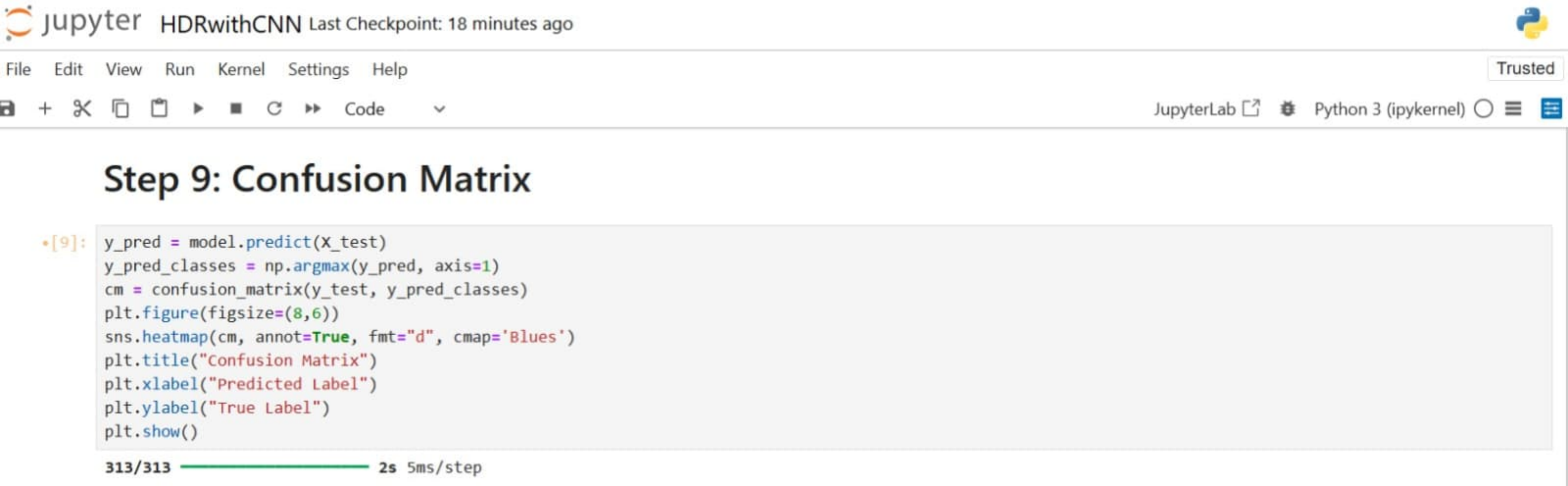
```
313/313 ━━━━━━━━━━━━━━━━━━━━ 2s 6ms/step - accuracy: 0.9886 - loss: 0.0339

✅ Test Accuracy: 99.16%
```



Step 8: Plot Accuracy and Loss Graphs

```
plt.figure(figsize=(12,5))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Accuracy', color='green')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy', color='blue')
plt.title('Model Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss', color='red')
plt.plot(history.history['val_loss'], label='Validation Loss', color='orange')
plt.title('Model Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()
plt.tight_layout()
plt.show()
```


Model Accuracy
Accuracy
0.92
0.94
0.96
0.98
0
2
4
6
8
Epochs
Train Accuracy
Validation Accuracy
Model Loss
Loss
0.05
0.10
0.15
0.20
0.25
0.30
0
2
4
6
8
Epochs
Train Loss
Validation Loss

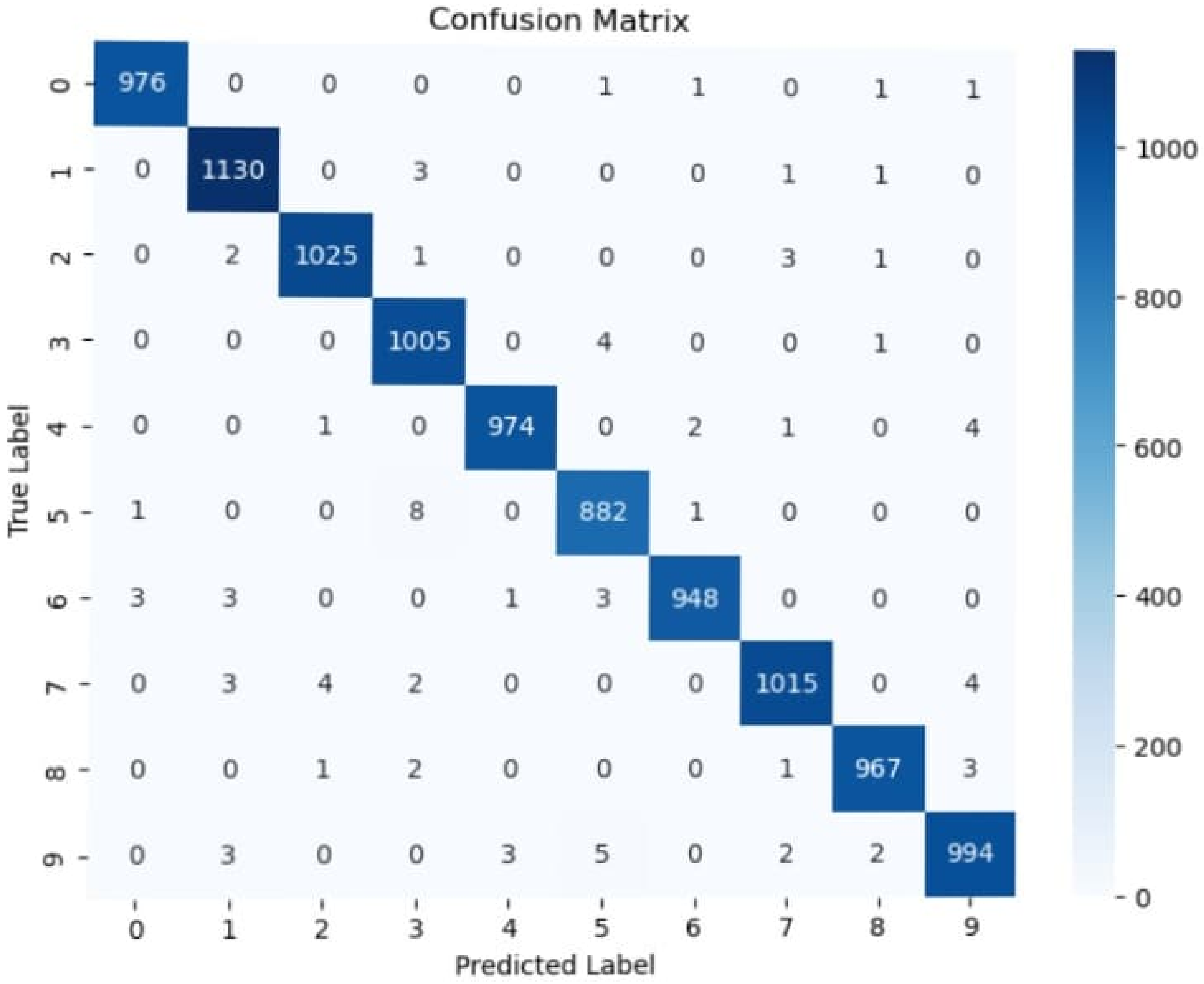


Step 9: Confusion Matrix

•[9]:

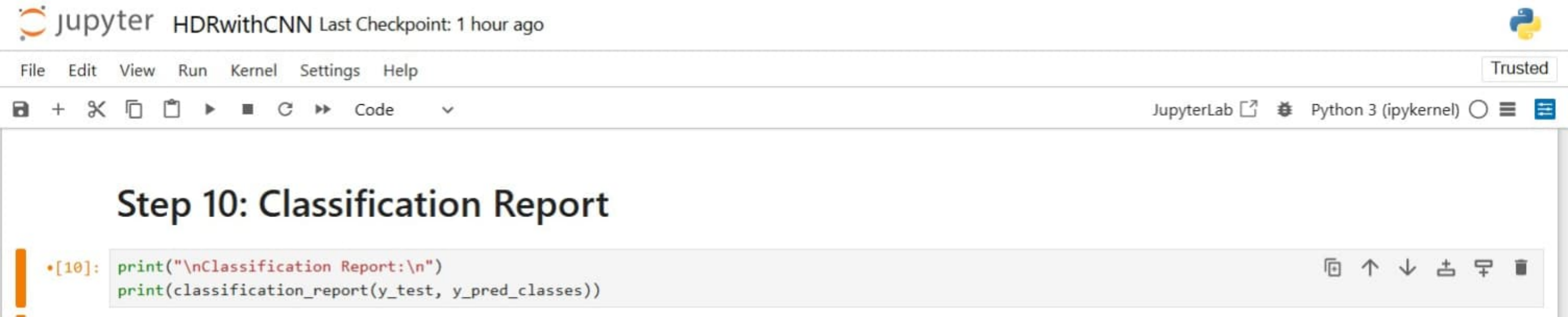
```
y_pred = model.predict(X_test)
y_pred_classes = np.argmax(y_pred, axis=1)
cm = confusion_matrix(y_test, y_pred_classes)
plt.figure(figsize=(8,6))
sns.heatmap(cm, annot=True, fmt="d", cmap='Blues')
plt.title("Confusion Matrix")
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.show()
```

```
313/313 ━━━━━━━━━━━━━━━━━━━━ 2s 5ms/step
```



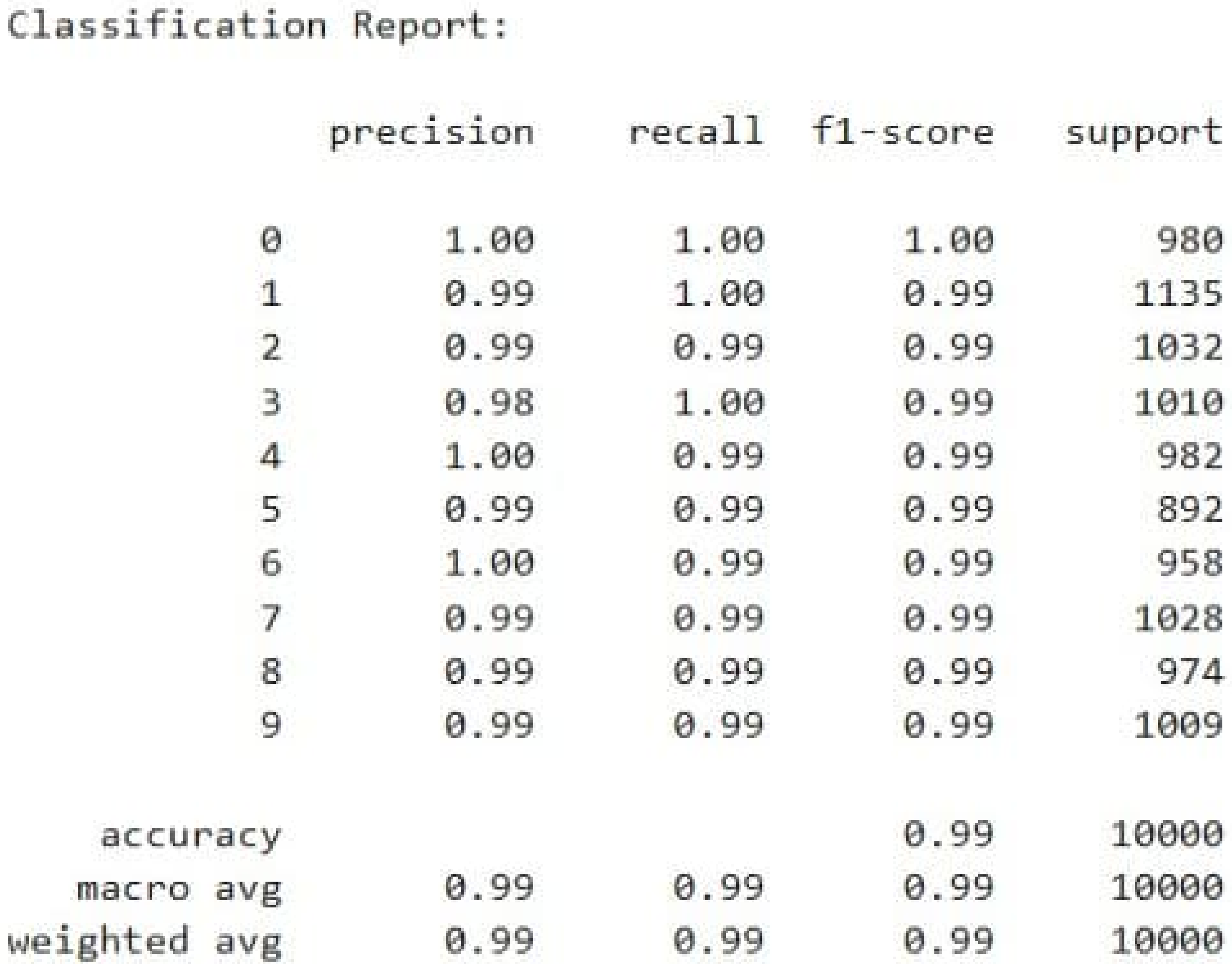
Confusion Matrix

	0	1	2	3	4	5	6	7	8	9
0	976	0	0	0	0	1	1	0	1	1
1	0	1130	0	3	0	0	0	1	1	0
2	0	2	1025	1	0	0	0	3	1	0
3	0	0	0	1005	0	4	0	0	1	0
4	0	0	1	0	974	0	2	1	0	4
5	1	0	0	8	0	882	1	0	0	0
6	3	3	0	0	1	3	948	0	0	0
7	0	3	4	2	0	0	0	1015	0	4
8	0	0	1	2	0	0	0	1	967	3
9	0	3	0	0	3	5	0	2	2	994

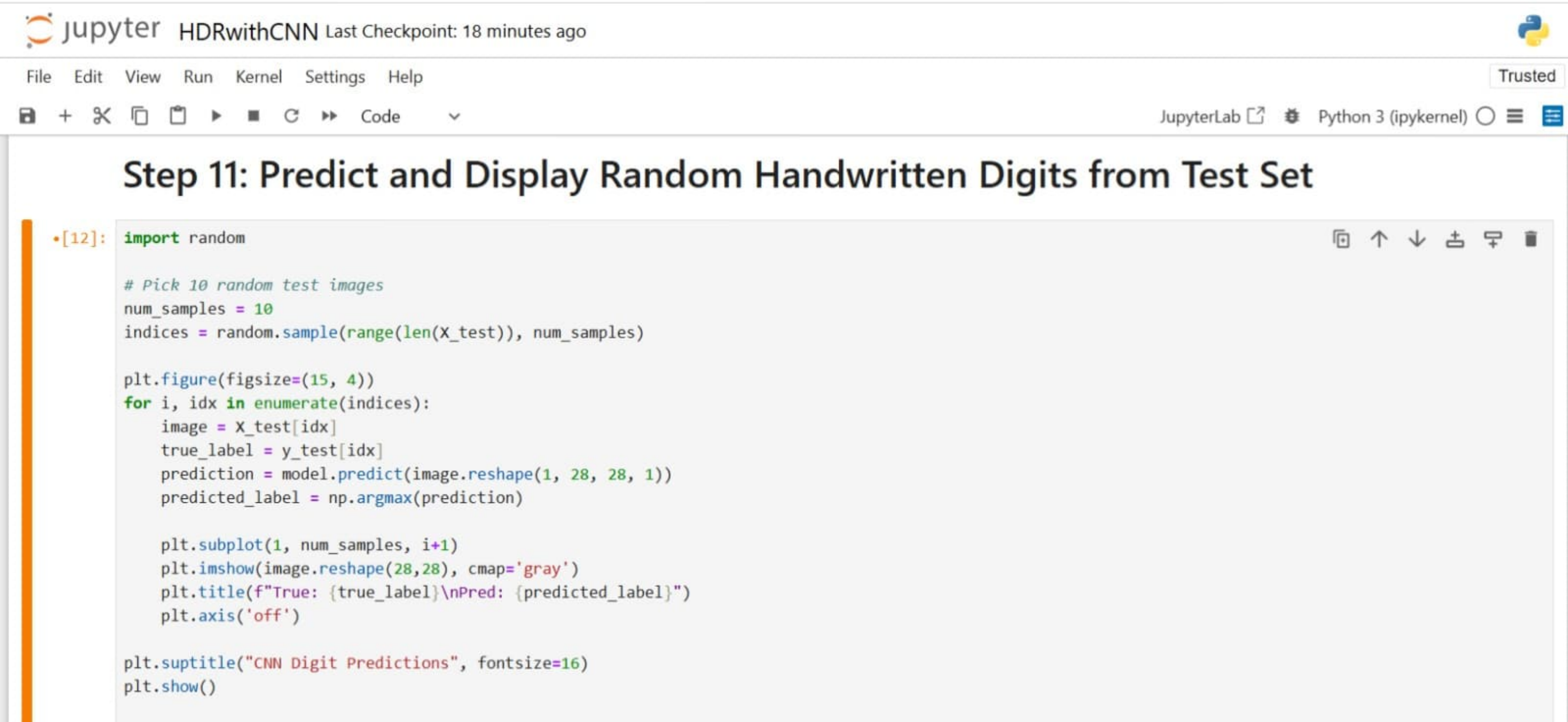


Step 10: Classification Report

```
print("\nClassification Report:\n")
print(classification_report(y_test, y_pred_classes))
```



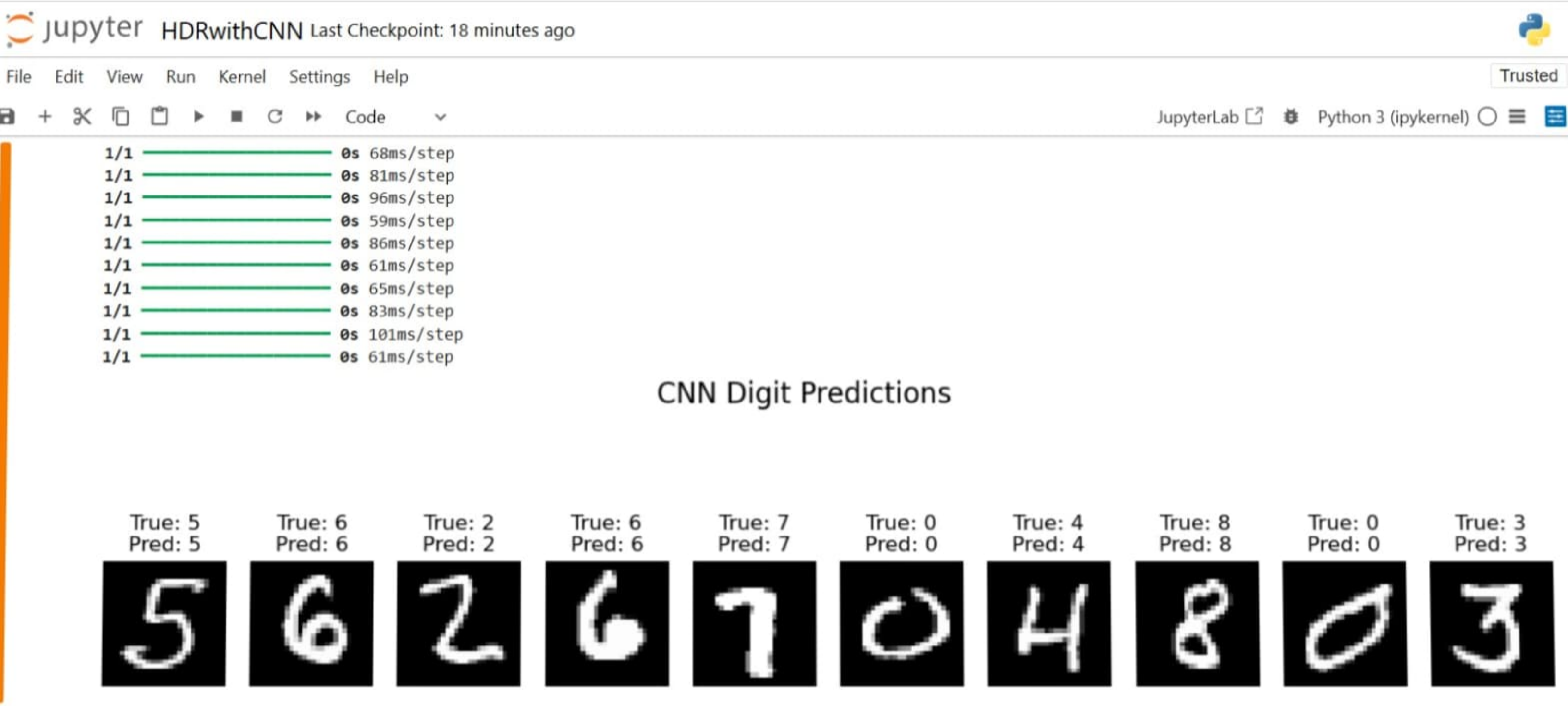
```
Classification Report:

              precision    recall  f1-score   support

           0       1.00      1.00      1.00       980
           1       0.99      1.00      0.99      1135
           2       0.99      0.99      0.99      1032
           3       0.98      1.00      0.99      1010
           4       1.00      0.99      0.99       982
           5       0.99      0.99      0.99       892
           6       1.00      0.99      0.99       958
           7       0.99      0.99      0.99      1028
           8       0.99      0.99      0.99       974
           9       0.99      0.99      0.99      1009

    accuracy                           0.99     10000
   macro avg       0.99      0.99      0.99     10000
weighted avg       0.99      0.99      0.99     10000
```



Step 11: Predict and Display Random Handwritten Digits from Test Set

•[12]:

```
import random

# Pick 10 random test images
num_samples = 10
indices = random.sample(range(len(X_test)), num_samples)

plt.figure(figsize=(15, 4))
for i, idx in enumerate(indices):
    image = X_test[idx]
    true_label = y_test[idx]
    prediction = model.predict(image.reshape(1, 28, 28, 1))
    predicted_label = np.argmax(prediction)

    plt.subplot(1, num_samples, i+1)
    plt.imshow(image.reshape(28,28), cmap='gray')
    plt.title(f"True: {true_label}\nPred: {predicted_label}")
    plt.axis('off')

plt.suptitle("CNN Digit Predictions", fontsize=16)
plt.show()
```



```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 68ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 81ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 96ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 59ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 86ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 61ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 65ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 83ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 101ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 61ms/step
```