Worksheet 4 Output

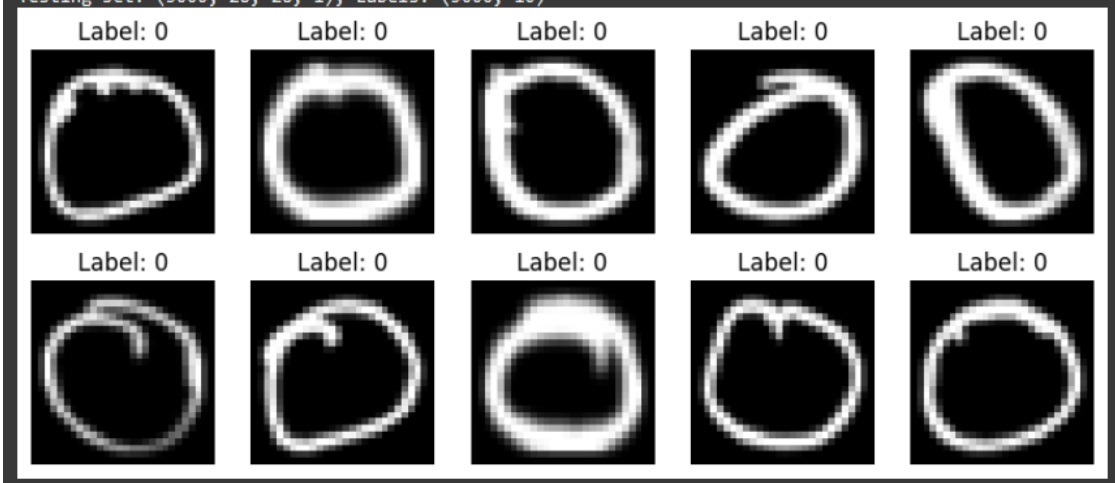
Importing Required Libraries

```
import os
import numpy as np
import tensorflow as tf
from tensorflow.keras.utils import to_categorical
from sklearn.model_selection import train_test_split
from sklearn.utils import shuffle
import matplotlib.pyplot as plt
from PIL import Image

from tensorflow import keras
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Flatten, BatchNormalization, Dropout
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import ModelCheckpoint, EarlyStopping

import matplotlib.pyplot as plt
```

```
Training set: (17000, 28, 28, 1), Labels: (17000, 10)
Testing set: (3000, 28, 28, 1), Labels: (3000, 10)
```




```
num_classes = 10
input_shape = (28*28, 1)
```

```python
num_classes = 10
input_shape = (28*28, 1)
model = keras.Sequential(
[
keras.layers.Input(shape=input_shape),
keras.layers.Flatten(),
keras.layers.Dense(64, activation="sigmoid"),
keras.layers.Dense(128, activation="sigmoid"),
keras.layers.Dense(256, activation="sigmoid"),
keras.layers.Dense(num_classes, activation="softmax"),
]
)
```

```python
model.summary()
```

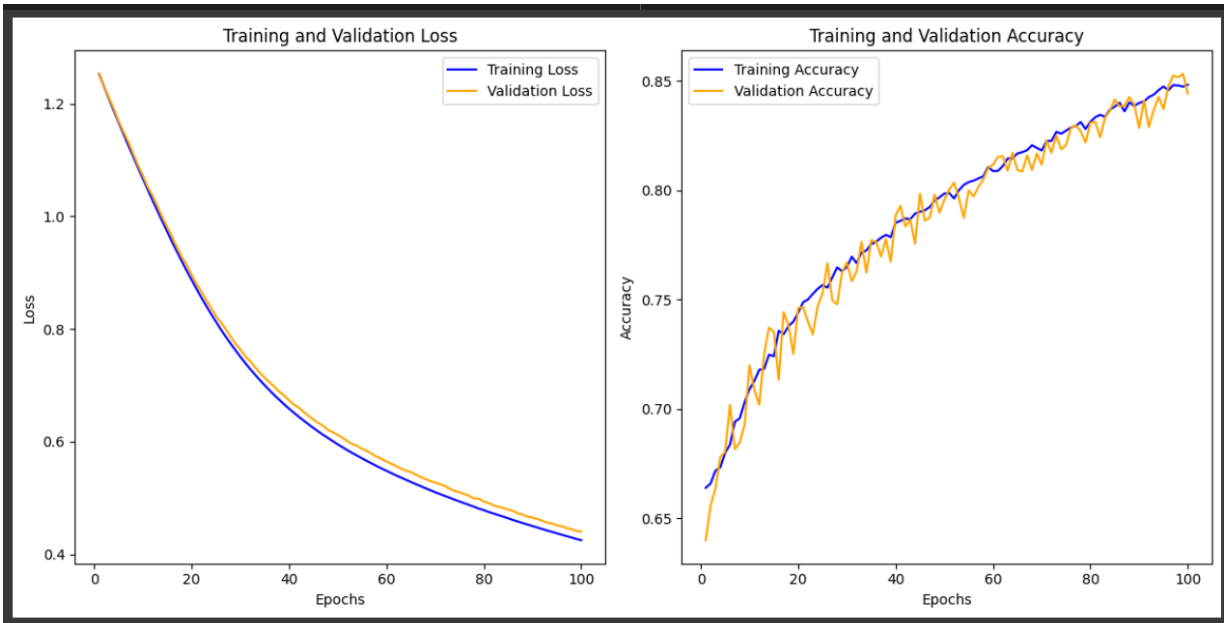
Model: "sequential_8"

Layer (type)	Output Shape	Param #
flatten_8 (Flatten)	(None, 784)	0
dense_26 (Dense)	(None, 64)	50,240
dense_27 (Dense)	(None, 128)	8,320
dense_28 (Dense)	(None, 256)	33,024
dense_29 (Dense)	(None, 10)	2,570

Total params: 94,154 (367.79 KB)
Trainable params: 94,154 (367.79 KB)
Non-trainable params: 0 (0.00 B)

```
Epoch 1/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.6654 - loss: 1.2685 - val_accuracy: 0.6400 - val_loss: 1.2532
Epoch 2/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 5ms/step - accuracy: 0.6653 - loss: 1.2388 - val_accuracy: 0.6557 - val_loss: 1.2308
Epoch 3/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.6652 - loss: 1.2198 - val_accuracy: 0.6635 - val_loss: 1.2108
Epoch 4/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.6711 - loss: 1.1970 - val_accuracy: 0.6780 - val_loss: 1.1919
Epoch 5/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.6748 - loss: 1.1754 - val_accuracy: 0.6804 - val_loss: 1.1698
Epoch 6/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 2s 9ms/step - accuracy: 0.6831 - loss: 1.1519 - val_accuracy: 0.7020 - val_loss: 1.1508
Epoch 7/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.7022 - loss: 1.1257 - val_accuracy: 0.6816 - val_loss: 1.1325
Epoch 8/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.6950 - loss: 1.1115 - val_accuracy: 0.6847 - val_loss: 1.1115
Epoch 9/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7025 - loss: 1.0855 - val_accuracy: 0.6929 - val_loss: 1.0912
Epoch 10/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7069 - loss: 1.0727 - val_accuracy: 0.7200 - val_loss: 1.0725
Epoch 11/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7100 - loss: 1.0556 - val_accuracy: 0.7086 - val_loss: 1.0521
Epoch 12/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7143 - loss: 1.0380 - val_accuracy: 0.7020 - val_loss: 1.0368
Epoch 13/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7191 - loss: 1.0172 - val_accuracy: 0.7251 - val_loss: 1.0180
Epoch 14/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.7238 - loss: 0.9874 - val_accuracy: 0.7373 - val_loss: 0.9985
Epoch 15/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7247 - loss: 0.9759 - val_accuracy: 0.7353 - val_loss: 0.9811
Epoch 16/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7364 - loss: 0.9618 - val_accuracy: 0.7133 - val_loss: 0.9639
Epoch 17/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7285 - loss: 0.9345 - val_accuracy: 0.7443 - val_loss: 0.9449
Epoch 18/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7389 - loss: 0.9195 - val_accuracy: 0.7384 - val_loss: 0.9282
Epoch 19/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.7388 - loss: 0.9055 - val_accuracy: 0.7251 - val_loss: 0.9141
Epoch 20/100
```

```
Epoch 84/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8329 - loss: 0.4772 - val_accuracy: 0.8365 - val_loss: 0.4822
Epoch 85/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8409 - loss: 0.4585 - val_accuracy: 0.8416 - val_loss: 0.4796
Epoch 86/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8382 - loss: 0.4651 - val_accuracy: 0.8384 - val_loss: 0.4770
Epoch 87/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 10ms/step - accuracy: 0.8408 - loss: 0.4545 - val_accuracy: 0.8388 - val_loss: 0.4727
Epoch 88/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.8449 - loss: 0.4488 - val_accuracy: 0.8427 - val_loss: 0.4704
Epoch 89/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.8372 - loss: 0.4509 - val_accuracy: 0.8392 - val_loss: 0.4669
Epoch 90/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8413 - loss: 0.4541 - val_accuracy: 0.8286 - val_loss: 0.4651
Epoch 91/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8382 - loss: 0.4506 - val_accuracy: 0.8412 - val_loss: 0.4628
Epoch 92/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8433 - loss: 0.4445 - val_accuracy: 0.8290 - val_loss: 0.4598
Epoch 93/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8411 - loss: 0.4479 - val_accuracy: 0.8369 - val_loss: 0.4562
Epoch 94/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8466 - loss: 0.4346 - val_accuracy: 0.8427 - val_loss: 0.4550
Epoch 95/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8500 - loss: 0.4386 - val_accuracy: 0.8373 - val_loss: 0.4511
Epoch 96/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8524 - loss: 0.4248 - val_accuracy: 0.8475 - val_loss: 0.4499
Epoch 97/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8493 - loss: 0.4279 - val_accuracy: 0.8525 - val_loss: 0.4467
Epoch 98/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8442 - loss: 0.4394 - val_accuracy: 0.8518 - val_loss: 0.4446
Epoch 99/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step - accuracy: 0.8483 - loss: 0.4290 - val_accuracy: 0.8533 - val_loss: 0.4417
Epoch 100/100
113/113 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.8466 - loss: 0.4299 - val_accuracy: 0.8443 - val_loss: 0.4401
```




```
test_loss, test_acc = model.evaluate(x_test, y_test, verbose=2)
```

```
94/94 - 0s - 2ms/step - accuracy: 0.8493 - loss: 0.4373
Test Accuracy: 0.8493
```

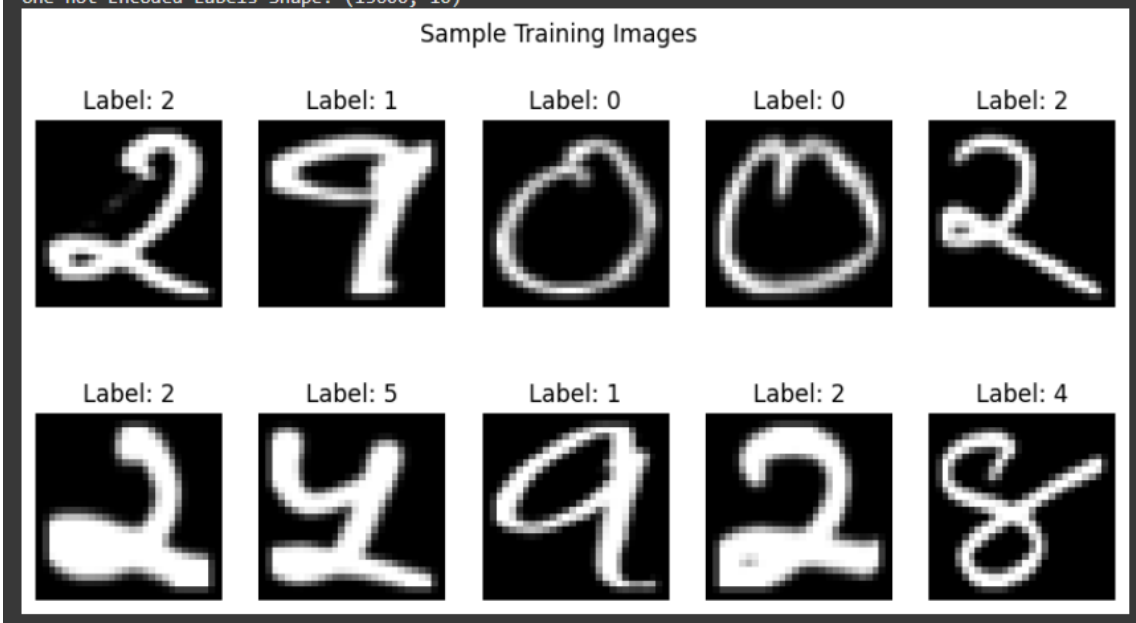
```
model.save("devnagari_digit_classifier.h5")
```

```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is considered legacy. We recommend using instead the native Keras format, e.g. `model.save('my_model.keras')` or `keras.saving.save_model(model, 'my_model.keras')`.
WARNING:absl:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` will be empty until you train or evaluate the model.
94/94 - 1s - 6ms/step - accuracy: 0.8493 - loss: 0.4373
Loaded Model Test Accuracy: 0.8493
```

```
94/94 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step
Predicted label for first image: 8
True label for first image: 0
```

```
plt.show()
```

```
Training Data Shape: (13600, 784), Validation Shape: (3400, 784), Test Shape: (3000, 784)
One-hot Encoded Labels Shape: (13600, 10)
```



Task 2 - Building Fully Connected Neural Network Model

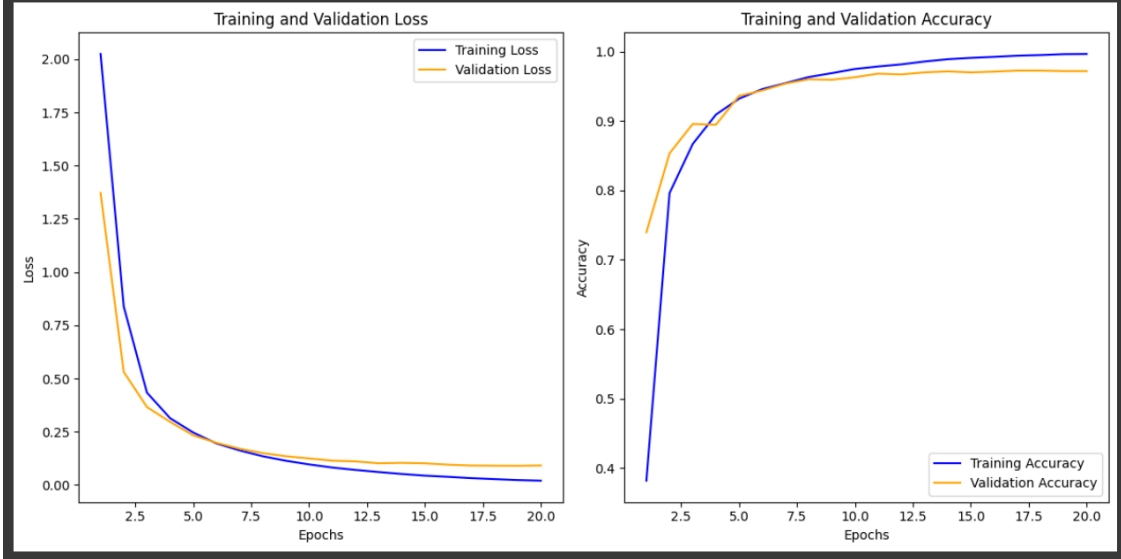
```
model1.summary()
```

Model: "sequential_11"

Layer (type)	Output Shape	Param #
dense_38 (Dense)	(None, 64)	50,240
dense_39 (Dense)	(None, 128)	8,320
dense_40 (Dense)	(None, 256)	33,024
dense_41 (Dense)	(None, 10)	2,570

Total params: 94,154 (367.79 KB)
Trainable params: 94,154 (367.79 KB)
Non-trainable params: 0 (0.00 B)

```
Epoch 1/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 2s 10ms/step - accuracy: 0.2127 - loss: 2.2424 - val_accuracy: 0.7397 - val_loss: 1.3718
Epoch 2/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.7700 - loss: 1.0598 - val_accuracy: 0.8533 - val_loss: 0.5311
Epoch 3/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step - accuracy: 0.8625 - loss: 0.4657 - val_accuracy: 0.8956 - val_loss: 0.3664
Epoch 4/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 2s 12ms/step - accuracy: 0.9023 - loss: 0.3371 - val_accuracy: 0.8945 - val_loss: 0.2967
Epoch 5/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 13ms/step - accuracy: 0.9271 - loss: 0.2592 - val_accuracy: 0.9360 - val_loss: 0.2332
Epoch 6/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - accuracy: 0.9412 - loss: 0.2048 - val_accuracy: 0.9438 - val_loss: 0.1983
Epoch 7/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9541 - loss: 0.1634 - val_accuracy: 0.9537 - val_loss: 0.1706
Epoch 8/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9595 - loss: 0.1449 - val_accuracy: 0.9599 - val_loss: 0.1500
Epoch 9/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9661 - loss: 0.1205 - val_accuracy: 0.9592 - val_loss: 0.1351
Epoch 10/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9766 - loss: 0.0954 - val_accuracy: 0.9629 - val_loss: 0.1247
Epoch 11/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step - accuracy: 0.9797 - loss: 0.0814 - val_accuracy: 0.9680 - val_loss: 0.1144
Epoch 12/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9808 - loss: 0.0727 - val_accuracy: 0.9669 - val_loss: 0.1112
Epoch 13/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9873 - loss: 0.0594 - val_accuracy: 0.9699 - val_loss: 0.1021
Epoch 14/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9899 - loss: 0.0505 - val_accuracy: 0.9713 - val_loss: 0.1041
Epoch 15/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 7ms/step - accuracy: 0.9924 - loss: 0.0418 - val_accuracy: 0.9699 - val_loss: 0.1021
Epoch 16/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step - accuracy: 0.9917 - loss: 0.0394 - val_accuracy: 0.9710 - val_loss: 0.0955
Epoch 17/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 9ms/step - accuracy: 0.9942 - loss: 0.0327 - val_accuracy: 0.9724 - val_loss: 0.0915
Epoch 18/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 2s 12ms/step - accuracy: 0.9949 - loss: 0.0264 - val_accuracy: 0.9724 - val_loss: 0.0907
Epoch 19/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 11ms/step - accuracy: 0.9966 - loss: 0.0240 - val_accuracy: 0.9717 - val_loss: 0.0902
Epoch 20/20
85/85 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step - accuracy: 0.9968 - loss: 0.0204 - val_accuracy: 0.9717 - val_loss: 0.0917
```



```
94/94 - 0s - 2ms/step - accuracy: 0.9740 - loss: 0.0903
Test Accuracy: 0.9740
Test Loss: 0.0903
```

```
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or `keras.saving.save_model(model)`. This file format is considered legacy. We recommend using instead the native Keras format, e.g. `model.save('my_model.keras')` or `keras.saving.save_model(model, 'my_model.keras')`.
WARNING:absl:Compiled the loaded model, but the compiled metrics have yet to be built. `model.compile_metrics` will be empty until you train or evaluate the model.
Model saved successfully as 'devnagari_digit_classifier.h5'!
Model loaded successfully!
94/94 - 1s - 6ms/step - accuracy: 0.9740 - loss: 0.0903
Loaded Model Test Accuracy: 0.9740
Loaded Model Test Loss: 0.0903
```

```
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 82ms/step
```