mnist

December 13, 2023

[ ]:
```
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, Flatten, Conv2D,␣
 ↪MaxPooling2D
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.utils import plot_model

import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
from sklearn.metrics import confusion_matrix
%matplotlib inline
```

[ ]:
```
(x_train, y_train), (x_test, y_test) = tf.keras.datasets.mnist.load_data(
    path='mnist.npz'
)
```

[ ]:
```
x_train.shape
```

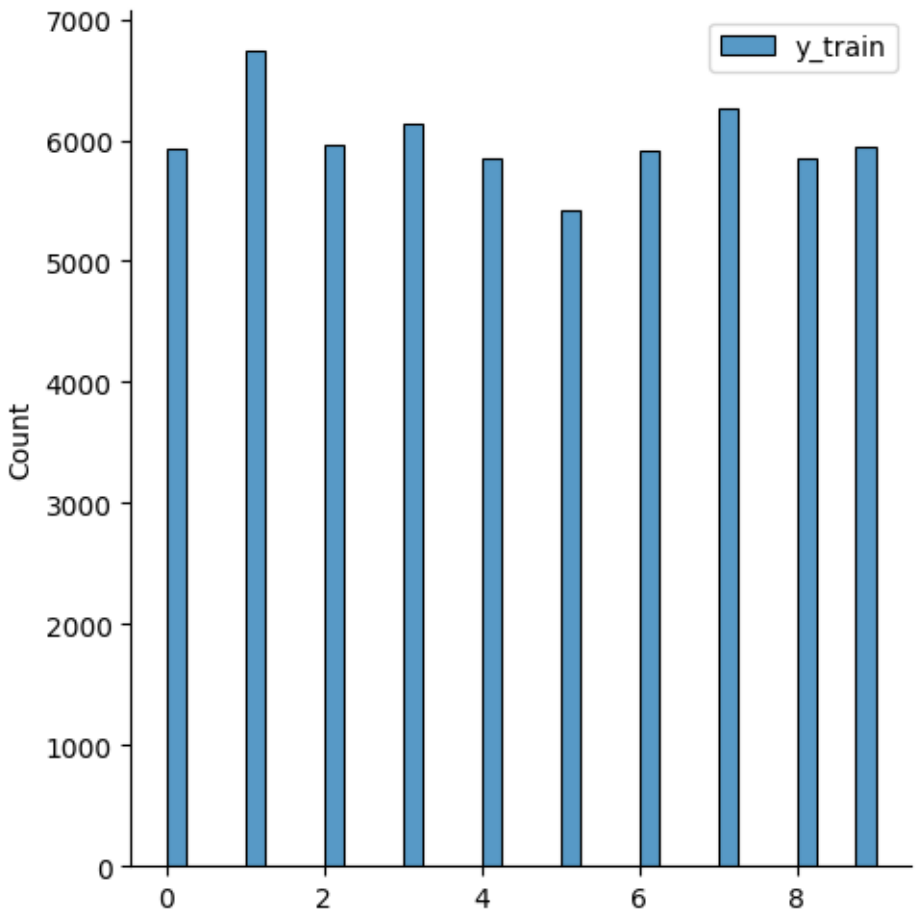
[ ]:
```
(10000, 28, 28)
```

[ ]:
```
y_train.shape
```

[ ]:
```
(60000,)
```

[ ]:
```
sns.displot(y_train, label='y_train')
plt.legend()
```

[ ]:
```
<matplotlib.legend.Legend at 0x2334ff2cd90>
```

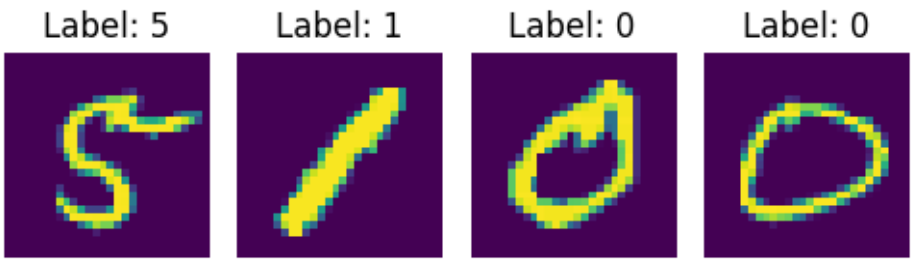


[ ]:
```
unique_values, counts = np.unique(y_train, return_counts=True)
print(unique_values)
```

```
[0 1 2 3 4 5 6 7 8 9]
```

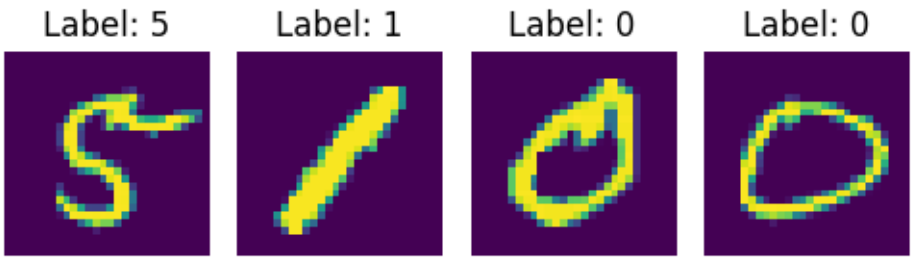
[ ]:
```
x_train, x_val, y_train, y_val = train_test_split(x_train, y_train, test_size=0.
↪2)
```

[ ]:
```
# Plotting 4 images in a row
plt.figure(figsize=(5, 5))
for i in range(4):
    plt.subplot(1, 4, i+1)
    plt.imshow(x_train[i])  # Display the image
    plt.title(f"Label: {y_train[i]}")  # Show the label
    plt.axis('off')  # Hide the axes
plt.tight_layout()
plt.show()
```



[ ]:
```
x_train = x_train.reshape(x_train.shape[0], 28, 28, 1).astype('float32') / 255
x_val = x_val.reshape(x_val.shape[0], 28, 28, 1).astype('float32') / 255
x_test = x_test.reshape(x_test.shape[0], 28, 28, 1).astype('float32') / 255
```

[ ]:
```
# Plotting 4 images in a row
plt.figure(figsize=(5, 5))
for i in range(4):
    plt.subplot(1, 4, i+1)
    plt.imshow(x_train[i])  # Display the image
    plt.title(f"Label: {y_train[i]}")  # Show the label
    plt.axis('off')  # Hide the axes
plt.tight_layout()
plt.show()
```



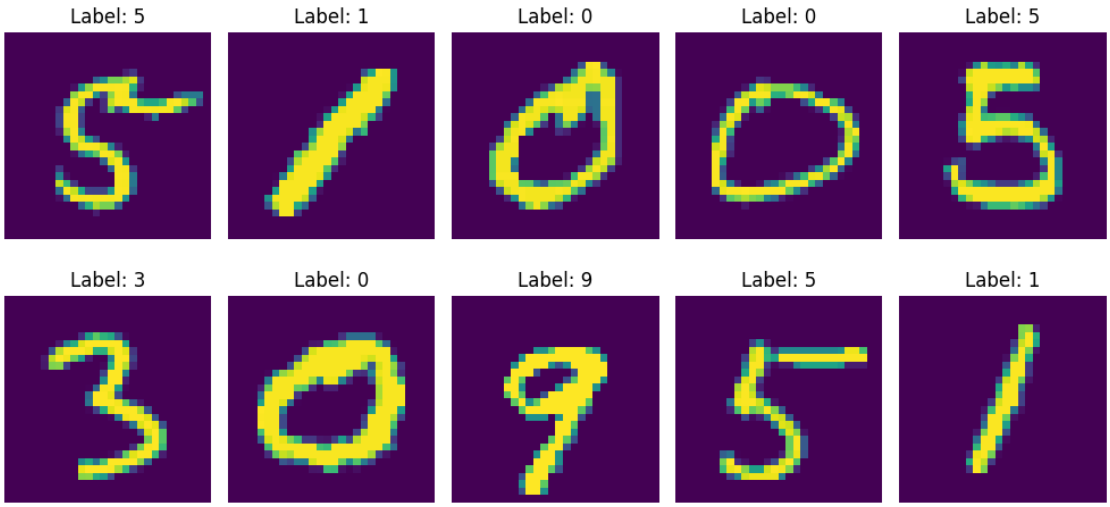
[ ]:
```
y_train_orig = y_train.copy()
y_test_orig = y_test.copy()
y_val_orig = y_val.copy()
y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
y_val = to_categorical(y_val)
```

[ ]:
```
y_train
```

[ ]:
```
array([[0., 0., 0., …, 0., 0., 0.],
       [0., 1., 0., …, 0., 0., 0.],
```

```
       [1., 0., 0., …, 0., 0., 0.],
       …,
       [0., 0., 0., …, 0., 0., 0.],
       [0., 0., 0., …, 0., 0., 0.],
       [0., 0., 0., …, 0., 0., 1.]], dtype=float32)
```

[ ]:
```
plt.figure(figsize=(10, 5))
for i in range(10):
    plt.subplot(2, 5 , i+1)
    plt.imshow(x_train[i])  # Display the image
    plt.title(f"Label: {y_train_orig[i]}")  # Set the title for each image
    plt.axis('off')  # Hide the axes
plt.tight_layout()
plt.show()
```



[ ]:
```
model = Sequential([
    Conv2D(32, (3, 3), padding='same', activation='relu', input_shape=(28, 28,␣
 ↪1)),
    MaxPooling2D((2, 2), strides=2),
    Conv2D(64, (3, 3), padding='same', activation='relu'),
    MaxPooling2D((2, 2), strides=2),
    Flatten(),
    Dense(128, activation='relu'),
    Dense(10, activation='softmax')
])
```

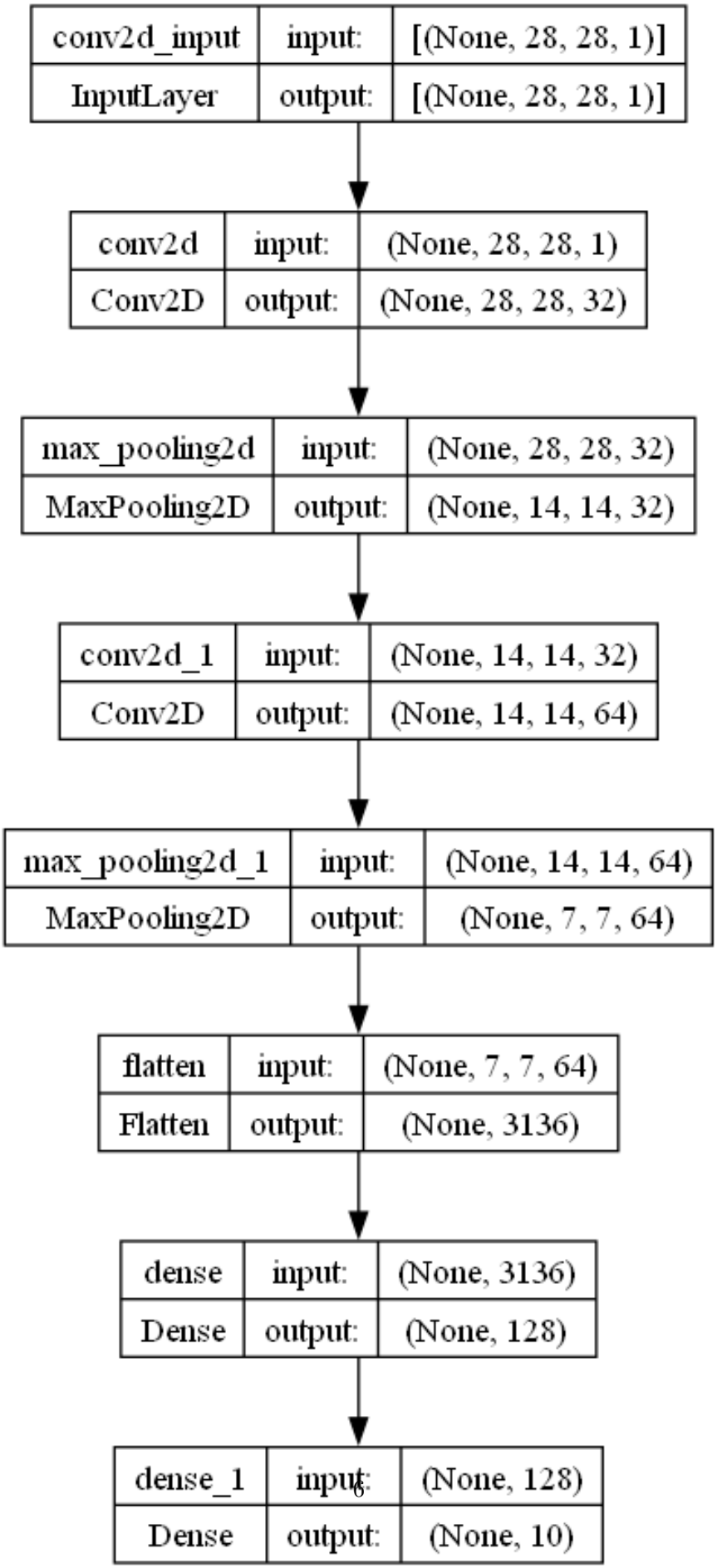
[ ]:
```
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
```

```
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 32)        320

 max_pooling2d (MaxPooling2D  (None, 14, 14, 32)       0
 )

 conv2d_1 (Conv2D)           (None, 14, 14, 64)        18496

 max_pooling2d_1 (MaxPooling  (None, 7, 7, 64)         0
 2D)

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 32)        320

 max_pooling2d (MaxPooling2D  (None, 14, 14, 32)       0
 )

 conv2d_1 (Conv2D)           (None, 14, 14, 64)        18496

 max_pooling2d_1 (MaxPooling  (None, 7, 7, 64)         0
 2D)

 flatten (Flatten)           (None, 3136)              0

 dense (Dense)               (None, 128)               401536

 dense_1 (Dense)             (None, 10)                1290

=================================================================
Total params: 421,642
Trainable params: 421,642
Non-trainable params: 0
_________________________________________________________________
```

[ ]:
```
plot_model(model, show_shapes=True)
```

[ ]:

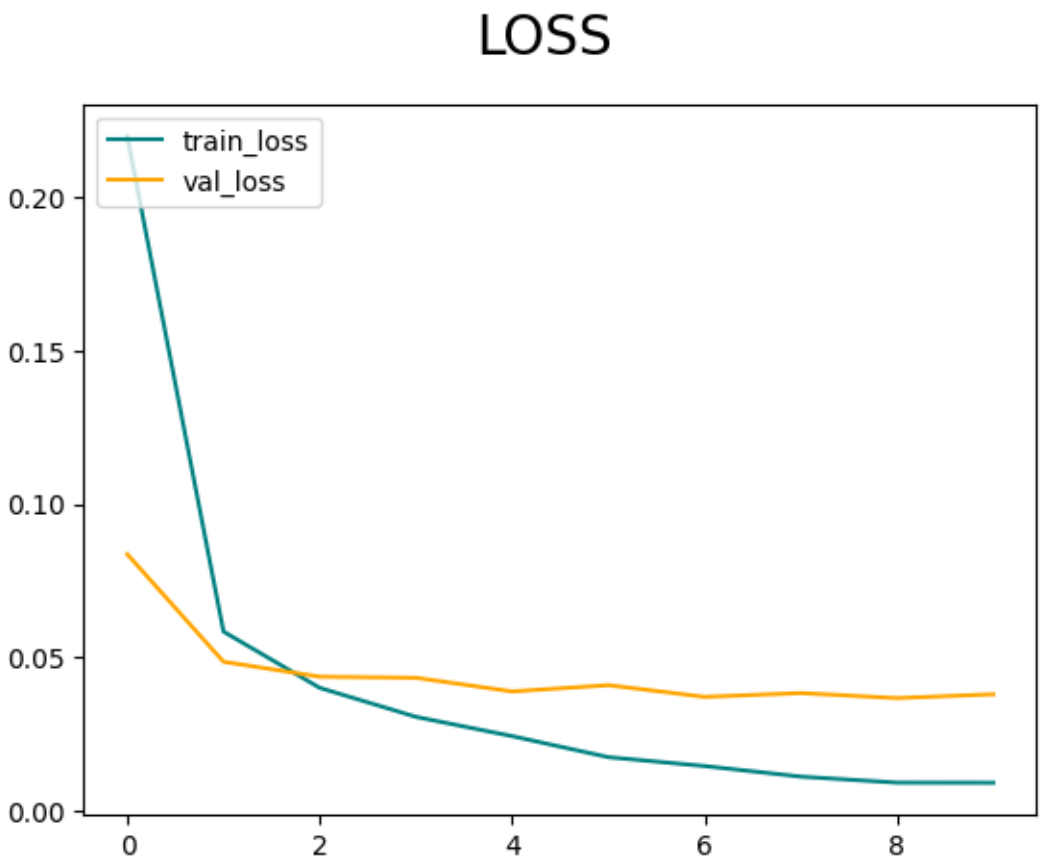

conv2d_input | input: | [(None, 28, 28, 1)]
InputLayer | output: | [(None, 28, 28, 1)]
conv2d | input: | (None, 28, 28, 1)
Conv2D | output: | (None, 28, 28, 32)
max_pooling2d | input: | (None, 28, 28, 32)
MaxPooling2D | output: | (None, 14, 14, 32)
conv2d_1 | input: | (None, 14, 14, 32)
Conv2D | output: | (None, 14, 14, 64)
max_pooling2d_1 | input: | (None, 14, 14, 64)
MaxPooling2D | output: | (None, 7, 7, 64)
flatten | input: | (None, 7, 7, 64)
Flatten | output: | (None, 3136)
dense | input: | (None, 3136)
Dense | output: | (None, 128)
dense_1 | input: | (None, 128)
Dense | output: | (None, 10)

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

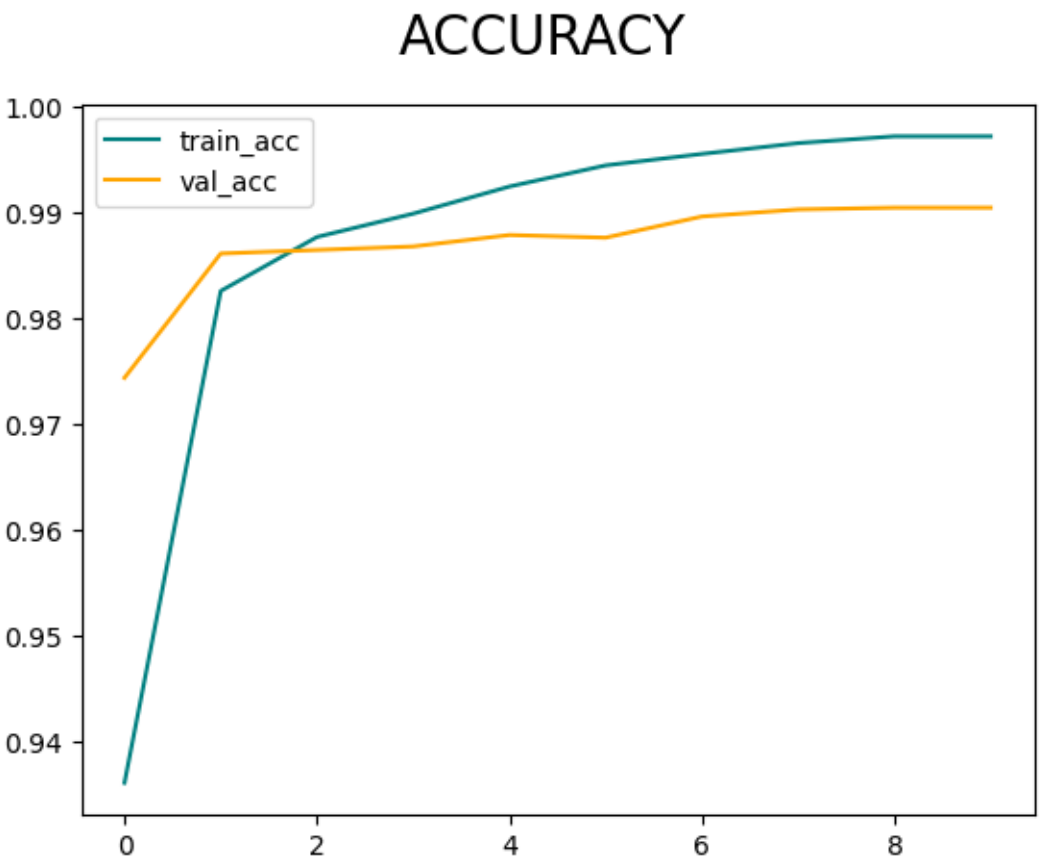
[ ]:
```
history = model.fit(x_train, y_train, epochs=10, batch_size=128,␣
↪validation_data=(x_val, y_val))
```

```
Epoch 1/10
375/375 [==============================] - 10s 8ms/step - loss: 0.2198 -
accuracy: 0.9360 - val_loss: 0.0836 - val_accuracy: 0.9743
Epoch 2/10
375/375 [==============================] - 3s 8ms/step - loss: 0.0584 -
accuracy: 0.9825 - val_loss: 0.0486 - val_accuracy: 0.9861
Epoch 3/10
375/375 [==============================] - 3s 7ms/step - loss: 0.0401 -
accuracy: 0.9876 - val_loss: 0.0437 - val_accuracy: 0.9864
Epoch 4/10
375/375 [==============================] - 3s 8ms/step - loss: 0.0306 -
accuracy: 0.9899 - val_loss: 0.0434 - val_accuracy: 0.9868
Epoch 5/10
375/375 [==============================] - 3s 7ms/step - loss: 0.0244 -
accuracy: 0.9924 - val_loss: 0.0389 - val_accuracy: 0.9878
Epoch 6/10
375/375 [==============================] - 3s 8ms/step - loss: 0.0175 -
accuracy: 0.9944 - val_loss: 0.0410 - val_accuracy: 0.9876
Epoch 7/10
375/375 [==============================] - 3s 7ms/step - loss: 0.0146 -
accuracy: 0.9955 - val_loss: 0.0372 - val_accuracy: 0.9896
Epoch 8/10
375/375 [==============================] - 3s 7ms/step - loss: 0.0112 -
accuracy: 0.9965 - val_loss: 0.0384 - val_accuracy: 0.9902
Epoch 9/10
375/375 [==============================] - 3s 7ms/step - loss: 0.0092 -
accuracy: 0.9972 - val_loss: 0.0368 - val_accuracy: 0.9904
Epoch 10/10
375/375 [==============================] - 3s 8ms/step - loss: 0.0092 -
accuracy: 0.9972 - val_loss: 0.0380 - val_accuracy: 0.9904
```

[ ]:
```
fig = plt.figure()
plt.plot(history.history["loss"], color='teal', label='train_loss')
plt.plot(history.history["val_loss"], color='orange', label='val_loss')
plt.suptitle('LOSS',fontsize=20)
plt.legend(loc="upper left")
plt.show()
```



[ ]:
```
fig = plt.figure()
plt.plot(history.history['accuracy'],color='teal', label='train_acc')
plt.plot(history.history['val_accuracy'],color='orange', label='val_acc')
plt.suptitle('ACCURACY',fontsize=20)
plt.legend(loc="upper left")
plt.show()
```



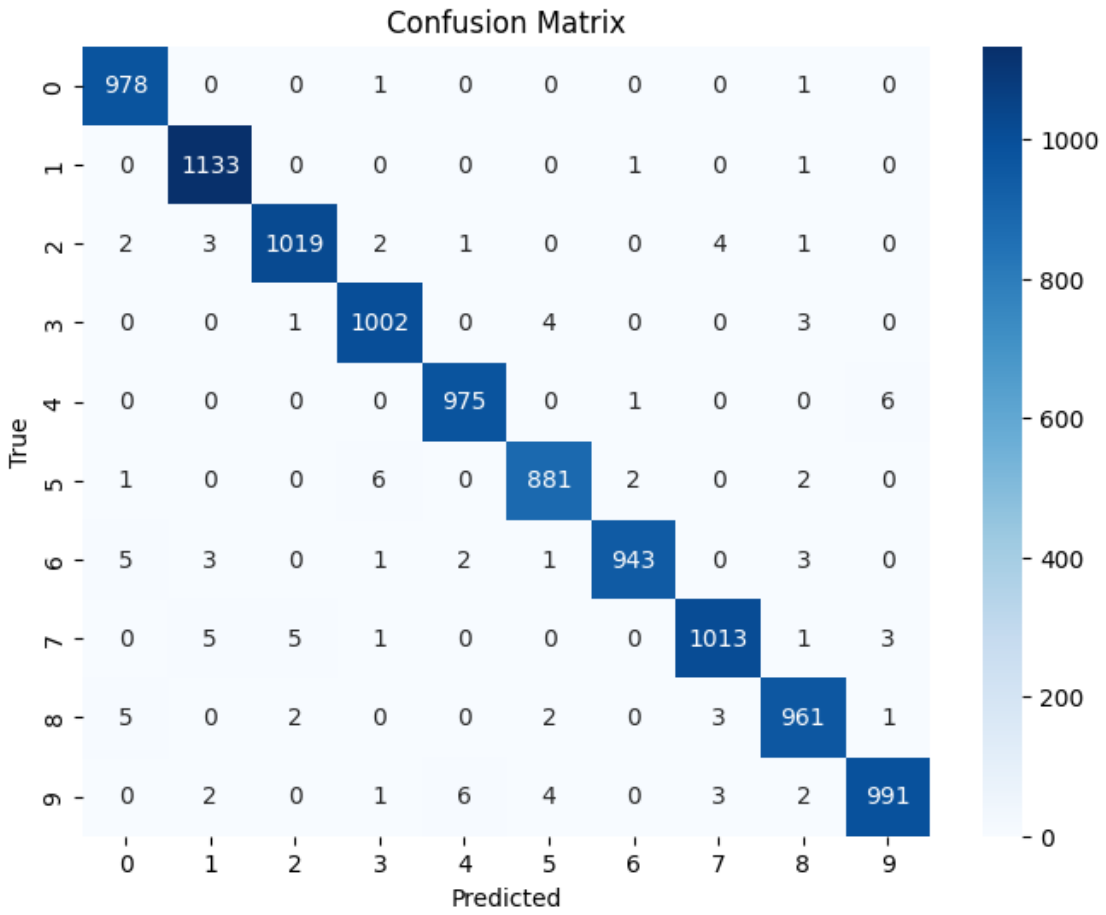
[ ]:
```
# Evaluate the model on the test set
test_loss, test_accuracy = model.evaluate(x_test, y_test)

print(f"Test Accuracy: {test_accuracy*100:.2f}%")
print(f"Test Loss: {test_loss}")
```

```
313/313 [==============================] - 1s 3ms/step - loss: 0.0330 -
accuracy: 0.9896
Test Accuracy: 98.96%
Test Loss: 0.033014994114637375
```

[ ]:
```
# Assuming you have predictions for x_test stored in y_pred
y_pred = model.predict(x_test)
categorical_y_pred = np.argmax(y_pred, axis=1)

# Calculate the confusion matrix
conf_matrix = confusion_matrix(y_test.argmax(axis=1), categorical_y_pred)

# Define class labels (if available)
class_labels = unique_values
```

```
# Create a heatmap
plt.figure(figsize=(8, 6))
sns.heatmap(conf_matrix, annot=True, cmap='Blues', fmt='d',␣
 ↪xticklabels=class_labels, yticklabels=class_labels)
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```

```
313/313 [==============================] - 1s 3ms/step
```



[ ]:
```
# Select a single image from the test set (e.g., the first image)
import random
image_index = random.randint(1, 499)  # Change this index to select a different␣
 ↪image
selected_image = x_test[image_index]
true_label = y_test[image_index].argmax()
```

```
# Make a prediction on the selected image
prediction = model.predict(np.expand_dims(selected_image, axis=0))
predicted_label = np.argmax(prediction)

# Display the selected image and prediction
plt.figure(figsize=(5, 5))
plt.imshow(selected_image)
plt.title(f"True Label: {true_label}, Predicted Label: {predicted_label}")
plt.axis('off')
plt.show()
```

```
1/1 [==============================] - 0s 267ms/step
```