In [ ]:
```
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 #class: B.E.A.I & D.S.
#Roll No:37
#Subject : Deep Learning (CL-IV)
```

In [ ]:
```
### (a) Data Pre-processing
```

In [ ]:
```
import tensorflow as tf
from tensorflow.keras.datasets import mnist
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Input,Conv2D, MaxPooling2D, Flatten, Dense
import seaborn as sns
from sklearn.metrics import confusion_matrix
import matplotlib.pyplot as plt
import numpy as np
from tensorflow.keras.utils import to_categorical
```

In [ ]:
```
# Load dataset
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

In [ ]:
```
# Normalize the images
x_train = x_train.astype("float32") / 255.0
x_test = x_test.astype("float32") / 255.0
```

In [ ]:
```
# Reshape images for CNN input
x_train = x_train.reshape(-1, 28, 28, 1)
x_test = x_test.reshape(-1, 28, 28, 1)
```

In [ ]:
```
# Convert labels to one-hot encoding
y_train = to_categorical(y_train, 10)
y_test = to_categorical(y_test, 10)
```

In [ ]:
```
print("Data pre-processing completed!")
```

```
Data pre-processing completed!
```

In [ ]:
```
### (b) Define Model and Perform Training
```

In [ ]:
```
# Define CNN model with explicit Input layer
model = Sequential([
    Input(shape=(28, 28, 1)),  # Explicit Input layer
    Conv2D(32, kernel_size=(3, 3), activation='relu'),
    MaxPooling2D(pool_size=(2, 2)),
    Conv2D(64, kernel_size=(3, 3), activation='relu'),
    MaxPooling2D(pool_size=(2, 2)),
    Flatten(),
    Dense(128, activation='relu'),
    Dense(10, activation='softmax')
])
```

In [ ]:
```
# Compile model
model.compile(optimizer='adam',  loss='categorical_crossentropy',  metrics=['accur
```

In [ ]:
```
# Train the model
```

```
history = model.fit(x_train, y_train, epochs=10, batch_size=64, validation_data=
```

```
Epoch 1/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 58s 59ms/step  - accuracy: 0.8842 - loss: 0.3822 - va
l_accuracy: 0.9850 - val_loss: 0.0467
Epoch 2/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 82s 59ms/step  - accuracy: 0.9837 - loss: 0.0520 - va
l_accuracy: 0.9886 - val_loss: 0.0337
Epoch 3/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 56s 60ms/step  - accuracy: 0.9896 - loss: 0.0335 - va
l_accuracy: 0.9882 - val_loss: 0.0357
Epoch 4/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 54s 57ms/step  - accuracy: 0.9925 - loss: 0.0234 - va
l_accuracy: 0.9859 - val_loss: 0.0438
Epoch 5/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 84s 60ms/step  - accuracy: 0.9940 - loss: 0.0195 - va
l_accuracy: 0.9917 - val_loss: 0.0255
Epoch 6/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 83s 61ms/step  - accuracy: 0.9962 - loss: 0.0126 - va
l_accuracy: 0.9907 - val_loss: 0.0305
Epoch 7/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 80s 58ms/step  - accuracy: 0.9970 - loss: 0.0093 - va
l_accuracy: 0.9893 - val_loss: 0.0321
Epoch 8/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 84s 60ms/step  - accuracy: 0.9966 - loss: 0.0094 - va
l_accuracy: 0.9901 - val_loss: 0.0374
Epoch 9/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 79s 58ms/step  - accuracy: 0.9980 - loss: 0.0073 - va
l_accuracy: 0.9917 - val_loss: 0.0290
Epoch 10/10
938/938 ━━━━━━━━━━━━━━━━━━━━ 83s 59ms/step  - accuracy: 0.9982 - loss: 0.0058 - va
l_accuracy: 0.9915 - val_loss: 0.0292
```

In [ ]:
```
print("Model training completed!")
```

```
Model training completed!
```

In [ ]:
```
# Predict the classes
y_pred = model.predict(x_test)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true = np.argmax(y_test, axis=1)
```

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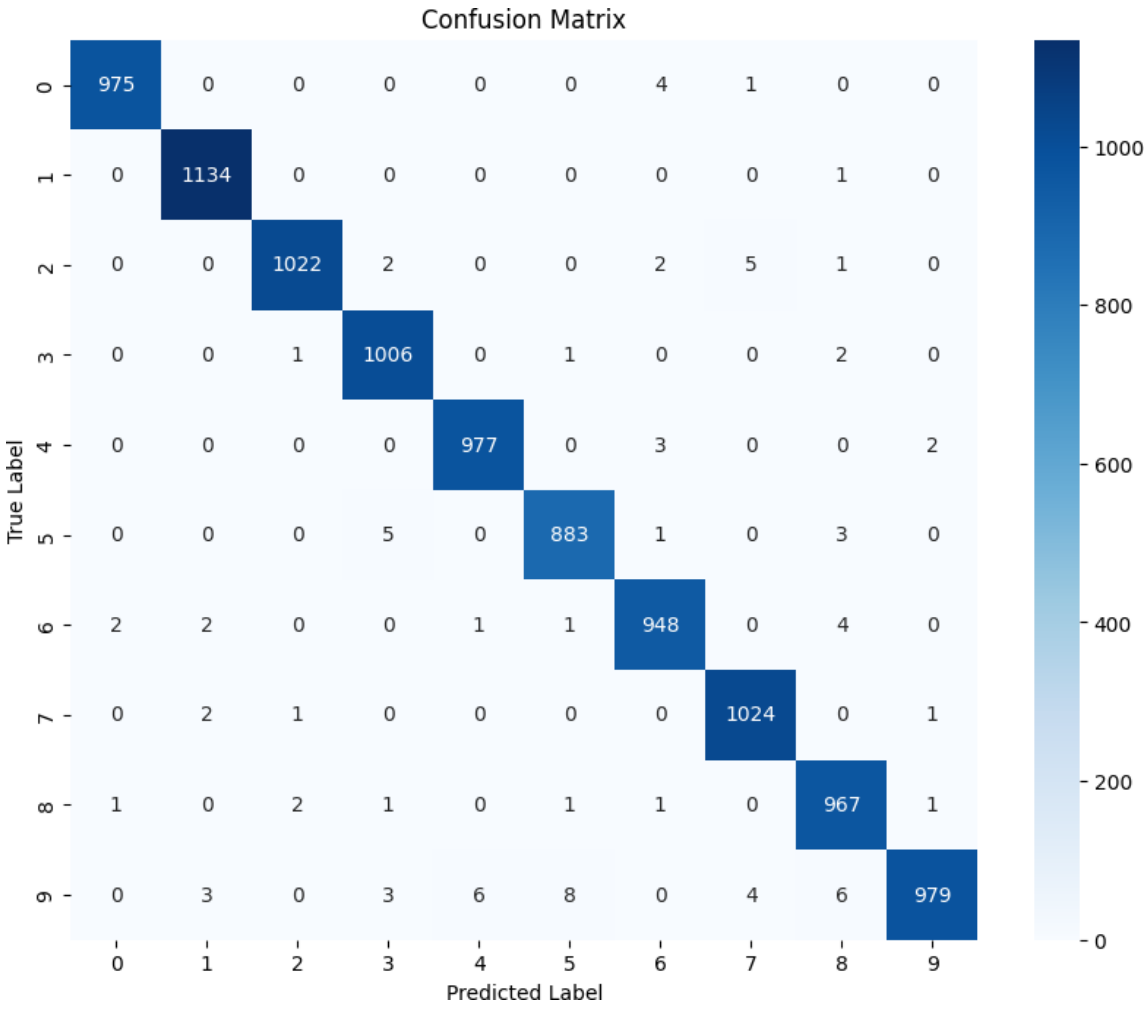
313/313 ━━━━━━━━━━━━━━━━━━━━ 3s 8ms/step
```

In [ ]:
```
# Generate confusion matrix
conf_matrix = confusion_matrix(y_true, y_pred_classes)
```

In [ ]:
```
# Plot confusion matrix
plt.figure(figsize=(10, 8))
sns.heatmap(conf_matrix, annot=True, fmt='d', cmap="Blues", xticklabels=range(10
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.title("Confusion Matrix")
plt.show()
```


Confusion Matrix
True Label
Predicted Label
0 975 0 0 0 0 0 4 1 0 0
1 0 1134 0 0 0 0 0 0 1 0
2 0 0 1022 2 0 0 2 5 1 0
3 0 0 1 1006 0 1 0 0 2 0
4 0 0 0 0 977 0 3 0 0 2
5 0 0 0 5 0 883 1 0 3 0
6 2 2 0 0 1 1 948 0 4 0
7 0 2 1 0 0 0 0 1024 0 1
8 1 0 2 1 0 1 1 0 967 1
9 0 3 0 3 6 8 0 4 6 979
0 1 2 3 4 5 6 7 8 9
1000
800
600
400
200
0