```
from google.colab import drive
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call
```

```
# Import necessary libraries
import numpy as np
import matplotlib.pyplot as plt
from sklearn.datasets import fetch_openml
from sklearn.metrics import classification_report, confusion_matrix, ConfusionMat
from sklearn.preprocessing import label_binarize, StandardScaler
from sklearn.model_selection import train_test_split
import torch
import torch.nn as nn
import torch.optim as optim
from torch.utils.data import DataLoader, TensorDataset
import os
```

```
#loading MNIST dataset and applying normalization and standardization of the data
mnist = fetch_openml('mnist_784', version=1)
X, y = mnist.data.to_numpy(), mnist.target.astype(int)

X = X / 255.0

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_s

scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/datasets/_openml.py:1022: Fut
  warn(
```

```
#MLP Model definition
class MLP(nn.Module):
    def __init__(self):
        super(MLP, self).__init__()
        self.fc1 = nn.Linear(784, 128)
        self.relu = nn.ReLU()
        self.fc2 = nn.Linear(128, 10)

    def forward(self, x):
        x = x.view(-1, 784)
        x = self.fc1(x)
        x = self.relu(x)
        x = self.fc2(x)
        return x

#Loading the saved MLP model
mlp_model = MLP()
```

```
drive_dir = '/content/drive/MyDrive/Colab Notebooks/harshith_neco'
model_filename = 'mlp_model.pth'
model_load_path = os.path.join(drive_dir, model_filename)
mlp_model.load_state_dict(torch.load(model_load_path))
```

```
<All keys matched successfully>
```

```
#Evaluating the MLP model
batch_size = 64
y_test_np = y_test.to_numpy()
test_dataset = TensorDataset(torch.tensor(X_test, dtype=torch.float32), torch.ter
test_loader = DataLoader(test_dataset, batch_size=batch_size, shuffle=False)


def evaluate_model(model, loader):
    model.eval()
    correct = 0
    total = 0
    with torch.no_grad():
        for inputs, labels in loader:
            outputs = model(inputs)
            _, predicted = torch.max(outputs, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()
    return correct / total



test_accuracy = evaluate_model(mlp_model, test_loader)
print(f"MLP Model Testing Accuracy: {test_accuracy:.4f}")
```

```
MLP Model Testing Accuracy: 0.9698
```

```
Start coding or generate with AI.
```

```
#CNN model definition
class CNN(nn.Module):
    def __init__(self):
        super(CNN, self).__init__()
        self.conv1 = nn.Conv2d(1, 32, kernel_size=3, padding=1)
        self.conv2 = nn.Conv2d(32, 64, kernel_size=3, padding=1)
        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        self.fc1 = nn.Linear(64 * 7 * 7, 128)
        self.fc2 = nn.Linear(128, 10)
        self.relu = nn.ReLU()

    def forward(self, x):
        x = self.conv1(x)
        x = self.relu(x)
        x = self.pool(x)
        x = self.conv2(x)
        x = self.relu(x)
        x = self.pool(x)
        x = x.view(-1, 64 * 7 * 7)
        x = self.fc1(x)
        x = self.relu(x)
        x = self.fc2(x)
        return x
#loading the cnn model
cnn_model = CNN()



cnn_model_filename = 'cnn_model.pth'
cnn_model_load_path = os.path.join(drive_dir, cnn_model_filename)

cnn_model.load_state_dict(torch.load(cnn_model_load_path))
```

```
<All keys matched successfully>
```

```
#evaluating the cnn model
test_dataset = TensorDataset(torch.tensor(X_test.reshape(-1, 1, 28, 28), dtype=tc
test_loader = DataLoader(test_dataset, batch_size=batch_size, shuffle=False)

test_accuracy = evaluate_model(cnn_model, test_loader)
print(f"CNN model Testing Accuracy: {test_accuracy:.4f}")
```

```
CNN model Testing Accuracy: 0.9894
```

```
from sklearn.metrics import classification_report


def print_classification_report(model, X_test, y_test, model_name):
    model.eval()
    with torch.no_grad():
        outputs = model(torch.tensor(X_test, dtype=torch.float32))
        _, predicted = torch.max(outputs, 1)
        print(f"Classification Report for {model_name} model:")
        print(classification_report(y_test, predicted.numpy()))
```

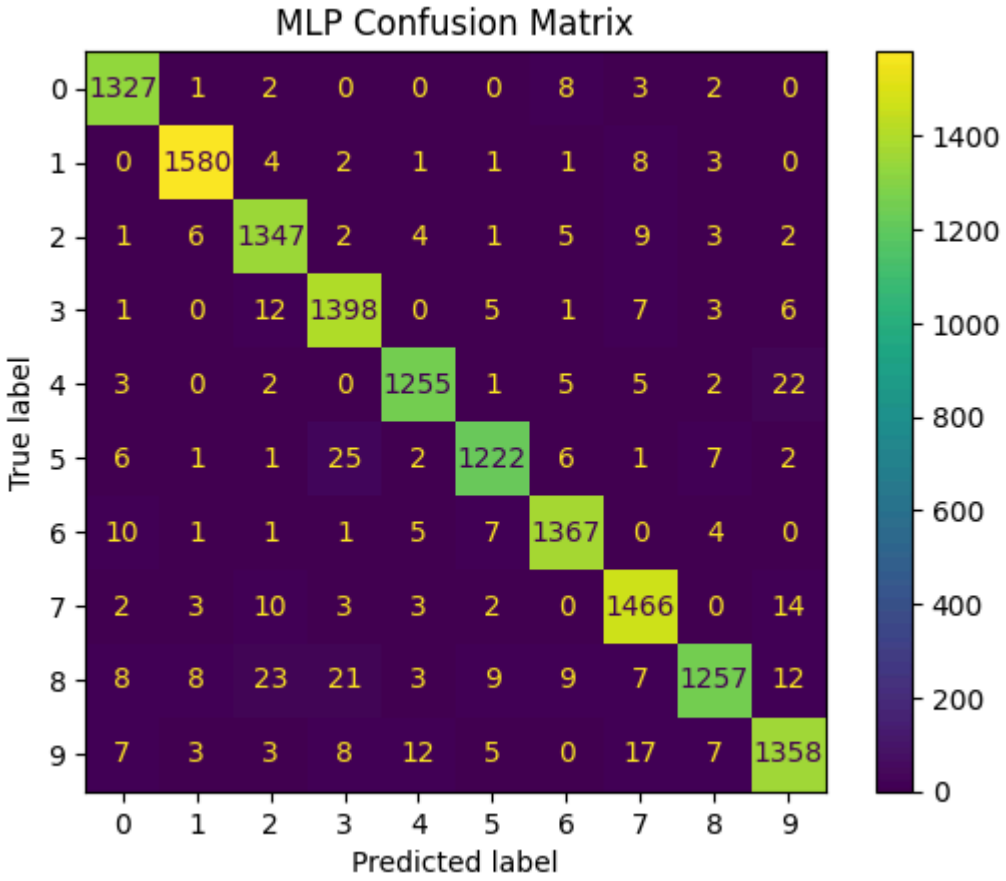
```
#classification report for MLP
print_classification_report(mlp_model, X_test, y_test_np, "MLP")

#classification report for CNN
print_classification_report(cnn_model, X_test.reshape(-1, 1, 28, 28), y_te
```

```
Classification Report for MLP model:
              precision    recall  f1-score   support

           0       0.97      0.99      0.98      1343
           1       0.99      0.99      0.99      1600
           2       0.96      0.98      0.97      1380
           3       0.96      0.98      0.97      1433
           4       0.98      0.97      0.97      1295
           5       0.98      0.96      0.97      1273
           6       0.98      0.98      0.98      1396
           7       0.96      0.98      0.97      1503
           8       0.98      0.93      0.95      1357
           9       0.96      0.96      0.96      1420

    accuracy                           0.97     14000
   macro avg       0.97      0.97      0.97     14000
weighted avg       0.97      0.97      0.97     14000

Classification Report for CNN model:
              precision    recall  f1-score   support

           0       0.99      0.99      0.99      1343
           1       0.99      1.00      0.99      1600
           2       0.99      0.99      0.99      1380
           3       0.99      0.98      0.99      1433
           4       1.00      0.98      0.99      1295
           5       0.99      0.99      0.99      1273
           6       1.00      0.99      0.99      1396
           7       0.99      0.99      0.99      1503
           8       0.98      0.98      0.98      1357
           9       0.98      0.99      0.99      1420

    accuracy                           0.99     14000
   macro avg       0.99      0.99      0.99     14000
weighted avg       0.99      0.99      0.99     14000
```

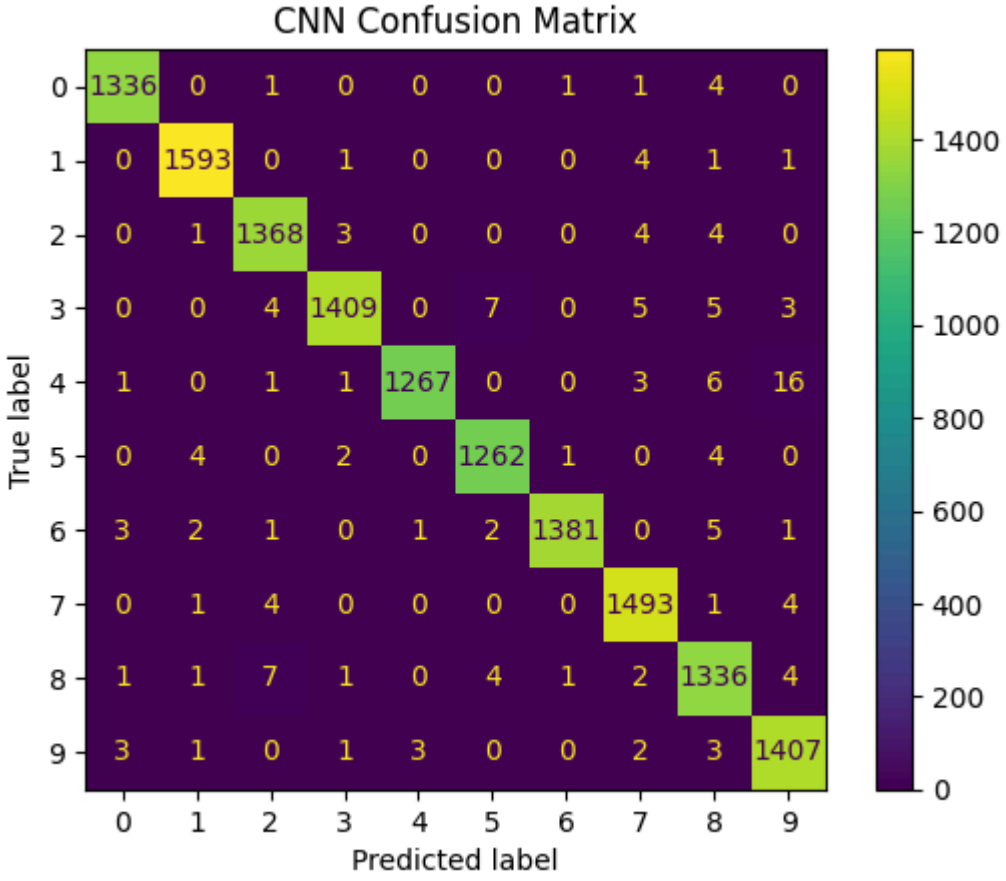
```
#confusionmatrix for MLP and CNN model
def plot_confusion_matrix(model, X_test, y_test, model_name):
    model.eval()
    with torch.no_grad():
        outputs = model(torch.tensor(X_test, dtype=torch.float32))
        _, predicted = torch.max(outputs, 1)
        cm = confusion_matrix(y_test, predicted.numpy())
        disp = ConfusionMatrixDisplay(confusion_matrix=cm)
        disp.plot()
        plt.title(f'{model_name} Confusion Matrix')
        plt.show()

# Plot confusion matrices
```

```
print("confusionmatrix for MLP model")
plot_confusion_matrix(mlp_model, X_test, y_test, 'MLP')
print("confusionmatrix for CNN model")
plot_confusion_matrix(cnn_model, X_test.reshape(-1, 1, 28, 28), y_test, 'C
```

```
confusionmatrix for MLP model
```

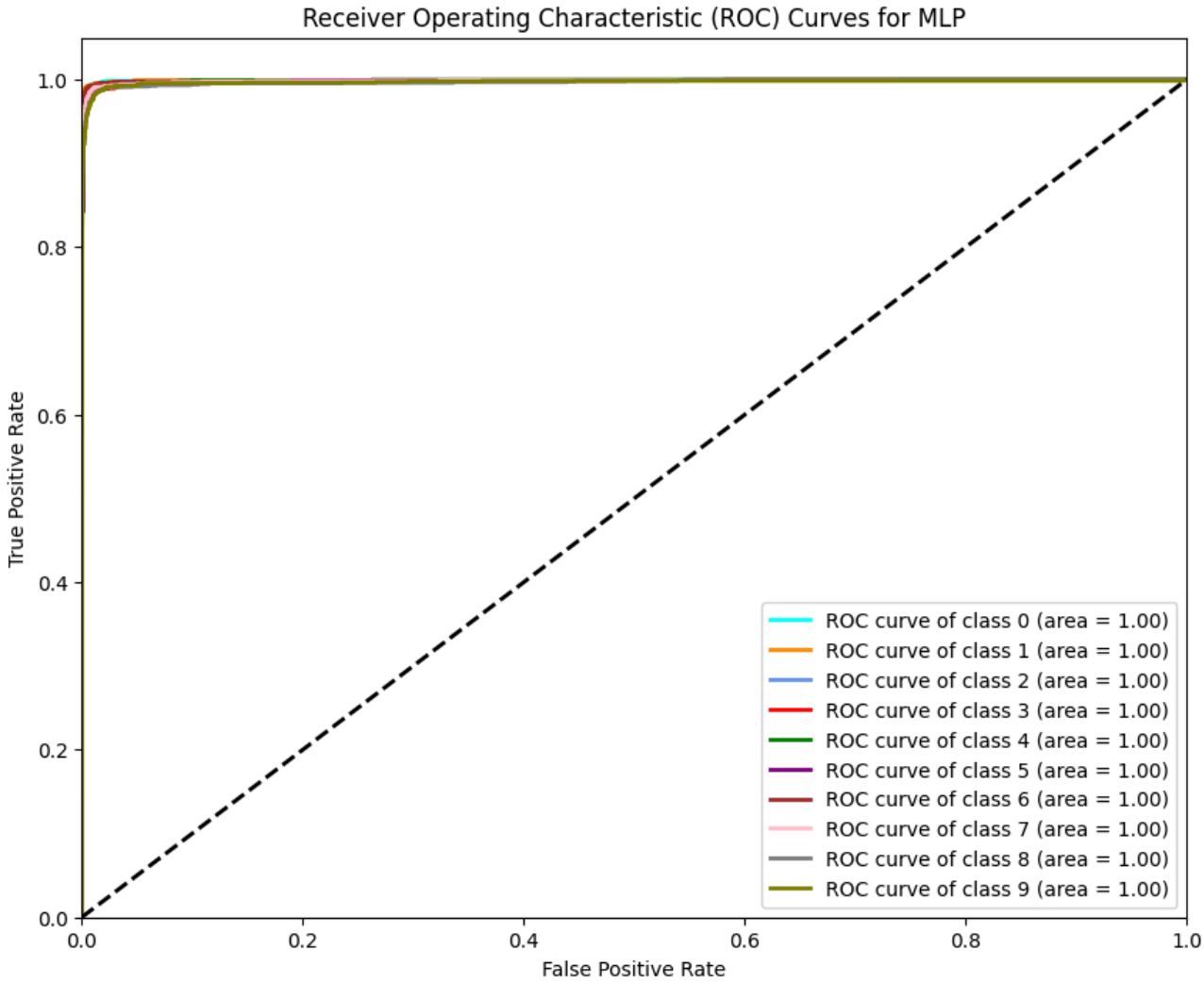



```
confusionmatrix for CNN model
```

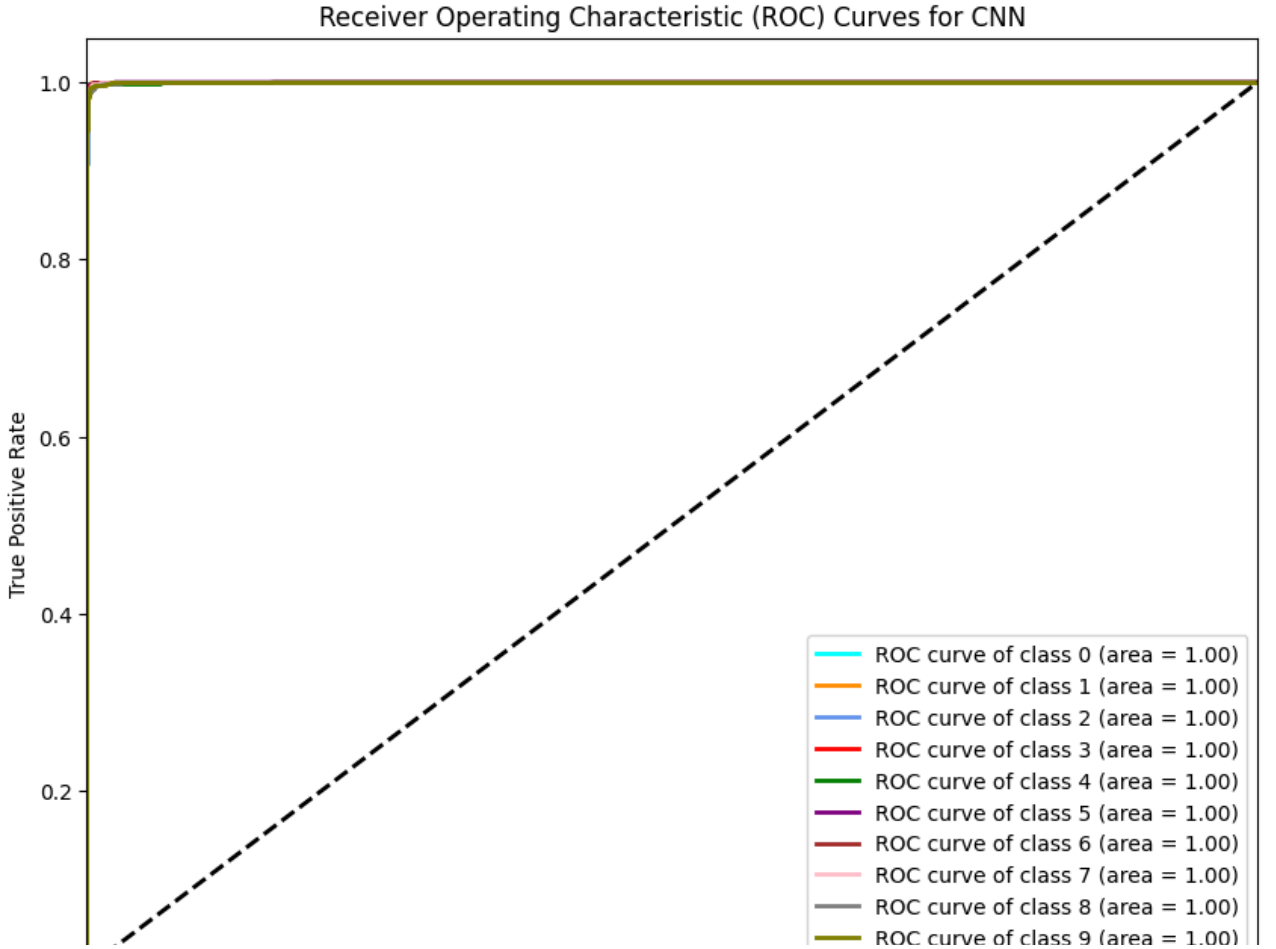


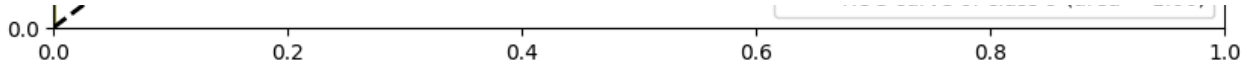
```
#ROC AUC curve for MLP and CNN models
from sklearn.metrics import roc_curve, auc, roc_auc_score
from sklearn.preprocessing import label_binarize
import matplotlib.pyplot as plt
from itertools import cycle

def plot_roc_auc(model, X_test, y_test, model_name):
    model.eval()
    with torch.no_grad():
        outputs = model(torch.tensor(X_test, dtype=torch.float32))
        probabilities = torch.softmax(outputs, dim=1).numpy()

    y_test_binarized = label_binarize(y_test, classes=np.arange(10))

    fpr = dict()
    tpr = dict()
    roc_auc = dict()
    for i in range(10):
        fpr[i], tpr[i], _ = roc_curve(y_test_binarized[:, i], probabilitie
        roc_auc[i] = auc(fpr[i], tpr[i])

    plt.figure(figsize=(10, 8))
    colors = cycle(['aqua', 'darkorange', 'cornflowerblue', 'red', 'green'
    for i, color in zip(range(10), colors):
        plt.plot(fpr[i], tpr[i], color=color, lw=2,
                 label=f'ROC curve of class {i} (area = {roc_auc[i]:0.2f})

    plt.plot([0, 1], [0, 1], 'k--', lw=2)
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title(f'Receiver Operating Characteristic (ROC) Curves for {model_
    plt.legend(loc='lower right')
    plt.show()

print("ROC AUC curve for MLP")
plot_roc_auc(mlp_model, X_test, y_test_np, "MLP")

print("ROC AUC curve for CNN")
plot_roc_auc(cnn_model, X_test.reshape(-1, 1, 28, 28), y_test_np, "CNN")
```

ROC AUC curve for MLP



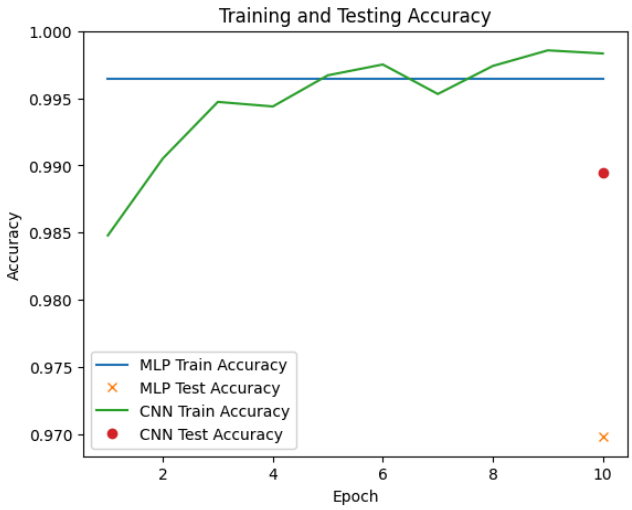
ROC AUC curve for CNN

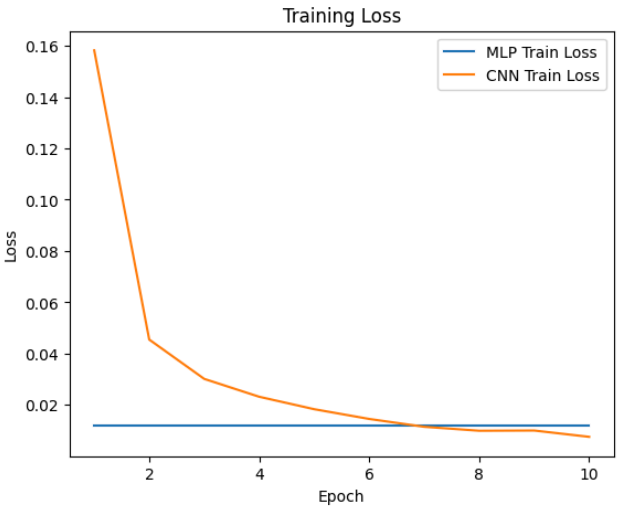




Start coding or generate with AI.

```
#Training and Test Accuracy and Loss comparison
mlp_train_losses_filename = 'mlp_train_losses.npy'
mlp_train_accuracies_filename = 'mlp_train_accuracies.npy'
cnn_train_losses_filename = 'cnn_train_losses.npy'
cnn_train_accuracies_filename = 'cnn_train_accuracies.npy'

mlp_train_losses_path = os.path.join(drive_dir, mlp_train_losses_filename)
mlp_train_accuracies_path = os.path.join(drive_dir, mlp_train_accuracies_f
cnn_train_losses_path = os.path.join(drive_dir, cnn_train_losses_filename)
cnn_train_accuracies_path = os.path.join(drive_dir, cnn_train_accuracies_f

mlp_train_losses = np.load(mlp_train_losses_path)
mlp_train_accuracies = np.load(mlp_train_accuracies_path)

cnn_train_losses = np.load(cnn_train_losses_path)
cnn_train_accuracies = np.load(cnn_train_accuracies_path)

mlp_test_accuracies = evaluate_model(mlp_model, test_loader)
cnn_test_accuracies = evaluate_model(cnn_model, test_loader)

plt.figure(figsize=(14, 5))

num_epochs = 10

plt.subplot(1, 2, 1)
plt.plot(range(1, num_epochs + 1), mlp_train_accuracies, label='MLP Train
plt.plot([num_epochs], [mlp_test_accuracies], 'x', label='MLP Test Accurac
plt.plot(range(1, num_epochs + 1), cnn_train_accuracies, label='CNN Train
plt.plot([num_epochs], [cnn_test_accuracies], 'o', label='CNN Test Accurac
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.title('Training and Testing Accuracy')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(range(1, num_epochs + 1), mlp_train_losses, label='MLP Train Loss
plt.plot(range(1, num_epochs + 1), cnn_train_losses, label='CNN Train Loss
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.title('Training Loss')
plt.legend()

plt.show()
```

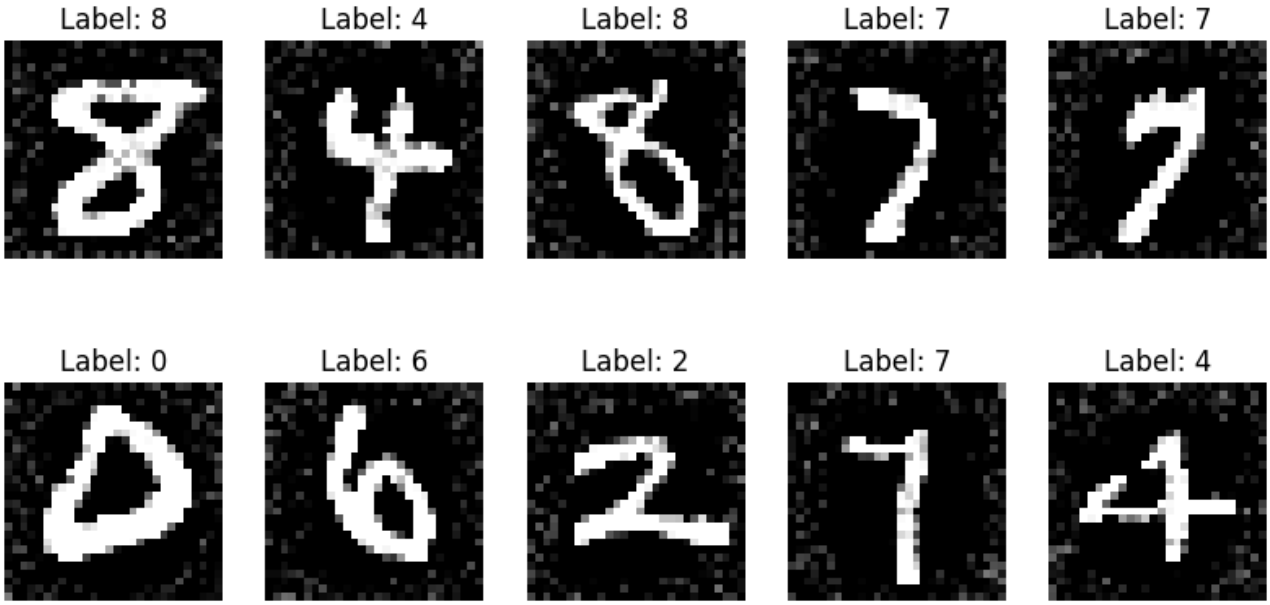




Start coding or generate with AI.

```
#Adding random noise to images and evaluating the trained models on noisy
import numpy as np

def add_noise(images, noise_factor=0.2):
    noisy_images = images + noise_factor * np.random.randn(*images.shape)
    noisy_images = np.clip(noisy_images, 0., 1.)
    return noisy_images

X_test_noisy = add_noise(X_test)
X_test_noisy_reshaped = X_test_noisy.reshape(-1, 1, 28, 28)

def evaluate_noisy_model(model, X_test_noisy, y_test, model_name):
    model.eval()
    with torch.no_grad():
        outputs = model(torch.tensor(X_test_noisy, dtype=torch.float32))
        _, predicted = torch.max(outputs, 1)
        accuracy = (predicted.numpy() == y_test).mean()
    print(f"{model_name} Accuracy on Noisy Test Images: {accuracy:.4f}")

evaluate_noisy_model(mlp_model, X_test_noisy, y_test_np, "MLP")

evaluate_noisy_model(cnn_model, X_test_noisy_reshaped, y_test_np, "CNN")

plt.figure(figsize=(10, 5))
for i in range(10):
    plt.subplot(2, 5, i + 1)
    plt.imshow(X_test_noisy[i].reshape(28, 28), cmap='gray')
    plt.title(f"Label: {y_test_np[i]}")
    plt.axis('off')
plt.show()
```

```
MLP Accuracy on Noisy Test Images: 0.9204
CNN Accuracy on Noisy Test Images: 0.8739
```

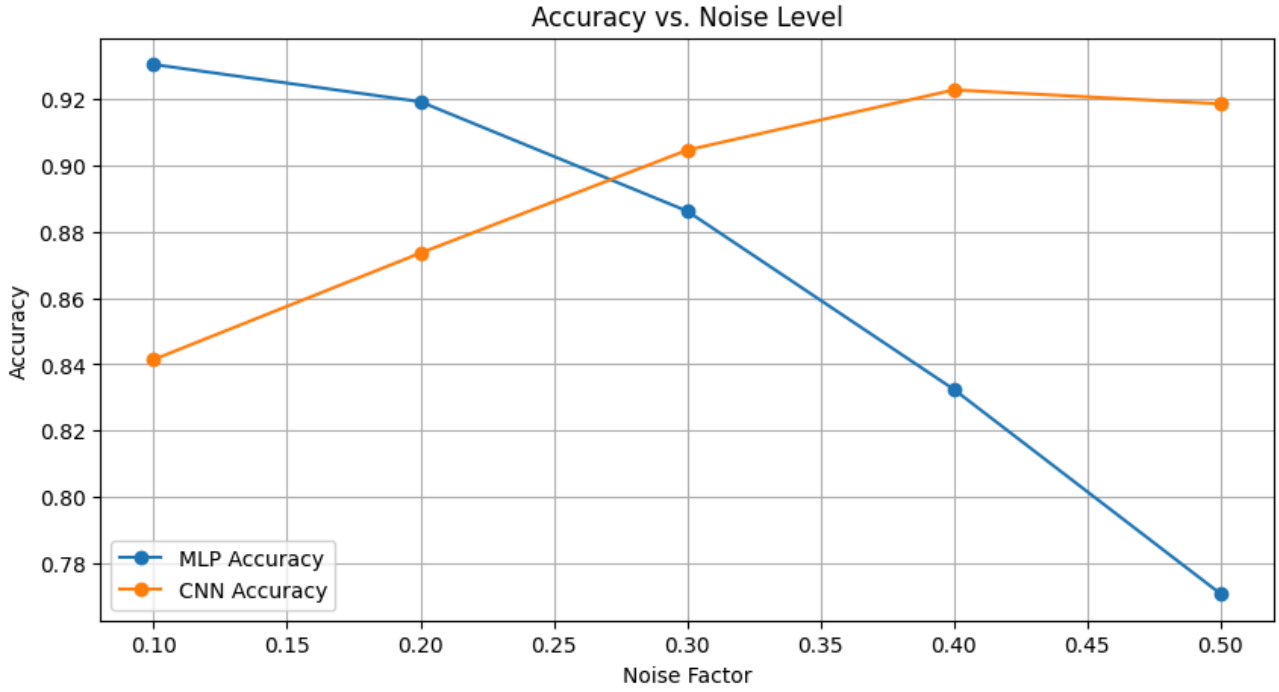


Start coding or generate with AI.

```
#adding noise to images with a specific noise factor and evaluating the tr
import torch
import matplotlib.pyplot as plt
import numpy as np

def add_noise(images, noise_factor):
    noisy_images = images + noise_factor * np.random.randn(*images.shape)
    noisy_images = np.clip(noisy_images, 0., 1.)
    return noisy_images

noise_levels = [0.1, 0.2, 0.3, 0.4, 0.5]

mlp_accuracies = []
cnn_accuracies = []

def evaluate_noisy_model(model, X_test_noisy, y_test, model_name):
    model.eval()
    with torch.no_grad():
        outputs = model(torch.tensor(X_test_noisy, dtype=torch.float32))
        _, predicted = torch.max(outputs, 1)
        accuracy = (predicted.numpy() == y_test).mean()
    print(f"{model_name} Accuracy on Noisy Test Images: {accuracy:.4f}")
    return accuracy

for noise_factor in noise_levels:
    X_test_noisy = add_noise(X_test, noise_factor)
    X_test_noisy_reshaped = X_test_noisy.reshape(-1, 1, 28, 28)

    mlp_accuracy = evaluate_noisy_model(mlp_model, X_test_noisy, y_test_np
    mlp_accuracies.append(mlp_accuracy)

    cnn_accuracy = evaluate_noisy_model(cnn_model, X_test_noisy_reshaped,
    cnn_accuracies.append(cnn_accuracy)
```

```
    cnn_accuracies.append(cnn_accuracy)

plt.figure(figsize=(10, 5))
plt.plot(noise_levels, mlp_accuracies, label='MLP Accuracy', marker='o')
plt.plot(noise_levels, cnn_accuracies, label='CNN Accuracy', marker='o')
plt.xlabel('Noise Factor')
plt.ylabel('Accuracy')
plt.title('Accuracy vs. Noise Level')
plt.legend()
plt.grid(True)
plt.show()
```

```
MLP (Noise 0.1) Accuracy on Noisy Test Images: 0.9303
CNN (Noise 0.1) Accuracy on Noisy Test Images: 0.8414
MLP (Noise 0.2) Accuracy on Noisy Test Images: 0.9191
CNN (Noise 0.2) Accuracy on Noisy Test Images: 0.8735
MLP (Noise 0.3) Accuracy on Noisy Test Images: 0.8861
CNN (Noise 0.3) Accuracy on Noisy Test Images: 0.9045
MLP (Noise 0.4) Accuracy on Noisy Test Images: 0.8324
CNN (Noise 0.4) Accuracy on Noisy Test Images: 0.9226
MLP (Noise 0.5) Accuracy on Noisy Test Images: 0.7709
CNN (Noise 0.5) Accuracy on Noisy Test Images: 0.9184
```




```
Start coding or generate with AI.
```

```
#Testing simple mlp and cnn with augmented data and noisy images
```

```
import torch
import numpy as np
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay, roc_
from sklearn.preprocessing import label_binarize
import matplotlib.pyplot as plt
import torch.nn as nn

y_train_np = y_train.to_numpy()
y_test_np = y_test.to_numpy()
```

```
def add_noise(images, noise_factor):
    noisy_images = images + noise_factor * np.random.randn(*images.shape)
    noisy_images = np.clip(noisy_images, 0., 1.)
    return noisy_images

noise_factor = 0.2

class MLP(nn.Module):
    def __init__(self):
        super(MLP, self).__init__()
        self.fc1 = nn.Linear(784, 128)
        self.relu = nn.ReLU()
        self.fc2 = nn.Linear(128, 10)

    def forward(self, x):
        x = x.view(-1, 784)
        x = self.fc1(x)
        x = self.relu(x)
        x = self.fc2(x)
        return x

class CNN(nn.Module):
    def __init__(self):
        super(CNN, self).__init__()
        self.conv1 = nn.Conv2d(1, 32, kernel_size=3, padding=1)
        self.conv2 = nn.Conv2d(32, 64, kernel_size=3, padding=1)
        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        self.fc1 = nn.Linear(64 * 7 * 7, 128)
        self.fc2 = nn.Linear(128, 10)
        self.relu = nn.ReLU()

    def forward(self, x):
        x = self.conv1(x)
        x = self.relu(x)
        x = self.pool(x)
        x = self.conv2(x)
        x = self.relu(x)
        x = self.pool(x)
        x = x.view(-1, 64 * 7 * 7)
        x = self.fc1(x)
        x = self.relu(x)
        x = self.fc2(x)
        return x

mlp_model_augmented = MLP()
cnn_model_augmented = CNN()

mlp_model_augmented_filename = 'mlp_model_augmented.pth'
cnn_model_augmented_filename = 'cnn_model_augmented.pth'

mlp_model_augmented_path = os.path.join(drive_dir, mlp_model_augmented_fil
cnn_model_augmented_path = os.path.join(drive_dir, cnn_model_augmented_fil

mlp_model_augmented.load_state_dict(torch.load(mlp_model_augmented_path))
```

```
cnn_model_augmented.load_state_dict(torch.load(cnn_model_augmented_path))

def evaluate_noisy_model(model, X_test_noisy, y_test, model_name):
    model.eval()
    with torch.no_grad():
        inputs = torch.tensor(X_test_noisy, dtype=torch.float32)
        if model_name.startswith("CNN"):
            inputs = inputs.view(-1, 1, 28, 28)  # Reshape inputs for CNN
        outputs = model(inputs)
        _, predicted = torch.max(outputs, 1)
        accuracy = (predicted.numpy() == y_test).mean()
    print(f"{model_name} Accuracy on Noisy Test Images: {accuracy:.4f}")
    return accuracy

print("Evaluating MLP trained on original train set...")
mlp_accuracy_original = evaluate_noisy_model(mlp_model_augmented, X_test,

print("Evaluating MLP trained on noisy train set...")
mlp_accuracy_noisy = evaluate_noisy_model(mlp_model_augmented, add_noise(X

print("Evaluating CNN trained on original train set...")
cnn_accuracy_original = evaluate_noisy_model(cnn_model_augmented, X_test.r

print("Evaluating CNN trained on noisy train set...")
cnn_accuracy_noisy = evaluate_noisy_model(cnn_model_augmented, add_noise(X
```

```
Evaluating MLP trained on original train set...
MLP  Accuracy on Noisy Test Images: 0.9138
Evaluating MLP trained on noisy train set...
MLP  Accuracy on Noisy Test Images: 0.9692
Evaluating CNN trained on original train set...
CNN  Accuracy on Noisy Test Images: 0.9334
Evaluating CNN trained on noisy train set...
CNN  Accuracy on Noisy Test Images: 0.9879
```

```
#Testing hyperparameter mlp and cnn with augmented data
```

```
Loader, TensorDataset
```

```
 images with a specified noise factor
r):
_factor * np.random.randn(*images.shape)
images, 0., 1.)
```

```
es with ReLU activation
```

```
=784, hidden_size=128, output_size=10):
).__init__()
t_size, hidden_size)
()
len_size, output_size)
```

```
).__init__()
 32, kernel_size=3, padding=1)
, 64, kernel_size=3, padding=1)
kernel_size=2, stride=2)
 7 * 7, 128)
 10)
()
```

```
')
```

```
in(drive_dir, 'best_mlp_params.json')
in(drive_dir, 'best_cnn_params.json')

r') as f:
)

r') as f:
)

ve_dir, 'best_mlp_model.pth')
ve_dir, 'best_cnn_model.pth')

{k: v for k, v in best_mlp_params.items() if k != 'lr'})
rch.load(mlp_model_path))
```

```
rch.load(cnn_model_path))

 and return accuracy
lel, data_loader, model_name):



a_loader:
with("CNN"):
iew(-1, 1, 28, 28)  # Reshape inputs for CNN
s)
 max(outputs, 1)
 0)
 == labels).sum().item()



l_hyperparam(best_mlp_model, DataLoader(TensorDataset(torch.tensor(X_test
mlp_test_accuracy:.4f}")

l_hyperparam(best_cnn_model, DataLoader(TensorDataset(torch.tensor(X_test
cnn_test_accuracy:.4f}")
```

```
Best MLP Test Accuracy: 0.9174
Best CNN Test Accuracy: 0.9324
```

+ Code + Text

Start coding or generate with AI.

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