```
In [ ]: from google.colab import drive
        drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/content/drive",
force_remount=True).
```

```
In [ ]: import os

        small_dataset = ['CNV', 'DME', 'DRUSEN', 'NORMAL']
        small_dataset_dir = '/content/drive/MyDrive/UofT/Third Year/Summer/APS360/APS360 Project - Group 7/Code/OC
        #small_dataset_dir = '/content/drive/MyDrive/Third Year/Summer/APS360/APS360 Project - Group 7/Code/small_
        #small_dataset_dir = '/content/drive/MyDrive/APS360 Project - Group 7/Code/small_dataset'
```

```
In [ ]: def num_images(dir, folders):
            print(f"Number of images in each folder:")
            for folder in folders:
                path = os.path.join(dir, folder)
                if os.path.isdir(path):
                    num_files = len(os.listdir(path))
                    print(f"{folder}: {num_files}")
                else:
                    print(f"Folder '{folder}' does not exist in the dataset directory.")
```

```
In [ ]: num_images(small_dataset_dir, small_dataset)
```

```
Number of images in each folder:
CNV: 50
DME: 50
DRUSEN: 50
NORMAL: 50
```

```
In [ ]: import numpy as np
        import torch

        device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
```

```
In [ ]: from torchvision import models, transforms, datasets
        from torch import nn

        resnet_model = models.resnet152(pretrained=True)
resnet_model = nn.Sequential(*list(resnet_model.children())[:-1]) # remove last classification layers
resnet_model.to(device)
resnet_model.eval()
```

In [ ]:

```
from PIL import Image
import cv2
from skimage.feature import local_binary_pattern  # for texture descriptors

def extract_texture_and_edges(image_path):
    img = cv2.imread(image_path, cv2.IMREAD_GRAYSCALE)

    # edge detection using Sobel filter, https://how.dev/answers/sobel-operator-in-digital-image-processin
    sobel_x = cv2.Sobel(img, cv2.CV_64F, 1, 0, ksize=3)  # Sobel in x-direction
    sobel_y = cv2.Sobel(img, cv2.CV_64F, 0, 1, ksize=3)  # Sobel in y-direction
    edges = np.hypot(sobel_x, sobel_y)  # combine gradients

    # https://scikit-image.org/docs/0.25.x/auto_examples/features_detection/plot_local_binary_pattern.html
    lbp = local_binary_pattern(img, P=8, R=1, method='uniform')  # texture descriptors using Uniform Local

    edges_flat = edges.flatten()
    lbp_flat = lbp.flatten()

    combined_features = np.concatenate((edges_flat, lbp_flat), axis=0) # combine all features
    return combined_features

def extract_features(image_path, model, transform):
    image = Image.open(image_path).convert('RGB') # convert to rgb because resnet works with rgb
    image = transform(image).unsqueeze(0)
    image = image.to(device)

    with torch.no_grad():
        features = model(image)  # extract features from resnet
        features = features.view(features.size(0), -1)  # flatten to vector
    return features.cpu().numpy() # convert to numpy for svm


def extract_combined_features(image_path, resnet_model, transform):
    resnet_features = extract_features(image_path, resnet_model, transform)
    texture_edge_features = extract_texture_and_edges(image_path)

    # combine features (flatten resnet + texture/edge)
    combined_features = np.concatenate((resnet_features.flatten(), texture_edge_features), axis=0)
    return combined_features
```

In [ ]:
```
data_transform = transforms.Compose([
    transforms.Resize((224, 224)),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225]) # normalization for resnet
])

dataset = datasets.ImageFolder(small_dataset_dir, transform=data_transform)
```

In [ ]:
```
features = []
labels = []

# extract features in batches to save RAM
batch_size = 16
diseases = os.listdir(small_dataset_dir)

for disease in diseases:
    disease_dir = os.path.join(small_dataset_dir, disease)

    image_paths = [os.path.join(disease_dir, img) for img in os.listdir(disease_dir)]

    for i in range(0, len(image_paths), batch_size):
        batch_paths = image_paths[i:i+batch_size]

        batch_features = []
        batch_labels = []

        for image_path in batch_paths:
            resnet_feature = extract_features(image_path, resnet_model, data_transform)
            texture_edge_feature = extract_texture_and_edges(image_path)

            combined_features = np.concatenate((resnet_feature.flatten(), texture_edge_feature), axis=0)
            batch_features.append(combined_features)
            batch_labels.append(disease)

        features.extend(batch_features)
        labels.extend(batch_labels)

        torch.cuda.empty_cache()
```

```
features = np.array(features)
labels = np.array(labels)
```

In [ ]:
```
from sklearn.svm import SVC
from sklearn.model_selection import train_test_split
from sklearn.metrics import accuracy_score, confusion_matrix, classification_report, roc_curve, auc
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.preprocessing import StandardScaler
from sklearn.decomposition import PCA
from sklearn.model_selection import train_test_split

X_train, X_test, y_train, y_test = train_test_split(features, labels, test_size=0.3, random_state=42) # sp

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

In [ ]:
```
pca = PCA(n_components=100)
X_train_pca = pca.fit_transform(X_train_scaled)
X_test_pca = pca.transform(X_test_scaled)
```

In [ ]:
```
svm_rbf = SVC(kernel='rbf', C=1, gamma='scale', class_weight='balanced') # rbf based on proposal
```

In [ ]:
```
svm_rbf.fit(X_train_pca, y_train)# train SVM
```

Out[ ]:
```
▾ SVC
SVC(C=1, class_weight='balanced')
```

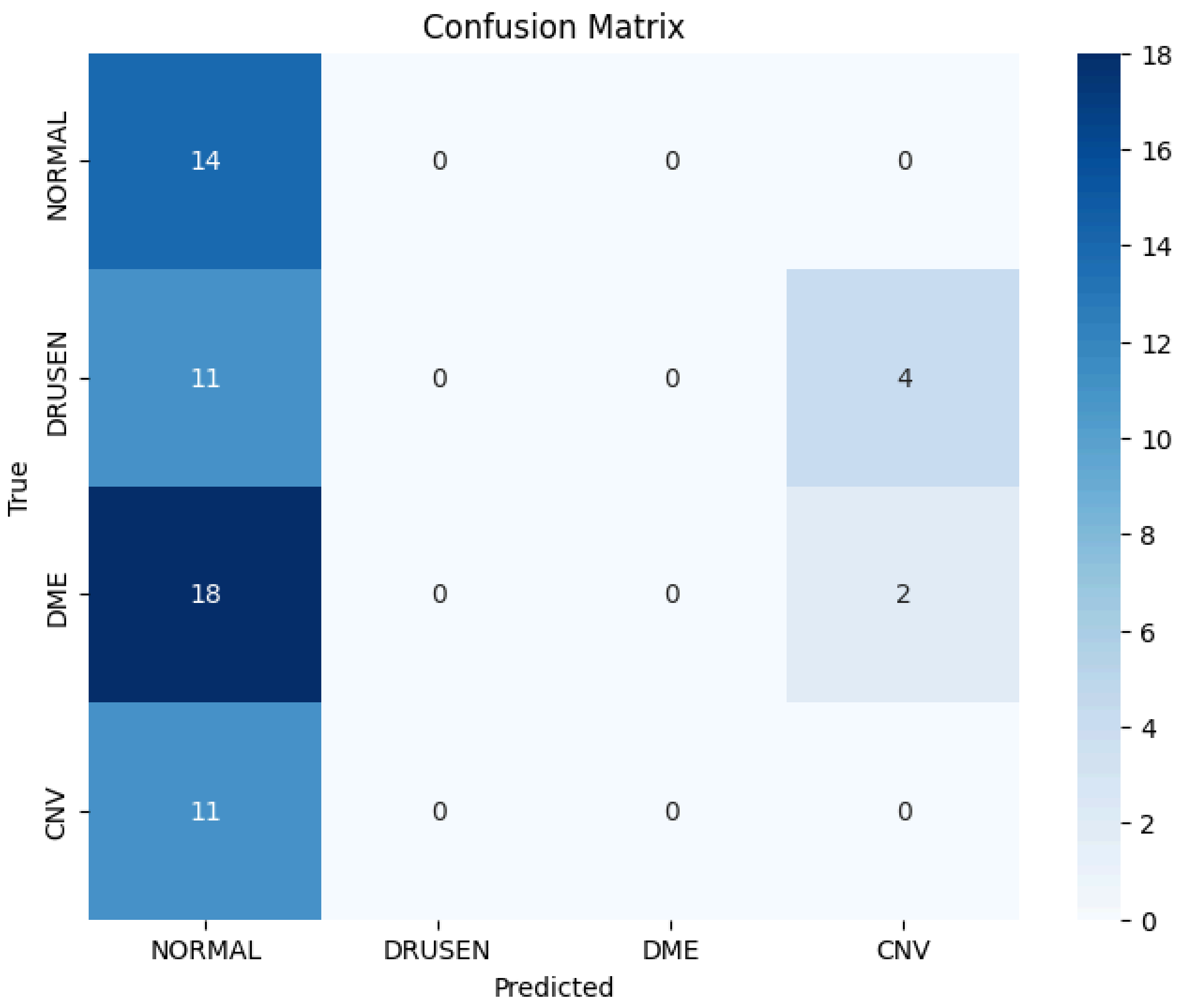
In [ ]:
```
y_pred = svm_rbf.predict(X_test_pca)
```

In [ ]:
```
# accuracy test

accuracy = accuracy_score(y_test, y_pred)
print(f"Accuracy: {accuracy:.4f}")
```

```
Accuracy: 0.2333
```

```
In [ ]: # confusion matrix test

        cm = confusion_matrix(y_test, y_pred)
        print(f"Confusion Matrix:\n{cm}")

        plt.figure(figsize=(8, 6))
        sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=diseases, yticklabels=diseases)
        plt.xlabel('Predicted')
        plt.ylabel('True')
        plt.title('Confusion Matrix')
        plt.show()
```

```
Confusion Matrix:
[[14  0  0  0]
 [11  0  0  4]
 [18  0  0  2]
 [11  0  0  0]]
```



```
In [ ]: report = classification_report(y_test, y_pred, target_names=diseases)
        print(f"Classification Report:\n{report}")
```

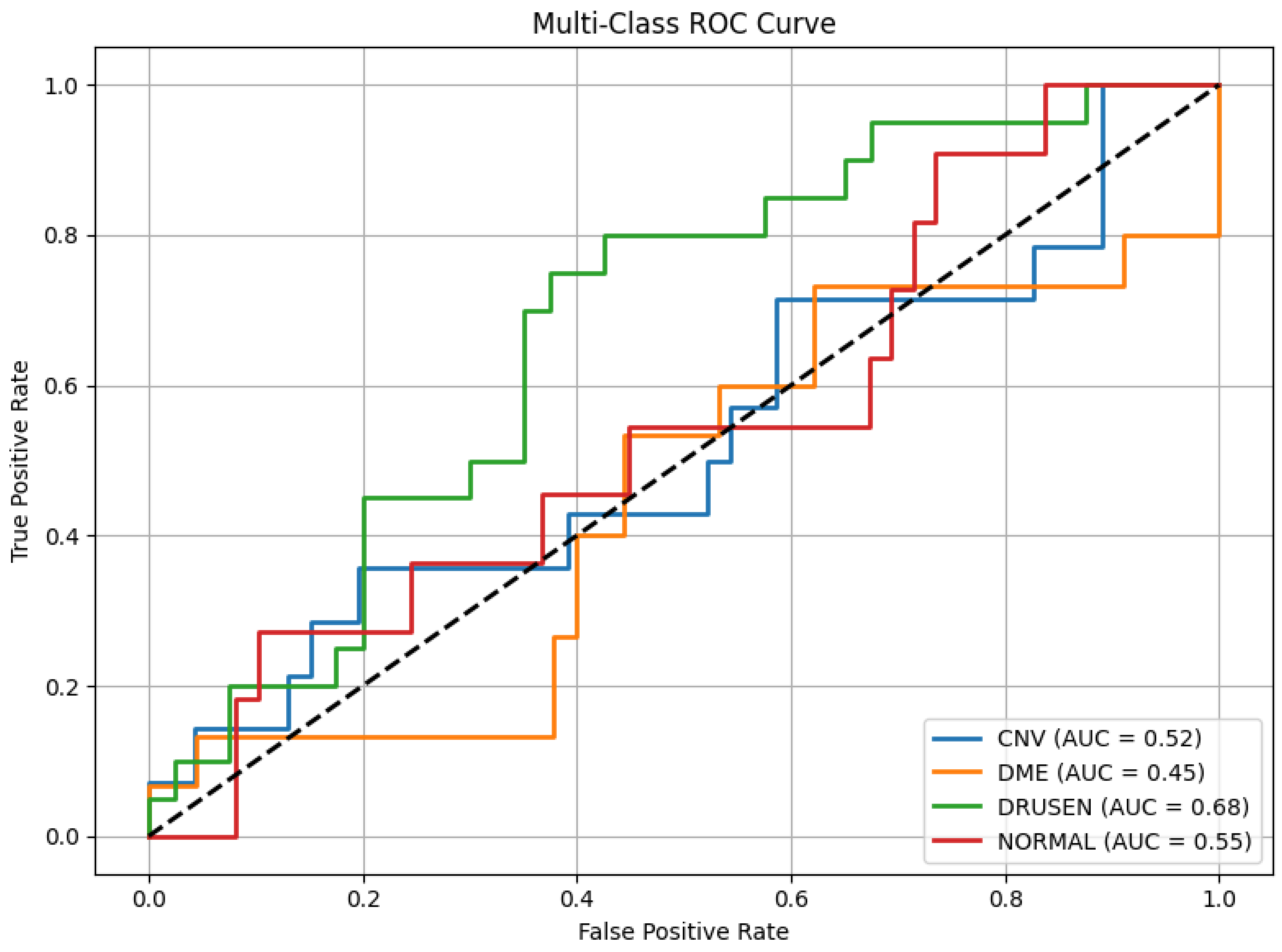
```
Classification Report:
              precision    recall  f1-score   support

      NORMAL       0.26      1.00      0.41        14
      DRUSEN       0.00      0.00      0.00        15
         DME       0.00      0.00      0.00        20
         CNV       0.00      0.00      0.00        11

    accuracy                           0.23        60
   macro avg       0.06      0.25      0.10        60
weighted avg       0.06      0.23      0.10        60
```

```
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Pr
ecision is ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parame
ter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Pr
ecision is ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parame
ter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
/usr/local/lib/python3.11/dist-packages/sklearn/metrics/_classification.py:1565: UndefinedMetricWarning: Pr
ecision is ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parame
ter to control this behavior.
  _warn_prf(average, modifier, f"{metric.capitalize()} is", len(result))
```

In [ ]:

```python
from sklearn.preprocessing import LabelBinarizer
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt
from sklearn.multiclass import OneVsRestClassifier
from sklearn.svm import SVC
from sklearn.preprocessing import StandardScaler
from sklearn.pipeline import make_pipeline


lb = LabelBinarizer()
y_test_bin = lb.fit_transform(y_test)
y_train_bin = lb.transform(y_train)

ovr_svm = OneVsRestClassifier(SVC(kernel='rbf', C=1, gamma='scale', probability=True))
ovr_svm.fit(X_train, y_train_bin)

y_score = ovr_svm.decision_function(X_test)
```

```python
n_classes = y_test_bin.shape[1]

plt.figure(figsize=(8, 6))

for i in range(n_classes):
    fpr, tpr, _ = roc_curve(y_test_bin[:, i], y_score[:, i])
    roc_auc = auc(fpr, tpr)
    plt.plot(fpr, tpr, lw=2, label=f'{lb.classes_[i]} (AUC = {roc_auc:.2f})')

plt.plot([0, 1], [0, 1], 'k--', lw=2)
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Multi-Class ROC Curve')
plt.legend(loc='lower right')
plt.grid()
plt.tight_layout()
plt.show()
```



```
In [ ]: from sklearn.preprocessing import StandardScaler
        from sklearn.decomposition import PCA
        from sklearn.pipeline import Pipeline
        from sklearn.model_selection import GridSearchCV

        pipeline = Pipeline([
    ('scaler', StandardScaler()),
    ('pca', PCA(n_components=100)),
    ('svm', SVC(kernel='rbf', class_weight='balanced'))
])

param_grid = {
    'pca__n_components': [20, 50, 100],
    'svm__C': [0.1, 1, 10],
    'svm__gamma': [0.1, 1, 10]
}

grid_search = GridSearchCV(pipeline, param_grid, cv=5, n_jobs=-1, verbose=2)
grid_search.fit(X_train, y_train)

print(f"Best params: {grid_search.best_params_}")

y_pred = grid_search.predict(X_test)
```

```
Fitting 5 folds for each of 27 candidates, totalling 135 fits
Best params: {'pca__n_components': 20, 'svm__C': 10, 'svm__gamma': 0.1}
```

In [ ]:
```
pca = PCA(n_components=20)
X_train_pca = pca.fit_transform(X_train_scaled)
X_test_pca = pca.transform(X_test_scaled)
```

In [ ]:
```
svm_rbf = SVC(kernel='rbf', C=10, gamma='scale', class_weight='balanced')  # rbf based on proposal
```

In [ ]:
```
svm_rbf.fit(X_train_pca, y_train)# train SVM
```

Out[ ]:
```
▾ SVC
SVC(C=10, class_weight='balanced')
```

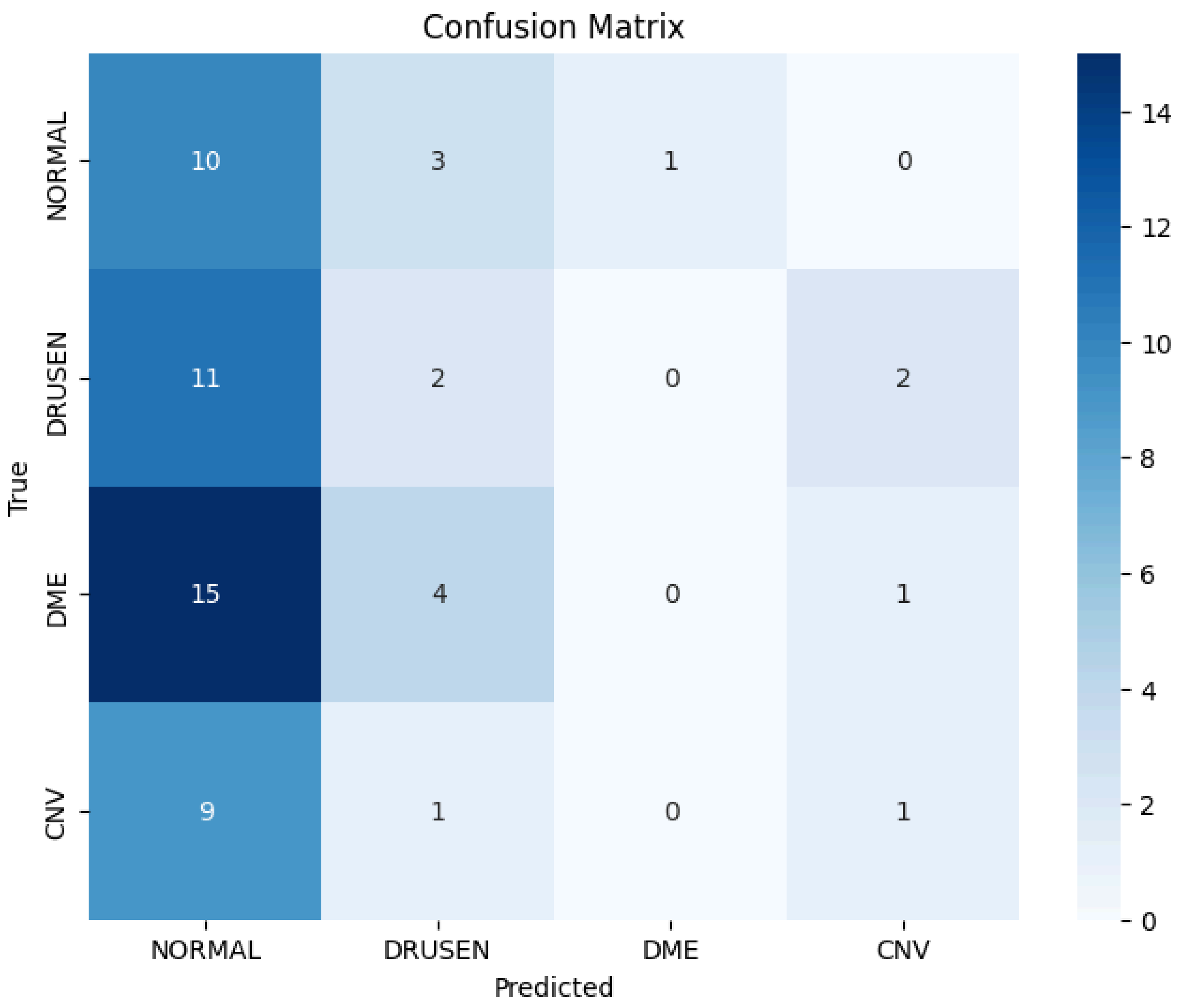
In [ ]:
```
y_pred = svm_rbf.predict(X_test_pca)
```

In [ ]:
```
# accuracy test

accuracy = accuracy_score(y_test, y_pred)
print(f"Accuracy: {accuracy:.4f}")
```

```
Accuracy: 0.2167
```

```
In [ ]: # confusion matrix test

        cm = confusion_matrix(y_test, y_pred)
        print(f"Confusion Matrix:\n{cm}")

        plt.figure(figsize=(8, 6))
        sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=diseases, yticklabels=diseases)
        plt.xlabel('Predicted')
        plt.ylabel('True')
        plt.title('Confusion Matrix')
        plt.show()
```

```
Confusion Matrix:
[[10  3  1  0]
 [11  2  0  2]
 [15  4  0  1]
 [ 9  1  0  1]]
```

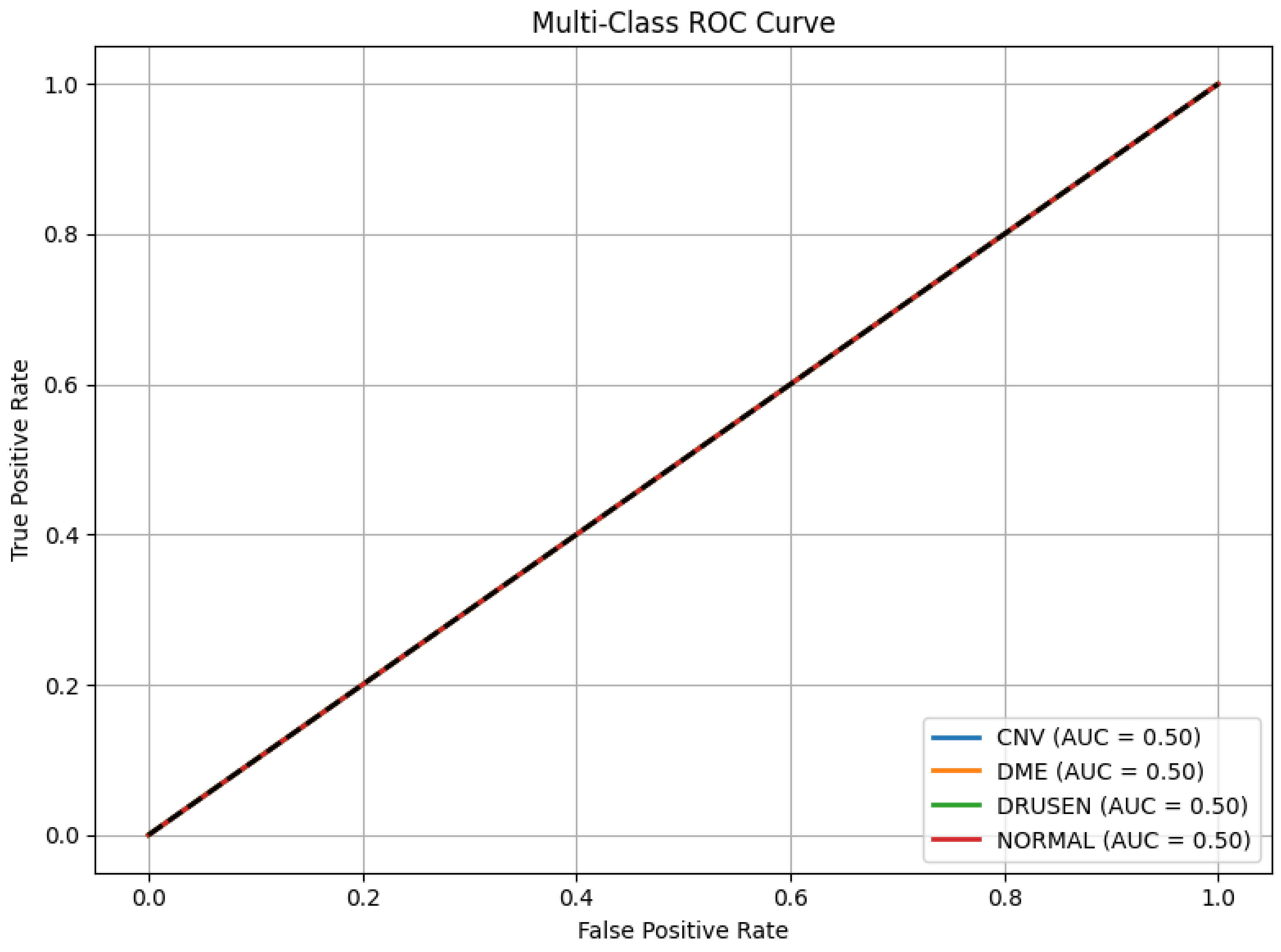


```
In [ ]: report = classification_report(y_test, y_pred, target_names=diseases)
        print(f"Classification Report:\n{report}")
```

```
Classification Report:
              precision    recall  f1-score   support

      NORMAL       0.22      0.71      0.34        14
      DRUSEN       0.20      0.13      0.16        15
         DME       0.00      0.00      0.00        20
         CNV       0.25      0.09      0.13        11

    accuracy                           0.22        60
   macro avg       0.17      0.23      0.16        60
weighted avg       0.15      0.22      0.14        60
```

In [ ]:

```python
from sklearn.preprocessing import LabelBinarizer
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt
from sklearn.multiclass import OneVsRestClassifier
from sklearn.svm import SVC
from sklearn.preprocessing import StandardScaler
from sklearn.pipeline import make_pipeline



lb = LabelBinarizer()
y_test_bin = lb.fit_transform(y_test)
y_train_bin = lb.transform(y_train)

ovr_svm = OneVsRestClassifier(SVC(kernel='rbf', C=1, gamma=0.001, probability=True))
ovr_svm.fit(X_train, y_train_bin)

y_score = ovr_svm.decision_function(X_test)

n_classes = y_test_bin.shape[1]

plt.figure(figsize=(8, 6))

for i in range(n_classes):
    fpr, tpr, _ = roc_curve(y_test_bin[:, i], y_score[:, i])
    roc_auc = auc(fpr, tpr)
    plt.plot(fpr, tpr, lw=2, label=f'{lb.classes_[i]} (AUC = {roc_auc:.2f})')

plt.plot([0, 1], [0, 1], 'k--', lw=2)
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Multi-Class ROC Curve')
plt.legend(loc='lower right')
plt.grid()
plt.tight_layout()
plt.show()
```


Multi-Class ROC Curve
True Positive Rate
False Positive Rate
CNV (AUC = 0.50)
DME (AUC = 0.50)
DRUSEN (AUC = 0.50)
NORMAL (AUC = 0.50)