

NIH Dataset

```
import os
import pandas as pd

nih_path = "/kaggle/input/data"
labels_path = os.path.join(nih_path, "Data_Entry_2017.csv")
df = pd.read_csv(labels_path)

# Number of images per folder (as per README)
folder_sizes = [4999] + [10000]*10 + [7121]
folder_names = [f"images_{i:03d}" for i in range(1, 13)]

# Compute cumulative limits
folder_ranges = []
start = 0
for folder, size in zip(folder_names, folder_sizes):
    end = start + size
    folder_ranges.append((folder, start, end))
    start = end

def get_image_path_by_index(idx, image_name):
    for folder, start, end in folder_ranges:
        if start <= idx < end:
            return os.path.join(nih_path, folder, "images",
image_name)
    return None

# Apply function
df["Image Path"] = [
    get_image_path_by_index(i, name) for i, name in
enumerate(df["Image Index"])
]

print(df.head())
print(df["Image Path"].iloc[0])
```

ID	Image Index	Finding Labels	Follow-up #	Patient
0	00000001_000.png	Cardiomegaly	0	1
1	00000001_001.png	Cardiomegaly Emphysema	1	1
2	00000001_002.png	Cardiomegaly Effusion	2	1
3	00000002_000.png	No Finding	0	2
4	00000003_000.png	Hernia	0	3

```

Patient Age Patient Gender View Position OriginalImage[Width
Height] \
0      58       M       PA           2682
2749
1      58       M       PA           2894
2729
2      58       M       PA           2500
2048
3      81       M       PA           2500
2048
4      81       F       PA           2582
2991

OriginalImagePixelSpacing[x      y] Unnamed: 11 \
0          0.143  0.143        NaN
1          0.143  0.143        NaN
2          0.168  0.168        NaN
3          0.171  0.171        NaN
4          0.143  0.143        NaN

Image Path
0 /kaggle/input/data/images_001/images/00000001_...
1 /kaggle/input/data/images_001/images/00000001_...
2 /kaggle/input/data/images_001/images/00000001_...
3 /kaggle/input/data/images_001/images/00000002_...
4 /kaggle/input/data/images_001/images/00000003_...
/kaggle/input/data/images_001/images/00000001_000.png

/usr/local/lib/python3.11/dist-packages/pandas/io/format.py:1458: RuntimeWarning: invalid value encountered in greater
    has_large_values = (abs_vals > 1e6).any()
/usr/local/lib/python3.11/dist-packages/pandas/io/format.py:14
59: RuntimeWarning: invalid value encountered in less
    has_small_values = ((abs_vals < 10 ** (-self.digits)) & (abs_vals >
0)).any()
/usr/local/lib/python3.11/dist-packages/pandas/io/format.py:14
59: RuntimeWarning: invalid value encountered in greater
    has_small_values = ((abs_vals < 10 ** (-self.digits)) & (abs_vals >
0)).any()

test_img = "00028173_002.png"
row = df[df["Image Index"] == test_img].index[0]
print(get_image_path_by_index(row, test_img))
print(row)

/kaggle/input/data/images_011/images/00028173_002.png
104998

df.iloc[104998]

```

```

Image Index
00028173_002.png
Finding Labels
No Finding
Follow-up #
2
Patient ID
28173
Patient Age
16
Patient Gender
F
View Position
AP
OriginalImage[Width
3056
Height]
2544
OriginalImagePixelSpacing[x
0.139
y]
0.139
Unnamed: 11
NaN
Image Path
/kaggle/input/data/images_011/images/00028173_...
Name: 104998, dtype: object

df.tail()

/usr/local/lib/python3.11/dist-packages/pandas/io/format/
format.py:1458: RuntimeWarning: invalid value encountered in greater
    has_large_values = (abs_vals > 1e6).any()
/usr/local/lib/python3.11/dist-packages/pandas/io/format/format.py:14
59: RuntimeWarning: invalid value encountered in less
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0)).any()
/usr/local/lib/python3.11/dist-packages/pandas/io/format/format.py:14
59: RuntimeWarning: invalid value encountered in greater
    has_small_values = ((abs_vals < 10 ** (-self.digits)) & (abs_vals >
0)).any()

      Image Index  Finding Labels  Follow-up #  Patient ID \
112115  00030801_001.png  Mass|Pneumonia           1       30801
112116  00030802_000.png  No Finding            0       30802
112117  00030803_000.png  No Finding            0       30803
112118  00030804_000.png  No Finding            0       30804
112119  00030805_000.png  No Finding            0       30805

  Patient Age  Patient Gender  View Position  OriginalImage[Width

```

```
\112115      39      M      PA      2048
112116      29      M      PA      2048
112117      42      F      PA      2048
112118      30      F      PA      2048
112119      27      M      PA      2048
```

```
Height] OriginalImagePixelSpacing[x     y] Unnamed: 11 \
112115    2500           0.168   0.168      NaN
112116    2500           0.168   0.168      NaN
112117    2500           0.168   0.168      NaN
112118    2500           0.168   0.168      NaN
112119    2500           0.171   0.171      NaN
```

```
Image Path
112115 /kaggle/input/data/images_012/images/00030801_...
112116 /kaggle/input/data/images_012/images/00030802_...
112117 /kaggle/input/data/images_012/images/00030803_...
112118 /kaggle/input/data/images_012/images/00030804_...
112119 /kaggle/input/data/images_012/images/00030805_...
```

```
import matplotlib.pyplot as plt
import cv2

img_name = "00029747_002.png"
img_path = "/kaggle/input/data/images_012/images/00029747_002.png"
row = df[df["Image Index"] == img_name].index[0]
img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)

plt.imshow(img, cmap='gray')
plt.title(df.iloc[row]["Finding Labels"])
plt.axis("off")
plt.show()
```

Effusion|Infiltration|Pneumonia



```
target_labels = ["Pneumonia", "Cardiomegaly", "Effusion", "No Finding"]

# Keep only rows with any of the 4 target findings
nih_df = df[df["Finding Labels"].str.contains("|".join(target_labels))].copy()

# --- Map to final 4-class labels ---
def map_label(x):
    if "Pneumonia" in x:
        return "Pneumonia"
    elif "Cardiomegaly" in x:
        return "Cardiomegaly"
    elif "Effusion" in x:
        return "Pleural Effusion"
    elif "No Finding" in x:
        return "Normal"
    else:
        return None

nih_df["label"] = nih_df["Finding Labels"].apply(map_label)
nih_df = nih_df.dropna(subset=["label"])

# --- Apply correct path mapping based on row index ---
nih_df["Image Path"] = [
    get_image_path_by_index(i, name) for i, name in zip(nih_df.index,
```

```

nih_df["Image Index"])
]

# Show preview
nih_df.head()

print("\nTotal samples:", len(nih_df))
print("\nSample image path:", nih_df["Image Path"].iloc[0])

nih_df.rename(columns={"Image Path": "image_path"}, inplace=True)

print("Class distribution:\n", nih_df["label"].value_counts())

```

Covid Dataset

```

import os
import pandas as pd

def load_covid_split(txt_file,
base_path="/kaggle/input/covidx-cxr2/train.txt"):
    rows = []
    with open(txt_file, "r") as f:
        for line in f.readlines():
            parts = line.strip().split()
            img_path = os.path.join(base_path, parts[1])
            label = parts[2].lower()

            if label == "positive":
                rows.append([img_path, "COVID-19"])
            elif label == "negative":
                rows.append([img_path, "Normal"])
            elif label == "pneumonia":
                rows.append([img_path, "Pneumonia"])

    return pd.DataFrame(rows, columns=["image_path", "label"])

# Use only train set
covid_train = load_covid_split("/kaggle/input/covidx-cxr2/train.txt",
base_path="/kaggle/input/covidx-cxr2/train/")

# Combine only train data (no val/test)
covid_df = covid_train.copy()

print("COVIDx class distribution:\n",
covid_df["label"].value_counts())
covid_df.head()

COVIDx class distribution:
label

```

```
COVID-19      57199
Normal       10664
Name: count, dtype: int64

          image_path    label
0  /kaggle/input/covidx-cxr2/train/1e64990d1b40c1...  Normal
1  /kaggle/input/covidx-cxr2/train/7223b8ad031187...  Normal
2  /kaggle/input/covidx-cxr2/train/3392dc7d262e28...  Normal
3  /kaggle/input/covidx-cxr2/train/ec3a480c0926de...  Normal
4  /kaggle/input/covidx-cxr2/train/a72aeb349a63c7...  Normal

print("COVIDx class distribution:\n",
covid_df["label"].value_counts())

COVIDx class distribution:
label
COVID-19      57199
Normal       10664
Name: count, dtype: int64

covid_df.tail()

          image_path    label
67858  /kaggle/input/covidx-cxr2/train/sub-S29624_ses...  Normal
67859  /kaggle/input/covidx-cxr2/train/sub-S29625_ses...  Normal
67860  /kaggle/input/covidx-cxr2/train/sub-S29626_ses...  Normal
67861  /kaggle/input/covidx-cxr2/train/sub-S29629_ses...  Normal
67862  /kaggle/input/covidx-cxr2/train/sub-S29630_ses...  Normal

covid_df['image_path'][60000]

'/kaggle/input/covidx-cxr2/train/sub-S326737_ses-E53636_run-1_bp-
chest_vp-ap_cr-corrected.png'

covid_df.iloc[60000]

image_path    /kaggle/input/covidx-cxr2/train/sub-S326737_se...
label                      COVID-19
Name: 60000, dtype: object

covid_df['image_path'][6000]

'/kaggle/input/covidx-cxr2/train/fd060e38-c89d-4bef-b9aa-
427a97a1cf9a.png'

covid_df.iloc[6000]

image_path    /kaggle/input/covidx-cxr2/train/fd060e38-c89d-...
label                      Normal
Name: 6000, dtype: object

covid_df['image_path'][600]
```

```

'/kaggle/input/covidx-cxr2/train/COVID(74).png'

covid_df.iloc[600]

image_path    /kaggle/input/covidx-cxr2/train/COVID(74).png
label          COVID-19
Name: 600, dtype: object

import matplotlib.pyplot as plt
import cv2

img_path = '/kaggle/input/covidx-cxr2/train/sub-S326737_ses-E53636_run-1_bp-chest_vp-ap_cr-corrected.png'
row = covid_df[covid_df["image_path"] == img_path].index[0]

img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)

plt.imshow(img, cmap='gray')
plt.title(covid_df.iloc[row]["label"])
plt.axis("off")
plt.show()

```

Tuberculosis Dataset

```

import glob
tb_data = []

# Montgomery TB
mont_path =
"/kaggle/input/pulmonary-chest-xray-abnormalities/Montgomery/MontgomerySet/CXR_png"
for f in glob.glob(os.path.join(mont_path, "*.png")):
    tb_data.append([f, "Tuberculosis"])

# China TB
china_path =
"/kaggle/input/pulmonary-chest-xray-abnormalities/ChinaSet_AllFiles/ChinaSet_AllFiles/CXR_png"
for f in glob.glob(os.path.join(china_path, "*.png")):
    tb_data.append([f, "Tuberculosis"])

tb_df = pd.DataFrame(tb_data, columns=["image_path", "label"])
print("Tuberculosis samples:", len(tb_df))

tb_df.head()

tb_df["image_path"][110]

import matplotlib.pyplot as plt
import cv2

```

```

img_path =
'/kaggle/input/pulmonary-chest-xray-abnormalities/Montgomery/MontgomerySet/CXR_png/MCUCXR_0068_0.png'
row = tb_df[tb_df["image_path"] == img_path].index[0]
img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)

plt.imshow(img, cmap='gray')
plt.title(tb_df.iloc[row]["label"])
plt.axis("off")
plt.show()

```

Concatenated Dataset

```

final_df = pd.concat([
    nih_df[["image_path", "label"]],
    covid_df,
    tb_df
], ignore_index=True)

print("Full dataset size:", len(final_df))
print("Class distribution:\n", final_df["label"].value_counts())

final_df.head()

import matplotlib.pyplot as plt

final_df["label"].value_counts().plot(kind="bar")
plt.title("Class Distribution (Before Balancing)")
plt.ylabel("Number of Samples")
plt.show()

```

Balanced Dataset

```

import numpy as np
from sklearn.utils import resample

balanced_dfs = []
target_size = 10000 # per class

for label, group in final_df.groupby("label"):
    if len(group) > target_size:
        # undersample
        sampled = group.sample(target_size, random_state=42)
    else:
        # oversample with replacement
        sampled = resample(group,
                           replace=True,
                           n_samples=target_size,
                           random_state=42)
    balanced_dfs.append(sampled)

```

```

balanced_dfs.append(sampled)

balanced_df = pd.concat(balanced_dfs, ignore_index=True)
print("Balanced distribution:\n", balanced_df["label"].value_counts())
balanced_df.to_csv("balanced_dataset.csv", index=False)

print("Final balanced dataset size:", len(balanced_df))
print("Class distribution:\n", balanced_df["label"].value_counts())

import pandas as pd

balanced_df =
pd.read_csv("/kaggle/input/balanced-dataset/balanced_dataset.csv")
balanced_df.head()

print(balanced_df["label"].value_counts())

```

Train-Test-Split (Balanced)

```

from sklearn.model_selection import train_test_split

# Train 70%, Validation 15%, Test 15%
train_df, temp_df = train_test_split(
    balanced_df,
    test_size=0.3,
    stratify=balanced_df["label"],
    random_state=42
)

val_df, test_df = train_test_split(
    temp_df,
    test_size=0.5,
    stratify=temp_df["label"],
    random_state=42
)

print("Train:", len(train_df))
print("Val:", len(val_df))
print("Test:", len(test_df))

train_df.to_csv("train_split.csv", index=False)
val_df.to_csv("val_split.csv", index=False)
test_df.to_csv("test_split.csv", index=False)

import pandas as pd

train_df =
pd.read_csv("/kaggle/input/balanced-dataset/train_split.csv")
val_df = pd.read_csv("/kaggle/input/balanced-dataset/val_split.csv")
test_df =

```

```

pd.read_csv("/kaggle/input/balanced-dataset/test_split.csv")

print(train_df["label"].value_counts())

label
Tuberculosis    7000
COVID-19         7000
Cardiomegaly     7000
Normal           7000
Pneumonia        7000
Pleural Effusion 7000
Name: count, dtype: int64

```

ResNet-50 Model Training

```

import torch
import torch.nn as nn
import torch.optim as optim
from torch.utils.data import DataLoader, Dataset
from torchvision import models, transforms
from PIL import Image
from sklearn.metrics import roc_auc_score
import numpy as np
import torch.nn.functional as F

train_transform = transforms.Compose([
    transforms.Resize((224, 224)),
    transforms.RandomHorizontalFlip(p=0.5),
    transforms.RandomRotation(10), # ±10° max
    transforms.ColorJitter(brightness=0.1, contrast=0.1),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.485, 0.456, 0.406],
                        std=[0.229, 0.224, 0.225])
])

val_test_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])
])

class XRayDataset(Dataset):
    def __init__(self, df, transform=None):
        self.df = df.reset_index(drop=True)
        self.transform = transform
        self.classes = sorted(df["label"].unique())
        self.class_to_idx = {c: i for i, c in enumerate(self.classes)}

```

```

def __len__(self):
    return len(self.df)

def __getitem__(self, idx):
    img_path = self.df.loc[idx, "image_path"]
    label = self.df.loc[idx, "label"]

    img = Image.open(img_path).convert("RGB")
    if self.transform:
        img = self.transform(img)

    return img, self.class_to_idx[label]

batch_size = 32
train_dataset = XRayDataset(train_df, transform=train_transform)
val_dataset = XRayDataset(val_df, transform=val_test_transform)
test_dataset = XRayDataset(test_df, transform=val_test_transform)

train_loader = DataLoader(train_dataset, batch_size=batch_size,
                           shuffle=True, num_workers=2)
val_loader = DataLoader(val_dataset, batch_size=batch_size,
                           shuffle=False, num_workers=2)
test_loader = DataLoader(test_dataset, batch_size=batch_size,
                           shuffle=False, num_workers=2)

print(train_dataset.class_to_idx)

{'COVID-19': 0, 'Cardiomegaly': 1, 'Normal': 2, 'Pleural Effusion': 3,
 'Pneumonia': 4, 'Tuberculosis': 5}

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

model = models.resnet50(pretrained=True)
num_features = model.fc.in_features
# add dropout for regularization
model.fc = nn.Sequential(
    nn.Dropout(0.3),
    nn.Linear(num_features, 6)
)
model = model.to(device)

criterion = nn.CrossEntropyLoss(label_smoothing=0.05) # label
smooth
optimizer = optim.AdamW(model.parameters(), lr=1e-4, weight_decay=1e-
4)

class EarlyStopping:
    def __init__(self, patience=5, mode="max"):
        self.patience = patience
        self.mode = mode

```

```

    self.best = None
    self.counter = 0

    def step(self, metric):
        if self.best is None:
            self.best = metric
            return False
        if (self.mode == "max" and metric > self.best) or (self.mode
== "min" and metric < self.best):
            self.best = metric
            self.counter = 0
            return False
        else:
            self.counter += 1
            if self.counter >= self.patience:
                return True
            return False

    def train_one_epoch(model, loader, optimizer, criterion, device):
        model.train()
        running_loss, correct, total = 0.0, 0, 0

        for imgs, labels in loader:
            imgs, labels = imgs.to(device), labels.to(device)

            optimizer.zero_grad()
            outputs = model(imgs)
            loss = criterion(outputs, labels)
            loss.backward()
            optimizer.step()

            running_loss += loss.item() * imgs.size(0)
            _, preds = torch.max(outputs, 1)
            correct += (preds == labels).sum().item()
            total += labels.size(0)

        return running_loss / total, correct / total

    def evaluate(model, loader, criterion, device):
        model.eval()
        running_loss, correct, total = 0.0, 0, 0

        with torch.no_grad():
            for imgs, labels in loader:
                imgs, labels = imgs.to(device), labels.to(device)
                outputs = model(imgs)
                loss = criterion(outputs, labels)

                running_loss += loss.item() * imgs.size(0)
                _, preds = torch.max(outputs, 1)

```

```

        correct += (preds == labels).sum().item()
        total += labels.size(0)

    return running_loss / total, correct / total

def compute_macro_auc(model, loader, device, n_classes=6):
    model.eval()
    probs_list, labels_list = [], []
    with torch.no_grad():
        for imgs, labels in loader:
            imgs = imgs.to(device)
            outputs = model(imgs)
            probs = F.softmax(outputs, dim=1).cpu().numpy()
            probs_list.append(probs)
            labels_list.append(labels.numpy())
    probs_all = np.concatenate(probs_list, axis=0)
    labels_all = np.concatenate(labels_list, axis=0)
    labels_onehot = np.eye(n_classes)[labels_all]
    aucs = []
    for i in range(n_classes):
        try:
            auc = roc_auc_score(labels_onehot[:, i], probs_all[:, i])
            aucs.append(auc)
        except ValueError:
            pass
    return np.mean(aucs) if aucs else 0.0

epochs = 20
best_val_auc = 0.0
early_stopper = EarlyStopping(patience=5, mode="max")

for epoch in range(epochs):
    train_loss, train_acc = train_one_epoch(model, train_loader,
optimizer, criterion, device)
    val_loss, val_acc = evaluate(model, val_loader, criterion, device)
    val_auc = compute_macro_auc(model, val_loader, device,
n_classes=6)

    print(f"Epoch {epoch+1}/{epochs}")
    print(f" Train Loss: {train_loss:.4f}, Train Acc: {train_acc:.4f}")
    print(f" Val Loss: {val_loss:.4f}, Val Acc: {val_acc:.4f}, Val AUC: {val_auc:.4f}")

    # Save best model
    if val_auc > best_val_auc:
        best_val_auc = val_auc
        torch.save(model.state_dict(), "best_resnet50.pth")

# Early stopping

```

```

if early_stopper.step(val_auc):
    print("Early stopping triggered.")
    break

model.load_state_dict(torch.load("best_resnet50.pth"))
test_loss, test_acc = evaluate(model, test_loader, criterion, device)
test_auc = compute_macro_auc(model, test_loader, device, n_classes=6)
print(f"Test Loss: {test_loss:.4f}, Test Acc: {test_acc:.4f}, Test AUC: {test_auc:.4f}")

```

Saving model weights to local machine

```

import shutil

# Copy file to /kaggle/working (the only place you can download from)
shutil.copy("best_resnet50.pth", "/kaggle/working/")

```

Setting up trained ResNet-50 model and evaluating on Test Set

```

import torch
import torch.nn as nn
from torch.utils.data import DataLoader, Dataset
from torchvision import models, transforms
from PIL import Image
import pandas as pd
from sklearn.metrics import accuracy_score, classification_report

import torch
import torch.nn as nn
from torchvision import models, transforms
from PIL import Image

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

n_classes = 6 # number of output classes

# Recreate model exactly as during training
model = models.resnet50(weights=None)
in_features = model.fc.in_features
model.fc = nn.Sequential(
    nn.Dropout(0.3),
    nn.Linear(in_features, n_classes)
)

# Load weights
state_dict =
torch.load("/kaggle/input/resnet-50-v1-weights/best_resnet50.pth",
map_location=device)

```

```

model.load_state_dict(state_dict)
model.to(device)
model.eval()

print("Model loaded successfully and ready for inference!")
Model loaded successfully and ready for inference!

# Define the same transform as used during training
transform = transforms.Compose([
    transforms.Resize((224, 224)),
    transforms.ToTensor(),
    transforms.Normalize([0.485, 0.456, 0.406],
                      [0.229, 0.224, 0.225])
])

# Load one test image
img_path = "/kaggle/input/covidx-cxr2/train/sub-S326737_ses-E53636_run-1_bp-chest_vp-ap_cr-corrected.png" # change path
image = Image.open(img_path).convert("RGB")
input_tensor = transform(image).unsqueeze(0).to(device)

# Predict
with torch.no_grad():
    outputs = model(input_tensor)
    probs = torch.softmax(outputs, dim=1)
    pred_class = torch.argmax(probs, dim=1).item()

print(f"Predicted class index: {pred_class}")

Predicted class index: 0

# 2 Correct class order (alphabetical)
# -----
class_names = [
    'COVID-19',
    'Cardiomegaly',
    'Normal',
    'Pleural Effusion',
    'Pneumonia',
    'Tuberculosis'
]

# -----
# 3 Image preprocessing
# -----
transform = transforms.Compose([
    transforms.Resize((224, 224)), # same as training input size
    transforms.ToTensor(),
    transforms.Normalize([0.485, 0.456, 0.406],
                      [0.229, 0.224, 0.225])
]

```

```

])

# Replace with your actual test image path
img_path =
"/kaggle/input/pulmonary-chest-xray-abnormalities/Montgomery/MontgomerySet/CXR_png/MCUCXR_0068_0.png"
image = Image.open(img_path).convert("RGB")
input_tensor = transform(image).unsqueeze(0).to(device)

# -----
# 4 Prediction
# -----
with torch.no_grad():
    outputs = model(input_tensor)
    probs = torch.softmax(outputs, dim=1).cpu().numpy()[0]
    pred_idx = probs.argmax()
    pred_label = class_names[pred_idx]

print(f" Predicted Disease: {pred_label}\n")

print("Class Probabilities:")
for name, p in zip(class_names, probs):
    print(f" {name:18s}: {p:.4f}")

Predicted Disease: Tuberculosis

Class Probabilities:
COVID-19          : 0.0081
Cardiomegaly      : 0.0030
Normal           : 0.0050
Pleural Effusion : 0.0035
Pneumonia         : 0.0059
Tuberculosis     : 0.9745

# 5 Evaluate on test set
# -----
criterion = nn.CrossEntropyLoss()
all_preds, all_labels = [], []
test_loss = 0.0

with torch.no_grad():
    for imgs, labels in test_loader:
        imgs, labels = imgs.to(device), labels.to(device)
        outputs = model(imgs)
        loss = criterion(outputs, labels)
        test_loss += loss.item() * imgs.size(0)
        preds = outputs.argmax(1)
        all_preds.extend(preds.cpu().numpy())
        all_labels.extend(labels.cpu().numpy())

```

```

test_loss /= len(test_dataset)
test_acc = accuracy_score(all_labels, all_preds)

print(f"\n Test Loss: {test_loss:.4f}")
print(f"\n Test Accuracy: {test_acc * 100:.2f}%")

# -----
❷ 6 Detailed per-class report
# -----
print("\nClassification Report:")
print(classification_report(all_labels, all_preds,
target_names=test_dataset.classes))

Classification Report:
      precision    recall  f1-score   support

COVID-19           0.98     0.98     0.98      1500
Cardiomegaly       0.90     0.92     0.91      1500
Normal            0.78     0.71     0.75      1500
Pleural Effusion   0.80     0.75     0.77      1500
Pneumonia          0.86     0.98     0.91      1500
Tuberculosis       1.00     1.00     1.00      1500

accuracy           0.89      —       0.89      9000
macro avg          0.89     0.89     0.89      9000
weighted avg        0.89     0.89     0.89      9000

```

DenseNet Model Training

```

import torch
import torch.nn as nn
import torch.optim as optim
from torch.utils.data import DataLoader, Dataset
from torchvision import models, transforms
from PIL import Image
from sklearn.metrics import roc_auc_score, accuracy_score,
classification_report
import numpy as np
import pandas as pd
import torch.nn.functional as F

# Load Dataset
train_df =
pd.read_csv("/kaggle/input/balanced-dataset/train_split.csv")
val_df   = pd.read_csv("/kaggle/input/balanced-dataset/val_split.csv")

```

```

test_df =
pd.read_csv("/kaggle/input/balanced-dataset/test_split.csv")

print("Train samples:", len(train_df))
print("Val samples:", len(val_df))
print("Test samples:", len(test_df))
print("\nClass distribution:")
print(train_df["label"].value_counts())

Train samples: 42000
Val samples: 9000
Test samples: 9000

Class distribution:
label
Tuberculosis    7000
COVID-19         7000
Cardiomegaly     7000
Normal           7000
Pneumonia         7000
Pleural Effusion 7000
Name: count, dtype: int64

train_transform = transforms.Compose([
    transforms.Resize((224, 224)),
    transforms.RandomHorizontalFlip(p=0.5),
    transforms.RandomRotation(10),
    transforms.ColorJitter(brightness=0.1, contrast=0.1),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.485, 0.456, 0.406],
                        std=[0.229, 0.224, 0.225])
])

val_test_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])
])

class XRayDataset(Dataset):
    def __init__(self, df, transform=None):
        self.df = df.reset_index(drop=True)
        self.transform = transform
        self.classes = sorted(df["label"].unique())
        self.class_to_idx = {c: i for i, c in enumerate(self.classes)}

    def __len__(self):
        return len(self.df)

```

```

def __getitem__(self, idx):
    img_path = self.df.loc[idx, "image_path"]
    label = self.df.loc[idx, "label"]

    img = Image.open(img_path).convert("RGB")
    if self.transform:
        img = self.transform(img)

    return img, self.class_to_idx[label]

batch_size = 32
train_dataset = XRayDataset(train_df, transform=train_transform)
val_dataset = XRayDataset(val_df, transform=val_test_transform)
test_dataset = XRayDataset(test_df, transform=val_test_transform)

train_loader = DataLoader(train_dataset, batch_size=batch_size,
shuffle=True, num_workers=2)
val_loader = DataLoader(val_dataset, batch_size=batch_size,
shuffle=False, num_workers=2)
test_loader = DataLoader(test_dataset, batch_size=batch_size,
shuffle=False, num_workers=2)

print("\nClass to Index mapping:", train_dataset.class_to_idx)

Class to Index mapping: {'COVID-19': 0, 'Cardiomegaly': 1, 'Normal': 2, 'Pleural Effusion': 3, 'Pneumonia': 4, 'Tuberculosis': 5}

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print(f"\nUsing device: {device}")

# Load pretrained DenseNet-121
model = models.densenet121(pretrained=True)

# Modify classifier for 6 classes
num_features = model.classifier.in_features
model.classifier = nn.Sequential(
    nn.Dropout(0.3),
    nn.Linear(num_features, 6)
)
model = model.to(device)

# Loss and optimizer
criterion = nn.CrossEntropyLoss(label_smoothing=0.05)
optimizer = optim.AdamW(model.parameters(), lr=1e-4, weight_decay=1e-4)

print(f"\nDenseNet-121 model initialized with {num_features} input features")

```

```

Using device: cpu

/usr/local/lib/python3.11/dist-packages/torchvision/models/
_utils.py:208: UserWarning: The parameter 'pretrained' is deprecated
since 0.13 and may be removed in the future, please use 'weights'
instead.
    warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:2
3: UserWarning: Arguments other than a weight enum or `None` for
'weights' are deprecated since 0.13 and may be removed in the future.
The current behavior is equivalent to passing
`weights=DenseNet121_Weights.IMAGENET1K_V1`. You can also use
`weights=DenseNet121_Weights.DEFAULT` to get the most up-to-date
weights.
    warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/densenet121-
a639ec97.pth" to /root/.cache/torch/hub/checkpoints/densenet121-
a639ec97.pth
100%|██████████| 30.8M/30.8M [00:00<00:00, 50.2MB/s]

```

□ DenseNet-121 model initialized with 1024 input features

```

class EarlyStopping:
    def __init__(self, patience=5, mode="max"):
        self.patience = patience
        self.mode = mode
        self.best = None
        self.counter = 0

    def step(self, metric):
        if self.best is None:
            self.best = metric
            return False
        if (self.mode == "max" and metric > self.best) or (self.mode
== "min" and metric < self.best):
            self.best = metric
            self.counter = 0
            return False
        else:
            self.counter += 1
            if self.counter >= self.patience:
                return True
            return False

def train_one_epoch(model, loader, optimizer, criterion, device):
    model.train()
    running_loss, correct, total = 0.0, 0, 0

    for imgs, labels in loader:

```

```

        imgs, labels = imgs.to(device), labels.to(device)

        optimizer.zero_grad()
        outputs = model(imgs)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()

        running_loss += loss.item() * imgs.size(0)
        _, preds = torch.max(outputs, 1)
        correct += (preds == labels).sum().item()
        total += labels.size(0)

    return running_loss / total, correct / total

def evaluate(model, loader, criterion, device):
    model.eval()
    running_loss, correct, total = 0.0, 0, 0

    with torch.no_grad():
        for imgs, labels in loader:
            imgs, labels = imgs.to(device), labels.to(device)
            outputs = model(imgs)
            loss = criterion(outputs, labels)

            running_loss += loss.item() * imgs.size(0)
            _, preds = torch.max(outputs, 1)
            correct += (preds == labels).sum().item()
            total += labels.size(0)

    return running_loss / total, correct / total

def compute_macro_auc(model, loader, device, n_classes=6):
    model.eval()
    probs_list, labels_list = [], []
    with torch.no_grad():
        for imgs, labels in loader:
            imgs = imgs.to(device)
            outputs = model(imgs)
            probs = F.softmax(outputs, dim=1).cpu().numpy()
            probs_list.append(probs)
            labels_list.append(labels.numpy())
    probs_all = np.concatenate(probs_list, axis=0)
    labels_all = np.concatenate(labels_list, axis=0)
    labels_onehot = np.eye(n_classes)[labels_all]
    aucs = []
    for i in range(n_classes):
        try:
            auc = roc_auc_score(labels_onehot[:, i], probs_all[:, i])
            aucs.append(auc)

```

```

        except ValueError:
            pass
    return np.mean(aucs) if aucs else 0.0

epochs = 20
best_val_auc = 0.0
early_stopper = EarlyStopping(patience=5, mode="max")

print("\n" + "*60)
print("Starting DenseNet-121 Training")
print("*60)

for epoch in range(epochs):
    train_loss, train_acc = train_one_epoch(model, train_loader,
optimizer, criterion, device)
    val_loss, val_acc = evaluate(model, val_loader, criterion, device)
    val_auc = compute_macro_auc(model, val_loader, device,
n_classes=6)

    print(f"\nEpoch {epoch+1}/{epochs}")
    print(f" Train Loss: {train_loss:.4f}, Train Acc:
{train_acc:.4f}")
    print(f" Val Loss: {val_loss:.4f}, Val Acc: {val_acc:.4f}, Val
AUC: {val_auc:.4f}")

# Save best model
if val_auc > best_val_auc:
    best_val_auc = val_auc
    torch.save(model.state_dict(), "best_densenet121.pth")
    print(f" □ Best model saved! (Val AUC: {val_auc:.4f})")

# Early stopping
if early_stopper.step(val_auc):
    print("\n⚠ Early stopping triggered.")
    break

```

```
=====
Starting DenseNet-121 Training
=====
```

```

import torch
import torch.nn as nn
import torch.optim as optim
import torchvision.models as models
from sklearn.metrics import classification_report

# =====
# Device setup
# =====
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")

```

```

print(f"\nUsing device: {device}")

# =====
# Model definition (must match training setup)
# =====
model = models.densenet121(pretrained=True)

num_features = model.classifier.in_features
model.classifier = nn.Sequential(
    nn.Dropout(0.3),
    nn.Linear(num_features, 6)
)
model = model.to(device)

criterion = nn.CrossEntropyLoss(label_smoothing=0.05)

print(f"\n\square DenseNet-121 model initialized with {num_features} input features")

# =====
# Load trained weights
# =====
print("\n" + "="*60)
print("Loading Trained Weights and Evaluating on Test Set")
print("="*60)

# Path to uploaded weight file (from your Kaggle dataset)
model.load_state_dict(torch.load("/kaggle/input/trained-densenet121-weights/best_densenet121.pth"))
model.to(device)
model.eval()

```

Using device: cuda

```

/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:208: UserWarning: The parameter 'pretrained' is deprecated since 0.13 and may be removed in the future, please use 'weights' instead.
  warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:23: UserWarning: Arguments other than a weight enum or `None` for 'weights' are deprecated since 0.13 and may be removed in the future.
The current behavior is equivalent to passing
`weights=DenseNet121_Weights.IMAGENET1K_V1`. You can also use
`weights=DenseNet121_Weights.DEFAULT` to get the most up-to-date
weights.
  warnings.warn(msg)

```

\square DenseNet-121 model initialized with 1024 input features

```
=====
Loading Trained Weights and Evaluating on Test Set
=====

DenseNet(
    (features): Sequential(
        (conv0): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2),
padding=(3, 3), bias=False)
        (norm0): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
        (relu0): ReLU(inplace=True)
        (pool0): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1,
ceil_mode=False)
        (denseblock1): _DenseBlock(
            (denselayer1): _DenseLayer(
                (norm1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
                (relu1): ReLU(inplace=True)
                (conv1): Conv2d(64, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
                (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
                (relu2): ReLU(inplace=True)
                (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
            )
            (denselayer2): _DenseLayer(
                (norm1): BatchNorm2d(96, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
                (relu1): ReLU(inplace=True)
                (conv1): Conv2d(96, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
                (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
                (relu2): ReLU(inplace=True)
                (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
            )
            (denselayer3): _DenseLayer(
                (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
                (relu1): ReLU(inplace=True)
                (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
                (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
                (relu2): ReLU(inplace=True)
                (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
            )
        )
    )
)
```

```
)  
    (denselayer4): _DenseLayer(  
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu1): ReLU(inplace=True)  
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu2): ReLU(inplace=True)  
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),  
padding=(1, 1), bias=False)  
    )  
    (denselayer5): _DenseLayer(  
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu1): ReLU(inplace=True)  
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu2): ReLU(inplace=True)  
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),  
padding=(1, 1), bias=False)  
    )  
    (denselayer6): _DenseLayer(  
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu1): ReLU(inplace=True)  
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu2): ReLU(inplace=True)  
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),  
padding=(1, 1), bias=False)  
    )  
)  
    (transition1): _Transition(  
        (norm): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,  
track_running_stats=True)  
        (relu): ReLU(inplace=True)  
        (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)  
    )  
    (denseblock2): _DenseBlock(  
        (denselayer1): _DenseLayer(  
            (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1,
```

```
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
```

```
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
)
(transition2): _Transition(
    (norm): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (relu): ReLU(inplace=True)
```

```
        (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock3): _DenseBlock(
        (denselayer1): _DenseLayer(
            (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer2): _DenseLayer(
            (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer3): _DenseLayer(
            (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer4): _DenseLayer(
            (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
```

```
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(512, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(544, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(544, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(576, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(576, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(608, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(608, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
```

```
padding=(1, 1), bias=False)
)
(denselayer13): _DenseLayer(
    (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
)
(denselayer14): _DenseLayer(
    (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
)
(denselayer15): _DenseLayer(
    (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
)
(denselayer16): _DenseLayer(
    (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
```

```
)  
    (denselayer17): _DenseLayer(  
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu1): ReLU(inplace=True)  
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu2): ReLU(inplace=True)  
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),  
padding=(1, 1), bias=False)  
    )  
    (denselayer18): _DenseLayer(  
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu1): ReLU(inplace=True)  
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu2): ReLU(inplace=True)  
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),  
padding=(1, 1), bias=False)  
    )  
    (denselayer19): _DenseLayer(  
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu1): ReLU(inplace=True)  
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu2): ReLU(inplace=True)  
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),  
padding=(1, 1), bias=False)  
    )  
    (denselayer20): _DenseLayer(  
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu1): ReLU(inplace=True)  
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1),  
bias=False)  
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,  
affine=True, track_running_stats=True)  
        (relu2): ReLU(inplace=True)  
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),  
padding=(1, 1), bias=False)  
    )
```

```
        (denselayer21): _DenseLayer(
            (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer22): _DenseLayer(
            (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer23): _DenseLayer(
            (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer24): _DenseLayer(
            (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
    )
    (transition3): _Transition(
```

```
        (norm): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
        (relu): ReLU(inplace=True)
        (conv): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock4): _DenseBlock(
        (denselayer1): _DenseLayer(
            (norm1): BatchNorm2d(512, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer2): _DenseLayer(
            (norm1): BatchNorm2d(544, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(544, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer3): _DenseLayer(
            (norm1): BatchNorm2d(576, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(576, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
            (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu2): ReLU(inplace=True)
            (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
        )
        (denselayer4): _DenseLayer(
            (norm1): BatchNorm2d(608, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
            (relu1): ReLU(inplace=True)
            (conv1): Conv2d(608, 128, kernel_size=(1, 1), stride=(1, 1),
```

```
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
```

```
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
    (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
```

```
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
)
(denselayer13): _DenseLayer(
    (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
)
(denselayer14): _DenseLayer(
    (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
)
(denselayer15): _DenseLayer(
    (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu2): ReLU(inplace=True)
    (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
)
(denselayer16): _DenseLayer(
    (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
    (relu1): ReLU(inplace=True)
    (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
    (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```

        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
    )
)
(norm5): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
)
(classifier): Sequential(
    (0): Dropout(p=0.3, inplace=False)
    (1): Linear(in_features=1024, out_features=6, bias=True)
)
)

# Evaluate on test data
test_loss, test_acc = evaluate(model, test_loader, criterion, device)
test_auc = compute_macro_auc(model, test_loader, device, n_classes=6)

print(f"\n\square Test Loss: {test_loss:.4f}")
print(f"\square Test Accuracy: {test_acc*100:.2f}%")
print(f"\square Test AUC: {test_auc:.4f}")

# Detailed classification report
all_preds, all_labels = [], []
with torch.no_grad():
    for imgs, labels in test_loader:
        imgs = imgs.to(device)
        outputs = model(imgs)
        preds = outputs.argmax(1)
        all_preds.extend(preds.cpu().numpy())
        all_labels.extend(labels.numpy())

print("\n" + "*60")
print("Classification Report")
print("*60")
print(classification_report(all_labels, all_preds,
target_names=test_dataset.classes))

\square Test Loss: 0.5340
\square Test Accuracy: 88.44%
\square Test AUC: 0.9789
=====
Classification Report
=====
precision    recall   f1-score   support
COVID-19      0.98      0.99      0.99      1500
Cardiomegaly   0.86      0.94      0.90      1500

```

Normal	0.79	0.68	0.73	1500
Pleural Effusion	0.79	0.75	0.77	1500
Pneumonia	0.87	0.95	0.91	1500
Tuberculosis	1.00	1.00	1.00	1500
accuracy			0.88	9000
macro avg	0.88	0.88	0.88	9000
weighted avg	0.88	0.88	0.88	9000

```
import shutil
shutil.copy("best_densenet121.pth", "/kaggle/working/")
print("\n Model saved to /kaggle/working/best_densenet121.pth")
```

Efficient-Net Model Training

```
import torch
import torch.nn as nn
import torch.optim as optim
from torch.utils.data import DataLoader, Dataset
from torchvision import models, transforms
from PIL import Image
from sklearn.metrics import roc_auc_score, accuracy_score,
classification_report, precision_score
import numpy as np
import pandas as pd
import torch.nn.functional as F

MODEL_TYPE = "efficientnet" # Options: "efficientnet", "vit",
"convnext"

train_df =
pd.read_csv("/kaggle/input/balanced-dataset/train_split.csv")
val_df = pd.read_csv("/kaggle/input/balanced-dataset/val_split.csv")
test_df =
pd.read_csv("/kaggle/input/balanced-dataset/test_split.csv")

print("Train samples:", len(train_df))
print("Val samples:", len(val_df))
print("Test samples:", len(test_df))
print("\nClass distribution:")
print(train_df["label"].value_counts())

Train samples: 42000
Val samples: 9000
Test samples: 9000

Class distribution:
label
Tuberculosis    7000
```

```

COVID-19           7000
Cardiomegaly      7000
Normal            7000
Pneumonia          7000
Pleural Effusion   7000
Name: count, dtype: int64

if MODEL_TYPE == "efficientnet":
    # EfficientNet works best with higher resolution
    img_size = 380
    train_transform = transforms.Compose([
        transforms.Resize((img_size, img_size)),
        transforms.RandomHorizontalFlip(p=0.5),
        transforms.RandomRotation(15),
        transforms.ColorJitter(brightness=0.2, contrast=0.2),
        transforms.RandomAffine(degrees=0, translate=(0.1, 0.1)),
        transforms.ToTensor(),
        transforms.Normalize(mean=[0.485, 0.456, 0.406],
                            std=[0.229, 0.224, 0.225]))
    ])
elif MODEL_TYPE == "vit":
    # ViT requires exactly 224x224
    img_size = 224
    train_transform = transforms.Compose([
        transforms.Resize((img_size, img_size)),
        transforms.RandomHorizontalFlip(p=0.5),
        transforms.RandomRotation(10),
        transforms.ColorJitter(brightness=0.15, contrast=0.15),
        transforms.ToTensor(),
        transforms.Normalize(mean=[0.5, 0.5, 0.5],
                            std=[0.5, 0.5, 0.5]))
    ])
else: # convnext
    img_size = 224
    train_transform = transforms.Compose([
        transforms.Resize((img_size, img_size)),
        transforms.RandomHorizontalFlip(p=0.5),
        transforms.RandomRotation(12),
        transforms.ColorJitter(brightness=0.15, contrast=0.15),
        transforms.ToTensor(),
        transforms.Normalize(mean=[0.485, 0.456, 0.406],
                            std=[0.229, 0.224, 0.225]))
    ])

val_test_transform = transforms.Compose([
    transforms.Resize((img_size, img_size)),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.485, 0.456, 0.406] if MODEL_TYPE != "vit" else [0.5, 0.5, 0.5],
                        std=[0.229, 0.224, 0.225] if MODEL_TYPE !=

```

```

"vit" else [0.5, 0.5, 0.5])
])

class XRayDataset(Dataset):
    def __init__(self, df, transform=None):
        self.df = df.reset_index(drop=True)
        self.transform = transform
        self.classes = sorted(df["label"].unique())
        self.class_to_idx = {c: i for i, c in enumerate(self.classes)}

    def __len__(self):
        return len(self.df)

    def __getitem__(self, idx):
        img_path = self.df.loc[idx, "image_path"]
        label = self.df.loc[idx, "label"]

        img = Image.open(img_path).convert("RGB")
        if self.transform:
            img = self.transform(img)

        return img, self.class_to_idx[label]

batch_size = 16 if MODEL_TYPE == "efficientnet" else 32 # Smaller
batch for EfficientNet

train_dataset = XRayDataset(train_df, transform=train_transform)
val_dataset = XRayDataset(val_df, transform=val_test_transform)
test_dataset = XRayDataset(test_df, transform=val_test_transform)

train_loader = DataLoader(train_dataset, batch_size=batch_size,
shuffle=True, num_workers=2)
val_loader = DataLoader(val_dataset, batch_size=batch_size,
shuffle=False, num_workers=2)
test_loader = DataLoader(test_dataset, batch_size=batch_size,
shuffle=False, num_workers=2)

print("\nClass to Index mapping:", train_dataset.class_to_idx)

Class to Index mapping: {'COVID-19': 0, 'Cardiomegaly': 1, 'Normal': 2, 'Pleural Effusion': 3, 'Pneumonia': 4, 'Tuberculosis': 5}

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
print(f"\nUsing device: {device}")

if MODEL_TYPE == "efficientnet":
    # EfficientNet-B4 (best balance of accuracy and speed)
    model = models.efficientnet_b4(pretrained=True)
    num_features = model.classifier[1].in_features
    model.classifier = nn.Sequential(

```

```

        nn.Dropout(0.4),
        nn.Linear(num_features, 6)
    )
model_name = "EfficientNet-B4"

elif MODEL_TYPE == "vit":
    # Vision Transformer
    model = models.vit_b_16(pretrained=True)
    num_features = model.heads.head.in_features
    model.heads = nn.Sequential(
        nn.Dropout(0.3),
        nn.Linear(num_features, 6)
    )
    model_name = "ViT-B/16"

else: # convnext
    # ConvNeXt Base
    model = models.convnext_base(pretrained=True)
    num_features = model.classifier[2].in_features
    model.classifier[2] = nn.Linear(num_features, 6)
    model.classifier = nn.Sequential(
        model.classifier[0], # LayerNorm
        model.classifier[1], # Flatten
        nn.Dropout(0.3),
        nn.Linear(num_features, 6)
    )
    model_name = "ConvNeXt-Base"

model = model.to(device)
print(f"\n\t{model_name} initialized with {num_features} input features")

```

Using device: cuda

```

/usr/local/lib/python3.11/dist-packages/torchvision/models/
_utils.py:208: UserWarning: The parameter 'pretrained' is deprecated
since 0.13 and may be removed in the future, please use 'weights'
instead.
    warnings.warn(
/usr/local/lib/python3.11/dist-packages/torchvision/models/_utils.py:2
23: UserWarning: Arguments other than a weight enum or `None` for
'weights' are deprecated since 0.13 and may be removed in the future.
The current behavior is equivalent to passing
`weights=EfficientNet_B4_Weights.IMAGENET1K_V1`. You can also use
`weights=EfficientNet_B4_Weights.DEFAULT` to get the most up-to-date
weights.
    warnings.warn(msg)
Downloading:
"https://download.pytorch.org/models/efficientnet_b4_rwightman-

```

```
23ab8bcd.pth" to
/root/.cache/torch/hub/checkpoints/efficientnet_b4_rwightman-
23ab8bcd.pth
100%|██████████| 74.5M/74.5M [00:00<00:00, 183MB/s]

[] EfficientNet-B4 initialized with 1792 input features

class_counts = train_df["label"].value_counts().sort_index()
total_samples = len(train_df)
class_weights = torch.FloatTensor([total_samples / (len(class_counts) * count)
                                    for count in
                                    class_counts.values]).to(device)

# Increase weight for "Normal" class (index 2) to boost precision
normal_idx = train_dataset.class_to_idx["Normal"]
class_weights[normal_idx] *= 1.5 # 50% more penalty for misclassifying Normal

print(f"\nClass weights: {class_weights}")

criterion = nn.CrossEntropyLoss(weight=class_weights,
label_smoothing=0.05)
optimizer = optim.AdamW(model.parameters(), lr=1e-4, weight_decay=1e-4)

# Learning rate scheduler
scheduler = optim.lr_scheduler.ReduceLROnPlateau(optimizer,
mode='max', factor=0.5,
                                         patience=3,
verbose=True)

Class weights: tensor([1.0000, 1.0000, 1.5000, 1.0000, 1.0000,
1.0000], device='cuda:0')

/usr/local/lib/python3.11/dist-packages/torch/optim/
lr_scheduler.py:62: UserWarning: The verbose parameter is deprecated.
Please use get_last_lr() to access the learning rate.
warnings.warn()

class EarlyStopping:
    def __init__(self, patience=7, mode="max"):
        self.patience = patience
        self.mode = mode
        self.best = None
        self.counter = 0

    def step(self, metric):
        if self.best is None:
```

```

        self.best = metric
        return False
    if (self.mode == "max" and metric > self.best) or (self.mode
== "min" and metric < self.best):
        self.best = metric
        self.counter = 0
        return False
    else:
        self.counter += 1
        if self.counter >= self.patience:
            return True
        return False

def train_one_epoch(model, loader, optimizer, criterion, device):
    model.train()
    running_loss, correct, total = 0.0, 0, 0

    for imgs, labels in loader:
        imgs, labels = imgs.to(device), labels.to(device)

        optimizer.zero_grad()
        outputs = model(imgs)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()

        running_loss += loss.item() * imgs.size(0)
        _, preds = torch.max(outputs, 1)
        correct += (preds == labels).sum().item()
        total += labels.size(0)

    return running_loss / total, correct / total

def evaluate(model, loader, criterion, device):
    model.eval()
    running_loss, correct, total = 0.0, 0, 0
    all_preds, all_labels = [], []

    with torch.no_grad():
        for imgs, labels in loader:
            imgs, labels = imgs.to(device), labels.to(device)
            outputs = model(imgs)
            loss = criterion(outputs, labels)

            running_loss += loss.item() * imgs.size(0)
            _, preds = torch.max(outputs, 1)
            correct += (preds == labels).sum().item()
            total += labels.size(0)

            all_preds.extend(preds.cpu().numpy())

```

```

        all_labels.extend(labels.cpu().numpy())

acc = correct / total

# Calculate precision for Normal class
normal_idx = 2 # Assuming alphabetical order
normal_precision = precision_score(all_labels, all_preds,
                                    labels=[normal_idx],
average='macro', zero_division=0)

    return running_loss / total, acc, normal_precision

def compute_macro_auc(model, loader, device, n_classes=6):
    model.eval()
    probs_list, labels_list = [], []
    with torch.no_grad():
        for imgs, labels in loader:
            imgs = imgs.to(device)
            outputs = model(imgs)
            probs = F.softmax(outputs, dim=1).cpu().numpy()
            probs_list.append(probs)
            labels_list.append(labels.numpy())
    probs_all = np.concatenate(probs_list, axis=0)
    labels_all = np.concatenate(labels_list, axis=0)
    labels_onehot = np.eye(n_classes)[labels_all]
    aucs = []
    for i in range(n_classes):
        try:
            auc = roc_auc_score(labels_onehot[:, i], probs_all[:, i])
            aucs.append(auc)
        except ValueError:
            pass
    return np.mean(aucs) if aucs else 0.0

epochs = 25
best_val_auc = 0.0
best_normal_precision = 0.0
early_stopper = EarlyStopping(patience=7, mode="max")

print("\n" + "*70)
print(f"Starting {model_name} Training")
print("*70)

for epoch in range(epochs):
    train_loss, train_acc = train_one_epoch(model, train_loader,
optimizer, criterion, device)
    val_loss, val_acc, val_normal_precision = evaluate(model,
val_loader, criterion, device)
    val_auc = compute_macro_auc(model, val_loader, device,
n_classes=6)

```

```

    print(f"\nEpoch {epoch+1}/{epochs}")
    print(f"  Train Loss: {train_loss:.4f}, Train Acc: {train_acc:.4f}")
    print(f"  Val Loss: {val_loss:.4f}, Val Acc: {val_acc:.4f}, Val AUC: {val_auc:.4f}")
    print(f"  Normal Precision: {val_normal_precision:.4f}")

# Update learning rate
scheduler.step(val_auc)

# Save best model based on validation AUC
if val_auc > best_val_auc:
    best_val_auc = val_auc
    best_normal_precision = val_normal_precision
    torch.save(model.state_dict(), f"best_{MODEL_TYPE}.pth")
    print(f"  ☐ Best model saved! (Val AUC: {val_auc:.4f}, Normal Precision: {val_normal_precision:.4f})")

# Early stopping
if early_stopper.step(val_auc):
    print("\n△ Early stopping triggered.")
    break

```

=====
Starting EfficientNet-B4 Training
=====

Epoch 1/25

```

Train Loss: 1.0844, Train Acc: 0.6068
Val Loss: 0.8302, Val Acc: 0.7326, Val AUC: 0.9344
Normal Precision: 0.5710
☐ Best model saved! (Val AUC: 0.9344, Normal Precision: 0.5710)

```

Epoch 2/25

```

Train Loss: 0.8561, Train Acc: 0.7291
Val Loss: 0.7690, Val Acc: 0.7763, Val AUC: 0.9482
Normal Precision: 0.6676
☐ Best model saved! (Val AUC: 0.9482, Normal Precision: 0.6676)

```

Epoch 3/25

```

Train Loss: 0.7664, Train Acc: 0.7741
Val Loss: 0.7041, Val Acc: 0.8134, Val AUC: 0.9596
Normal Precision: 0.7068
☐ Best model saved! (Val AUC: 0.9596, Normal Precision: 0.7068)

```

Epoch 4/25

```

Train Loss: 0.6877, Train Acc: 0.8151
Val Loss: 0.6657, Val Acc: 0.8336, Val AUC: 0.9683

```

```
Normal Precision: 0.7823
[] Best model saved! (Val AUC: 0.9683, Normal Precision: 0.7823)
```

Epoch 5/25

```
Train Loss: 0.6257, Train Acc: 0.8428
Val Loss: 0.5921, Val Acc: 0.8634, Val AUC: 0.9748
Normal Precision: 0.7288
[] Best model saved! (Val AUC: 0.9748, Normal Precision: 0.7288)
```

Epoch 6/25

```
Train Loss: 0.5765, Train Acc: 0.8659
Val Loss: 0.5726, Val Acc: 0.8684, Val AUC: 0.9767
Normal Precision: 0.7301
[] Best model saved! (Val AUC: 0.9767, Normal Precision: 0.7301)
```

Epoch 7/25

```
Train Loss: 0.5410, Train Acc: 0.8811
Val Loss: 0.5451, Val Acc: 0.8834, Val AUC: 0.9798
Normal Precision: 0.7424
[] Best model saved! (Val AUC: 0.9798, Normal Precision: 0.7424)
```

Epoch 8/25

```
Train Loss: 0.5058, Train Acc: 0.8977
Val Loss: 0.5387, Val Acc: 0.8874, Val AUC: 0.9808
Normal Precision: 0.7812
[] Best model saved! (Val AUC: 0.9808, Normal Precision: 0.7812)
```

Epoch 9/25

```
Train Loss: 0.4781, Train Acc: 0.9079
Val Loss: 0.5561, Val Acc: 0.8883, Val AUC: 0.9800
Normal Precision: 0.8115
```

Epoch 10/25

```
Train Loss: 0.4575, Train Acc: 0.9178
Val Loss: 0.5582, Val Acc: 0.8888, Val AUC: 0.9788
Normal Precision: 0.7772
```

Epoch 11/25

```
Train Loss: 0.4388, Train Acc: 0.9235
Val Loss: 0.5265, Val Acc: 0.8996, Val AUC: 0.9805
Normal Precision: 0.7503
```

Epoch 12/25

```
Train Loss: 0.4192, Train Acc: 0.9320
Val Loss: 0.5401, Val Acc: 0.8973, Val AUC: 0.9795
Normal Precision: 0.7648
```

Epoch 13/25

```
Train Loss: 0.3829, Train Acc: 0.9487
Val Loss: 0.5636, Val Acc: 0.8956, Val AUC: 0.9774
```

```

Normal Precision: 0.7777

Epoch 14/25
Train Loss: 0.3723, Train Acc: 0.9521
Val Loss: 0.5428, Val Acc: 0.9013, Val AUC: 0.9777
Normal Precision: 0.7829

Epoch 15/25
Train Loss: 0.3620, Train Acc: 0.9565
Val Loss: 0.5673, Val Acc: 0.8952, Val AUC: 0.9768
Normal Precision: 0.7604

△ Early stopping triggered.

print("\n" + "*70)
print("Evaluating on Test Set")
print("*70)

model.load_state_dict(torch.load(f"best_{MODEL_TYPE}.pth"))
test_loss, test_acc, test_normal_precision = evaluate(model,
test_loader, criterion, device)
test_auc = compute_macro_auc(model, test_loader, device, n_classes=6)

print(f"\n\square Test Loss: {test_loss:.4f}")
print(f"\square Test Accuracy: {test_acc*100:.2f}%")
print(f"\square Test AUC: {test_auc:.4f}")
print(f"\square Normal Precision: {test_normal_precision*100:.2f}%")

# Detailed classification report
all_preds, all_labels = [], []
with torch.no_grad():
    for imgs, labels in test_loader:
        imgs = imgs.to(device)
        outputs = model(imgs)
        preds = outputs.argmax(1)
        all_preds.extend(preds.cpu().numpy())
        all_labels.extend(labels.numpy())

print("\n" + "*70)
print("Classification Report")
print("*70)
report = classification_report(all_labels, all_preds,
target_names=test_dataset.classes, digits=4)
print(report)

# Highlight Normal class metrics
from sklearn.metrics import confusion_matrix
cm = confusion_matrix(all_labels, all_preds)
normal_idx = test_dataset.class_to_idx["Normal"]
normal_tp = cm[normal_idx, normal_idx]

```

```

normal_total = cm[normal_idx, :].sum()
normal_predicted = cm[:, normal_idx].sum()
normal_recall = normal_tp / normal_total if normal_total > 0 else 0
normal_precision = normal_tp / normal_predicted if normal_predicted >
0 else 0

print("\n" + "*70)
print("□ Normal Class Detailed Metrics")
print("*70)
print(f"Precision: {normal_precision*100:.2f}% (How many predicted
Normal are actually Normal)")
print(f"Recall: {normal_recall*100:.2f}% (How many actual Normal
were detected)")
print(f"F1-Score:
{2*normal_precision*normal_recall/(normal_precision+normal_recall)*100
:.2f}%"')
print(f"\nFalse Positives (Diseased predicted as Normal):
{normal_predicted - normal_tp}")
print(f"False Negatives (Normal predicted as Diseased): {normal_total
- normal_tp}")

=====

```

Evaluating on Test Set

```

□ Test Loss: 0.5365
□ Test Accuracy: 89.13%
□ Test AUC: 0.9809
□ Normal Precision: 79.36%

```

Classification Report

	precision	recall	f1-score	support
COVID-19	0.9807	0.9813	0.9810	1500
Cardiomegaly	0.8489	0.9553	0.8990	1500
Normal	0.7936	0.6920	0.7393	1500
Pleural Effusion	0.8219	0.7540	0.7865	1500
Pneumonia	0.8916	0.9653	0.9270	1500
Tuberculosis	0.9980	1.0000	0.9990	1500
accuracy			0.8913	9000
macro avg	0.8891	0.8913	0.8886	9000
weighted avg	0.8891	0.8913	0.8886	9000

□ Normal Class Detailed Metrics

```
=====
Precision: 79.36% (How many predicted Normal are actually Normal)
Recall:    69.20% (How many actual Normal were detected)
F1-Score:   73.93%

False Positives (Diseased predicted as Normal): 270
False Negatives (Normal predicted as Diseased): 462

import shutil
shutil.copy(f"best_{MODEL_TYPE}.pth", "/kaggle/working/")
print(f"\n Model saved to /kaggle/working/best_{MODEL_TYPE}.pth")

print("\n" + "*70)
print(f"\n {model_name} Training Complete!")
print("*70)

-----
-----
SameFileError                                     Traceback (most recent call
last)
/tmp/ipykernel_38/80766252.py in <cell line: 0>()
      1 import shutil
----> 2 shutil.copy(f"best_{MODEL_TYPE}.pth", "/kaggle/working/")
      3 print(f"\n Model saved to
/kaggle/working/best_{MODEL_TYPE}.pth")
      4
      5 print("\n" + "*70)

/usr/lib/python3.11/shutil.py in copy(src, dst, follow_symlinks)
  429     if os.path.isdir(dst):
  430         dst = os.path.join(dst, os.path.basename(src))
--> 431     copyfile(src, dst, follow_symlinks=follow_symlinks)
  432     copymode(src, dst, follow_symlinks=follow_symlinks)
  433     return dst

/usr/lib/python3.11/shutil.py in copyfile(src, dst, follow_symlinks)
  234
  235     if _samefile(src, dst):
--> 236         raise SameFileError("{!r} and {!r} are the same
file".format(src, dst))
  237
  238     file_size = 0

SameFileError: 'best_efficientnet.pth' and
'/kaggle/working/best_efficientnet.pth' are the same file
```

EXAI

Resnet-50

```
# =====
# QUICK XAI DEMO - COPY THIS TO KAGGLE NOTEBOOK
# =====

# Install required packages (run once)
# !pip install grad-cam -q

import torch
import torch.nn as nn
import torch.nn.functional as F
from torchvision import models, transforms
from PIL import Image
import numpy as np
import matplotlib.pyplot as plt
import cv2

# =====
# STEP 1: Choose Your Settings
# =====

MODEL_TYPE = "resnet50" # Options: "resnet50", "densenet121",
"efficientnet"
MODEL_PATH = "/kaggle/input/resnet-50-v1-weights/best_resnet50.pth"
IMAGE_PATH = "/kaggle/input/covidx-cxr2/train/sub-S326737_ses-
E53636_run-1_bp-chest_vp-ap_cr-corrected.png"

# =====
# STEP 2: Load Model
# =====

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
class_names = ['COVID-19', 'Cardiomegaly', 'Normal',
               'Pleural Effusion', 'Pneumonia', 'Tuberculosis']

def load_model(model_path, model_type):
    n_classes = 6

    if model_type == "resnet50":
        model = models.resnet50(weights=None)
        in_features = model.fc.in_features
        model.fc = nn.Sequential(nn.Dropout(0.3),
nn.Linear(in_features, n_classes))
        target_layer = model.layer4[-1].conv3

    elif model_type == "densenet121":
        model = models.densenet121(weights=None)
        num_features = model.classifier.in_features
```

```

        model.classifier = nn.Sequential(nn.Dropout(0.3),
nn.Linear(num_features, n_classes))
        target_layer = model.features.denseblock4.denselayer16.conv2

    elif model_type == "efficientnet":
        model = models.efficientnet_b4(weights=None)
        num_features = model.classifier[1].in_features
        model.classifier = nn.Sequential(nn.Dropout(0.4),
nn.Linear(num_features, n_classes))
        target_layer = model.features[-1][0]

    state_dict = torch.load(model_path, map_location=device)
    model.load_state_dict(state_dict)
    model.to(device)
    model.eval()

    return model, target_layer

model, target_layer = load_model(MODEL_PATH, MODEL_TYPE)
print(f"\t{MODEL_TYPE.upper()} loaded successfully!")

# =====
# STEP 3: Grad-CAM Implementation
# =====

class GradCAM:
    def __init__(self, model, target_layer):
        self.model = model
        self.target_layer = target_layer
        self.gradients = None
        self.activations = None
        # Use full_backward_hook to avoid warning
        target_layer.register_forward_hook(self.save_activation)
        target_layer.register_full_backward_hook(self.save_gradient)

    def save_activation(self, module, input, output):
        self.activations = output.detach()

    def save_gradient(self, module, grad_input, grad_output):
        self.gradients = grad_output[0].detach()

    def generate(self, input_tensor, target_class=None):
        # Use no_grad for forward pass, then enable for backward
        with torch.set_grad_enabled(True):
            output = self.model(input_tensor)

        if target_class is None:
            target_class = output.argmax(dim=1).item()

        self.model.zero_grad()

```

```

        output[0, target_class].backward()

        gradients = self.gradients[0]
        activations = self.activations[0]
        weights = gradients.mean(dim=(1, 2), keepdim=True)
        cam = (weights * activations).sum(dim=0)
        cam = F.relu(cam)
        cam = cam - cam.min()
        cam = cam / (cam.max() + 1e-8)

    return cam.cpu().numpy(), target_class, output.detach()

# =====
# STEP 4: Process Image
# =====
img_size = 380 if MODEL_TYPE == "efficientnet" else 224
transform = transforms.Compose([
    transforms.Resize((img_size, img_size)),
    transforms.ToTensor(),
    transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.225])
])

original_image = Image.open(IMAGE_PATH).convert("RGB")
original_np = np.array(original_image.resize((img_size, img_size)))
input_tensor = transform(original_image).unsqueeze(0).to(device)

# =====
# STEP 5: Generate Visualization
# =====
gradcam = GradCAM(model, target_layer)
cam, pred_class, output = gradcam.generate(input_tensor)

probs = F.softmax(output, dim=1)[0].detach()
confidence = probs[pred_class].item()

# Overlay heatmap
cam_resized = cv2.resize(cam, (img_size, img_size))
heatmap = cv2.applyColorMap(np.uint8(255 * cam_resized),
cv2.COLORMAP_JET)
heatmap = cv2.cvtColor(heatmap, cv2.COLOR_BGR2RGB)
overlay = heatmap * 0.5 + original_np * 0.5
overlay = np.uint8(overlay)

# =====
# STEP 6: Display Results
# =====
fig, axes = plt.subplots(2, 3, figsize=(18, 12))

# Row 1
axes[0, 0].imshow(original_np)

```

```

axes[0, 0].set_title(f'Original X-Ray\n{MODEL_TYPE.upper()}',  

                    fontsize=14, fontweight='bold')  

axes[0, 0].axis('off')  
  

axes[0, 1].imshow(cam, cmap='jet')  

axes[0, 1].set_title('Grad-CAM Heatmap\n(Red = High Importance)',  

                     fontsize=14, fontweight='bold')  

axes[0, 1].axis('off')  
  

axes[0, 2].imshow(overlay)  

axes[0, 2].set_title(f'Overlay\nPrediction:  

{class_names[pred_class]}', fontsize=14, fontweight='bold')  

axes[0, 2].axis('off')  
  

# Row 2  

axes[1, 0].barh(class_names, probs.cpu().numpy())  

axes[1, 0].set_xlim([0, 1])  

axes[1, 0].set_xlabel('Confidence', fontsize=12)  

axes[1, 0].set_title('Prediction Probabilities', fontsize=14,  

                     fontweight='bold')  
  

# Clinical interpretation  

interpretation = """  

    □ CLINICAL INTERPRETATION:  
  

        Predicted Disease: {class_names[pred_class]}  

        Confidence: {confidence*100:.1f}%  
  

        □ Red/Yellow Areas:  

            High diagnostic importance  

            These regions strongly influenced  

            the AI's decision  
  

        □ Blue/Purple Areas:  

            Low diagnostic importance  
  

        * Medical Professional should verify:  

            - Are highlighted regions clinically  

                relevant for {class_names[pred_class]}?  

            - Any abnormalities in non-highlighted  

                areas that AI might have missed?  

    """  

    axes[1, 1].text(0.1, 0.5, interpretation, fontsize=11,  

                   verticalalignment='center', family='monospace',  

                   bbox=dict(boxstyle='round', facecolor='lightblue',  

                             alpha=0.5))  

    axes[1, 1].axis('off')  
  

# Top 3 predictions  

top3_idx = probs.argsort(descending=True)[:3]

```

```

top3_text = "□ TOP 3 PREDICTIONS:\n\n"
for i, idx in enumerate(top3_idx, 1):
    top3_text += f"{i}. {class_names[idx]}: {probs[idx]*100:.1f}%\n"

axes[1, 2].text(0.1, 0.5, top3_text, fontsize=13,
                verticalalignment='center', family='monospace',
                bbox=dict(boxstyle='round', facecolor='lightyellow',
                alpha=0.7))
axes[1, 2].axis('off')

plt.suptitle(f'Explainable AI - Medical X-Ray Analysis
({MODEL_TYPE.upper()}),
                fontsize=16, fontweight='bold')
plt.tight_layout()
plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
plt.show()

print("\n" + "="*70)
print(f"□ PREDICTION SUMMARY")
print("=*70)
print(f"Model: {MODEL_TYPE.upper()}")
print(f"Diagnosis: {class_names[pred_class]}")
print(f"Confidence: {confidence*100:.2f}%")
print(f"\nTop 3 Differential Diagnoses:")
for i, idx in enumerate(top3_idx, 1):
    print(f" {i}. {class_names[idx]}: {probs[idx]*100:.2f}%")
print("=*70)

# =====
# BONUS: Analyze Multiple Images
# =====
def analyze_test_samples(model, model_type, target_layer, test_df,
n_samples=5):
    """Analyze random test samples with XAI"""
    samples = test_df.sample(n_samples, random_state=42)

    fig, axes = plt.subplots(n_samples, 4, figsize=(20, 5*n_samples))

    for idx, (_, row) in enumerate(samples.iterrows()):
        img_path = row['image_path']
        true_label = row['label']

        # Process image
        img_size = 380 if model_type == "efficientnet" else 224
        transform = transforms.Compose([
            transforms.Resize((img_size, img_size)),
            transforms.ToTensor(),
            transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,
0.225])
        ])

```

```

        original_image = Image.open(img_path).convert("RGB")
        original_np = np.array(original_image.resize((img_size,
img_size)))
        input_tensor =
transform(original_image).unsqueeze(0).to(device)

    # Generate Grad-CAM
    gradcam = GradCAM(model, target_layer)
    cam, pred_class, output = gradcam.generate(input_tensor)
    probs = F.softmax(output, dim=1)[0].detach()

    # Create overlay
    cam_resized = cv2.resize(cam, (img_size, img_size))
    heatmap = cv2.applyColorMap(np.uint8(255 * cam_resized),
cv2.COLORMAP_JET)
    heatmap = cv2.cvtColor(heatmap, cv2.COLOR_BGR2RGB)
    overlay = heatmap * 0.5 + original_np * 0.5

    # Plot
    axes[idx, 0].imshow(original_np)
    axes[idx, 0].set_title(f'True: {true_label}', fontsize=10)
    axes[idx, 0].axis('off')

    axes[idx, 1].imshow(cam, cmap='jet')
    axes[idx, 1].set_title('Grad-CAM', fontsize=10)
    axes[idx, 1].axis('off')

    axes[idx, 2].imshow(overlay)
    correct = "True" if class_names[pred_class] == true_label else
"False"
    axes[idx, 2].set_title(f'{correct} Pred:
{class_names[pred_class]}', fontsize=10)
    axes[idx, 2].axis('off')

    axes[idx, 3].barh(class_names, probs.cpu().numpy())
    axes[idx, 3].set_xlim([0, 1])
    axes[idx, 3].tick_params(labelsize=8)

    plt.suptitle(f'Test Set Analysis - {model_type.upper()}',

font-size=16, font-weight='bold')
    plt.tight_layout()
    plt.savefig(f'test_analysis_{model_type}.png', dpi=150,
bbox_inches='tight')
    plt.show()

# Uncomment to analyze test samples
# import pandas as pd
# test_df =

```

```
pd.read_csv("/kaggle/input/balanced-dataset/test_split.csv")
# analyze_test_samples(model, MODEL_TYPE, target_layer, test_df,
n_samples=5)

print("\n\square XAI visualization complete!")
print("\square Saved as: xai_{}.png".format(MODEL_TYPE))

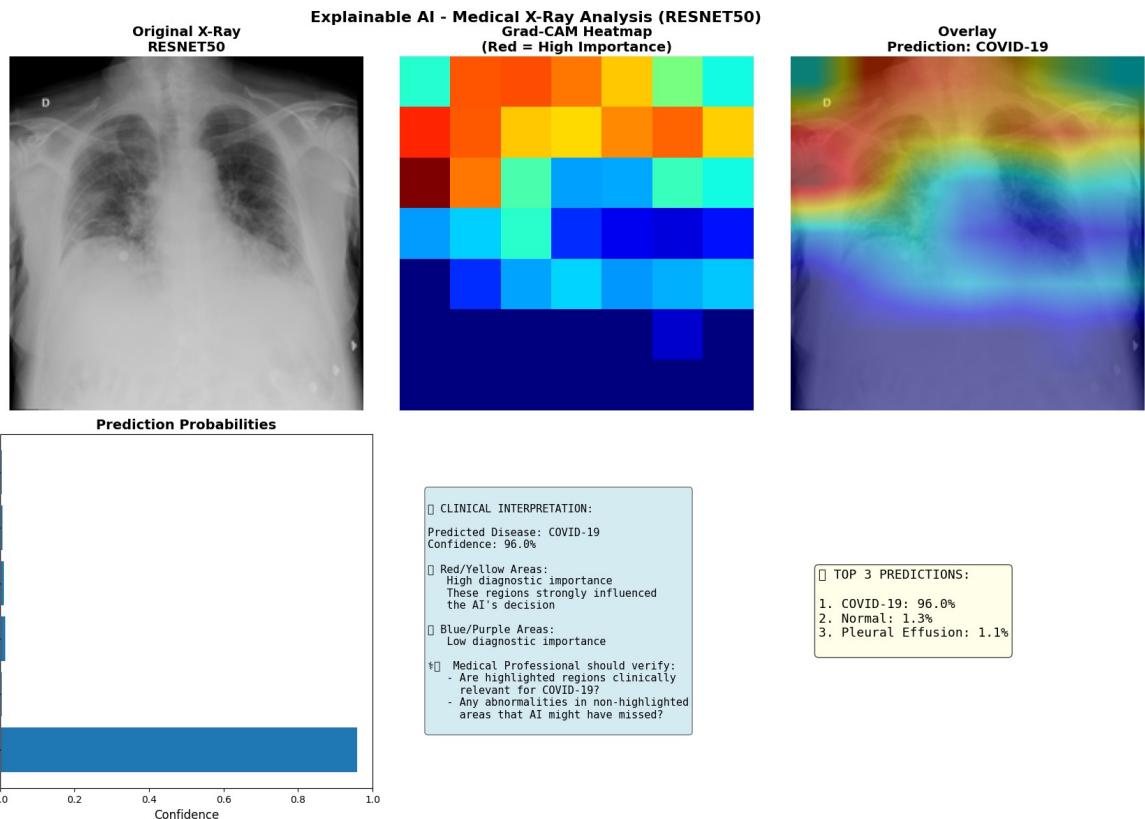
\square RESNET50 loaded successfully!

/tmp/ipykernel_38/2791409445.py:195: UserWarning: Glyph 127973 (\N{HOSPITAL}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/2791409445.py:195: UserWarning: Glyph 128308 (\N{LARGE RED CIRCLE}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/2791409445.py:195: UserWarning: Glyph 128309 (\N{LARGE BLUE CIRCLE}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/2791409445.py:195: UserWarning: Glyph 65039 (\N{VARIATION SELECTOR-16}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/2791409445.py:195: UserWarning: Glyph 128285 (\N{TOP WITH UPWARDS ARROW ABOVE}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/2791409445.py:196: UserWarning: Glyph 127973 (\N{HOSPITAL}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/2791409445.py:196: UserWarning: Glyph 128308 (\N{LARGE RED CIRCLE}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/2791409445.py:196: UserWarning: Glyph 128309 (\N{LARGE BLUE CIRCLE}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/2791409445.py:196: UserWarning: Glyph 65039 (\N{VARIATION SELECTOR-16}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/2791409445.py:196: UserWarning: Glyph 128285 (\N{TOP WITH UPWARDS ARROW ABOVE}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151 : UserWarning: Glyph 127973 (\N{HOSPITAL}) missing from current font.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151 : UserWarning: Glyph 128308 (\N{LARGE RED CIRCLE}) missing from current font.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151 : UserWarning: Glyph 128309 (\N{LARGE BLUE CIRCLE}) missing from current font.
    fig.canvas.print_figure(bytes_io, **kw)
```

```

/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151
: UserWarning: Glyph 65039 (\N{VARIATION SELECTOR-16}) missing from
current font.
    fig.canvas.print_figure(bytes_io, **kw)
/usr/local/lib/python3.11/dist-packages/IPython/core/pylabtools.py:151
: UserWarning: Glyph 128285 (\N{TOP WITH UPWARDS ARROW ABOVE}) missing
from current font.
    fig.canvas.print_figure(bytes_io, **kw)

```



=====

□ PREDICTION SUMMARY

=====

Model: RESNET50
 Diagnosis: COVID-19
 Confidence: 95.95%

Top 3 Differential Diagnoses:

1. COVID-19: 95.95%
2. Normal: 1.31%
3. Pleural Effusion: 1.09%

```
□ XAI visualization complete!
□ Saved as: xai_resnet50.png
```

Densenet-121

```
# =====
# QUICK XAI DEMO - COPY THIS TO KAGGLE NOTEBOOK
# =====

# Install required packages (run once)
# !pip install grad-cam -q

import torch
import torch.nn as nn
import torch.nn.functional as F
from torchvision import models, transforms
from PIL import Image
import numpy as np
import matplotlib.pyplot as plt
import cv2

# =====
# STEP 1: Choose Your Settings
# =====
MODEL_TYPE = "densenet121" # Options: "resnet50", "densenet121",
"efficientnet"
MODEL_PATH =
"/kaggle/input/trained-densenet121-weights/best_densenet121.pth"
IMAGE_PATH = "/kaggle/input/covidx-cxr2/train/sub-S326737_ses-
E53636_run-1_bp-chest_vp-ap_cr-corrected.png"

# =====
# STEP 2: Load Model
# =====
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
class_names = ['COVID-19', 'Cardiomegaly', 'Normal',
               'Pleural Effusion', 'Pneumonia', 'Tuberculosis']

def load_model(model_path, model_type):
    n_classes = 6

    if model_type == "resnet50":
        model = models.resnet50(weights=None)
        in_features = model.fc.in_features
        model.fc = nn.Sequential(nn.Dropout(0.3),
nn.Linear(in_features, n_classes))
        target_layer = model.layer4[-1].conv3

    elif model_type == "densenet121":
```

```

model = models.densenet121(weights=None)
num_features = model.classifier.in_features
model.classifier = nn.Sequential(nn.Dropout(0.3),
nn.Linear(num_features, n_classes))
target_layer = model.features.denseblock4.denselayer15.conv2

elif model_type == "efficientnet":
    model = models.efficientnet_b4(weights=None)
    num_features = model.classifier[1].in_features
    model.classifier = nn.Sequential(nn.Dropout(0.4),
nn.Linear(num_features, n_classes))
    target_layer = model.features[-1][0]

state_dict = torch.load(model_path, map_location=device)
model.load_state_dict(state_dict)
model.to(device)
model.eval()

return model, target_layer

model, target_layer = load_model(MODEL_PATH, MODEL_TYPE)
print(f"\t{MODEL_TYPE.upper()} loaded successfully!")

# =====
# STEP 3: Grad-CAM Implementation
# =====

class GradCAM:
    def __init__(self, model, target_layer):
        self.model = model
        self.target_layer = target_layer
        self.gradients = None
        self.activations = None
        # Use full_backward_hook to avoid warning
        target_layer.register_forward_hook(self.save_activation)
        target_layer.register_full_backward_hook(self.save_gradient)

    def save_activation(self, module, input, output):
        self.activations = output.detach()

    def save_gradient(self, module, grad_input, grad_output):
        self.gradients = grad_output[0].detach()

    def generate(self, input_tensor, target_class=None):
        # Use no_grad for forward pass, then enable for backward
        with torch.set_grad_enabled(True):
            output = self.model(input_tensor)

        if target_class is None:
            target_class = output.argmax(dim=1).item()

```

```

        self.model.zero_grad()
        output[0, target_class].backward()

        gradients = self.gradients[0]
        activations = self.activations[0]
        weights = gradients.mean(dim=(1, 2), keepdim=True)
        cam = (weights * activations).sum(dim=0)
        cam = F.relu(cam)
        cam = cam - cam.min()
        cam = cam / (cam.max() + 1e-8)

    return cam.cpu().numpy(), target_class, output.detach()

# =====
# STEP 4: Process Image
# =====
img_size = 380 if MODEL_TYPE == "efficientnet" else 224
transform = transforms.Compose([
    transforms.Resize((img_size, img_size)),
    transforms.ToTensor(),
    transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224, 0.225])
])

original_image = Image.open(IMAGE_PATH).convert("RGB")
original_np = np.array(original_image.resize((img_size, img_size)))
input_tensor = transform(original_image).unsqueeze(0).to(device)

# =====
# STEP 5: Generate Visualization
# =====
gradcam = GradCAM(model, target_layer)
cam, pred_class, output = gradcam.generate(input_tensor)

probs = F.softmax(output, dim=1)[0].detach()
confidence = probs[pred_class].item()

# Overlay heatmap
cam_resized = cv2.resize(cam, (img_size, img_size))
heatmap = cv2.applyColorMap(np.uint8(255 * cam_resized),
cv2.COLORMAP_JET)
heatmap = cv2.cvtColor(heatmap, cv2.COLOR_BGR2RGB)
overlay = heatmap * 0.5 + original_np * 0.5
overlay = np.uint8(overlay)

# =====
# STEP 6: Display Results
# =====
fig, axes = plt.subplots(2, 3, figsize=(18, 12))

```

```

# Row 1
axes[0, 0].imshow(original_np)
axes[0, 0].set_title(f'Original X-Ray\n{MODEL_TYPE.upper()}', fontsize=14, fontweight='bold')
axes[0, 0].axis('off')

axes[0, 1].imshow(cam, cmap='jet')
axes[0, 1].set_title('Grad-CAM Heatmap\n(Red = High Importance)', fontsize=14, fontweight='bold')
axes[0, 1].axis('off')

axes[0, 2].imshow(overlay)
axes[0, 2].set_title(f'Overlay\nPrediction:\n{class_names[pred_class]}', fontsize=14, fontweight='bold')
axes[0, 2].axis('off')

# Row 2
axes[1, 0].barh(class_names, probs.cpu().numpy())
axes[1, 0].set_xlim([0, 1])
axes[1, 0].set_xlabel('Confidence', fontsize=12)
axes[1, 0].set_title('Prediction Probabilities', fontsize=14, fontweight='bold')

# Clinical interpretation
interpretation = f"""
□ CLINICAL INTERPRETATION:

Predicted Disease: {class_names[pred_class]}
Confidence: {confidence*100:.1f}%

□ Red/Yellow Areas:
    High diagnostic importance
    These regions strongly influenced
    the AI's decision

□ Blue/Purple Areas:
    Low diagnostic importance

⌘ Medical Professional should verify:
    - Are highlighted regions clinically
        relevant for {class_names[pred_class]}?
    - Any abnormalities in non-highlighted
        areas that AI might have missed?
"""

axes[1, 1].text(0.1, 0.5, interpretation, fontsize=11,
                verticalalignment='center', family='monospace',
                bbox=dict(boxstyle='round', facecolor='lightblue',
                alpha=0.5))
axes[1, 1].axis('off')

```

```

# Top 3 predictions
top3_idx = probs.argsort(descending=True)[:3]
top3_text = "TOP 3 PREDICTIONS:\n\n"
for i, idx in enumerate(top3_idx, 1):
    top3_text += f"{i}. {class_names[idx]}: {probs[idx]*100:.1f}%\n"

axes[1, 2].text(0.1, 0.5, top3_text, fontsize=13,
                verticalalignment='center', family='monospace',
                bbox=dict(boxstyle='round', facecolor='lightyellow',
                alpha=0.7))
axes[1, 2].axis('off')

plt.suptitle(f'Explainable AI - Medical X-Ray Analysis
({MODEL_TYPE.upper()})',
             fontsize=16, fontweight='bold')
plt.tight_layout()
plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
plt.show()

print("\n" + "*70)
print(f" PREDICTION SUMMARY")
print("*70)
print(f"Model: {MODEL_TYPE.upper()}")
print(f"Diagnosis: {class_names[pred_class]}")
print(f"Confidence: {confidence*100:.2f}%")
print(f"\nTop 3 Differential Diagnoses:")
for i, idx in enumerate(top3_idx, 1):
    print(f" {i}. {class_names[idx]}: {probs[idx]*100:.2f}%")
print("*70)

# =====
# BONUS: Analyze Multiple Images
# =====

def analyze_test_samples(model, model_type, target_layer, test_df,
n_samples=5):
    """Analyze random test samples with XAI"""
    samples = test_df.sample(n_samples, random_state=42)

    fig, axes = plt.subplots(n_samples, 4, figsize=(20, 5*n_samples))

    for idx, (_, row) in enumerate(samples.iterrows()):
        img_path = row['image_path']
        true_label = row['label']

        # Process image
        img_size = 380 if model_type == "efficientnet" else 224
        transform = transforms.Compose([
            transforms.Resize((img_size, img_size)),
            transforms.ToTensor(),
            transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,

```

```

0.225])
])

original_image = Image.open(img_path).convert("RGB")
original_np = np.array(original_image.resize((img_size,
img_size)))
input_tensor =
transform(original_image).unsqueeze(0).to(device)

# Generate Grad-CAM
gradcam = GradCAM(model, target_layer)
cam, pred_class, output = gradcam.generate(input_tensor)
probs = F.softmax(output, dim=1)[0].detach()

# Create overlay
cam_resized = cv2.resize(cam, (img_size, img_size))
heatmap = cv2.applyColorMap(np.uint8(255 * cam_resized),
cv2.COLORMAP_JET)
heatmap = cv2.cvtColor(heatmap, cv2.COLOR_BGR2RGB)
overlay = heatmap * 0.5 + original_np * 0.5

# Plot
axes[idx, 0].imshow(original_np)
axes[idx, 0].set_title(f'True: {true_label}', fontsize=10)
axes[idx, 0].axis('off')

axes[idx, 1].imshow(cam, cmap='jet')
axes[idx, 1].set_title('Grad-CAM', fontsize=10)
axes[idx, 1].axis('off')

axes[idx, 2].imshow(overlay)
correct = "□" if class_names[pred_class] == true_label else
"☒"
axes[idx, 2].set_title(f'{correct} Pred:
{class_names[pred_class]}', fontsize=10)
axes[idx, 2].axis('off')

axes[idx, 3].barh(class_names, probs.cpu().numpy())
axes[idx, 3].set_xlim([0, 1])
axes[idx, 3].tick_params(labelsize=8)

plt.suptitle(f'Test Set Analysis - {model_type.upper()}', 
fontsize=16, fontweight='bold')
plt.tight_layout()
plt.savefig(f'test_analysis_{model_type}.png', dpi=150,
bbox_inches='tight')
plt.show()

# Uncomment to analyze test samples

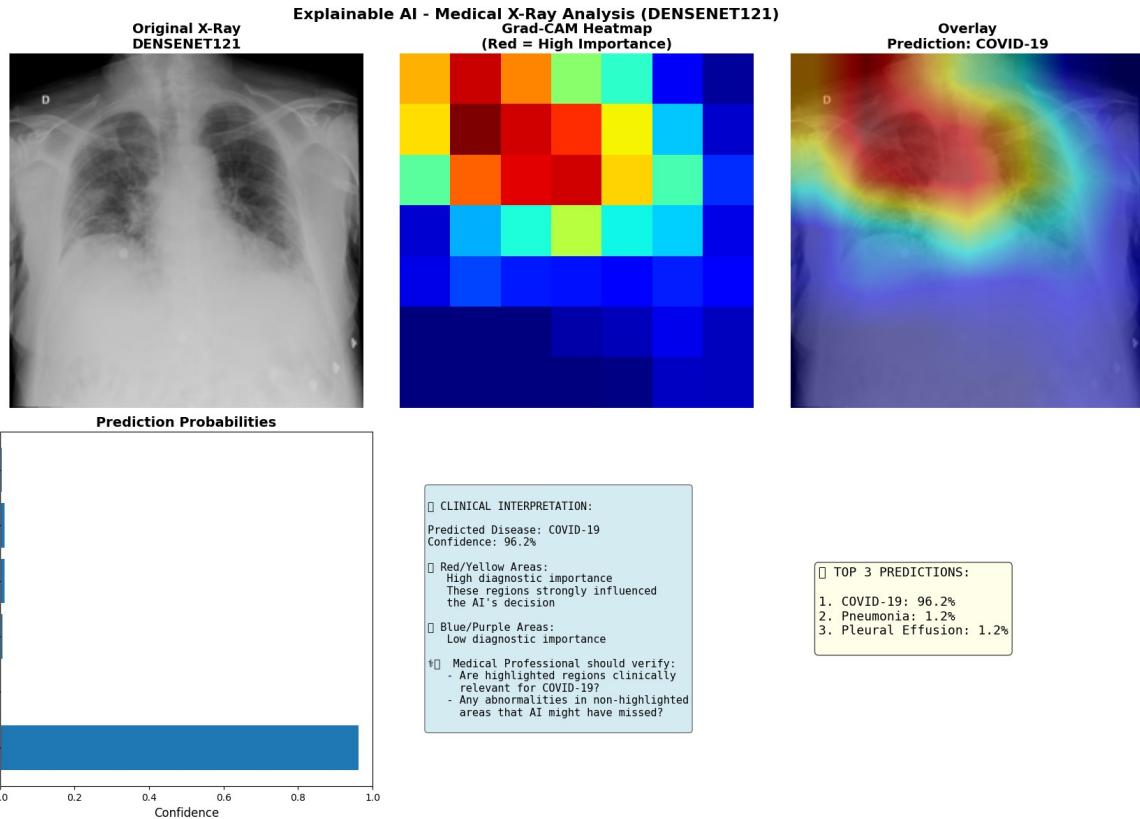
```

```
# import pandas as pd
# test_df =
pd.read_csv("/kaggle/input/balanced-dataset/test_split.csv")
# analyze_test_samples(model, MODEL_TYPE, target_layer, test_df,
n_samples=5)

print("\n\square XAI visualization complete!")
print("\square Saved as: xai_{}.png".format(MODEL_TYPE))

\square DENSENET121 loaded successfully!

/tmp/ipykernel_38/1822279767.py:195: UserWarning: Glyph 127973 (\N{HOSPITAL}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/1822279767.py:195: UserWarning: Glyph 128308 (\N{LARGE RED CIRCLE}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/1822279767.py:195: UserWarning: Glyph 128309 (\N{LARGE BLUE CIRCLE}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/1822279767.py:195: UserWarning: Glyph 65039 (\N{VARIATION SELECTOR-16}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/1822279767.py:195: UserWarning: Glyph 128285 (\N{TOP WITH UPWARDS ARROW ABOVE}) missing from current font.
    plt.tight_layout()
/tmp/ipykernel_38/1822279767.py:196: UserWarning: Glyph 127973 (\N{HOSPITAL}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/1822279767.py:196: UserWarning: Glyph 128308 (\N{LARGE RED CIRCLE}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/1822279767.py:196: UserWarning: Glyph 128309 (\N{LARGE BLUE CIRCLE}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/1822279767.py:196: UserWarning: Glyph 65039 (\N{VARIATION SELECTOR-16}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
/tmp/ipykernel_38/1822279767.py:196: UserWarning: Glyph 128285 (\N{TOP WITH UPWARDS ARROW ABOVE}) missing from current font.
    plt.savefig(f'xai_{MODEL_TYPE}.png', dpi=150, bbox_inches='tight')
```



□ PREDICTION SUMMARY

Model: DENSENET121
Diagnosis: COVID-19
Confidence: 96.24%

Top 3 Differential Diagnoses:
1. COVID-19: 96.24%
2. Pneumonia: 1.19%
3. Pleural Effusion: 1.18%

□ XAI visualization complete!
□ Saved as: xai_densenet121.png

Efficient-net

```
!pip install grad-cam
```

```
Collecting grad-cam
  Downloading grad-cam-1.5.5.tar.gz (7.8 MB)
    7.8/7.8 MB 59.0 MB/s eta
0:00:0000:0100:01
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ents to build wheel ... etadata (pyproject.toml) ... ent already
satisfied: numpy in /usr/local/lib/python3.11/dist-packages (from
grad-cam) (1.26.4)
Requirement already satisfied: Pillow in
/usr/local/lib/python3.11/dist-packages (from grad-cam) (11.2.1)
Requirement already satisfied: torch>=1.7.1 in
/usr/local/lib/python3.11/dist-packages (from grad-cam) (2.6.0+cu124)
Requirement already satisfied: torchvision>=0.8.2 in
/usr/local/lib/python3.11/dist-packages (from grad-cam) (0.21.0+cu124)
Collecting ttach (from grad-cam)
  Downloading ttach-0.0.3-py3-none-any.whl.metadata (5.2 kB)
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-
packages (from grad-cam) (4.67.1)
Requirement already satisfied: opencv-python in
/usr/local/lib/python3.11/dist-packages (from grad-cam) (4.11.0.86)
Requirement already satisfied: matplotlib in
/usr/local/lib/python3.11/dist-packages (from grad-cam) (3.7.2)
Requirement already satisfied: scikit-learn in
/usr/local/lib/python3.11/dist-packages (from grad-cam) (1.2.2)
Requirement already satisfied: filelock in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(3.18.0)
Requirement already satisfied: typing-extensions>=4.10.0 in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(4.14.0)
Requirement already satisfied: networkx in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(3.5)
Requirement already satisfied: jinja2 in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(3.1.6)
Requirement already satisfied: fsspec in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(2025.5.1)
Collecting nvidia-cuda-nvrtc-cu12==12.4.127 (from torch>=1.7.1->grad-
cam)
  Downloading nvidia_cuda_nvrtc_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cuda-runtime-cu12==12.4.127 (from torch>=1.7.1-
>grad-cam)
  Downloading nvidia_cuda_runtime_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cuda-cupti-cu12==12.4.127 (from torch>=1.7.1->grad-
cam)
  Downloading nvidia_cuda_cupti_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
Collecting nvidia-cudnn-cu12==9.1.0.70 (from torch>=1.7.1->grad-cam)
  Downloading nvidia_cudnn_cu12-9.1.0.70-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
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Collecting nvidia-cublas-cu12==12.4.5.8 (from torch>=1.7.1->grad-cam)
  Downloading nvidia_cublas_cu12-12.4.5.8-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
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  Downloading nvidia_cufft_cu12-11.2.1.3-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-curand-cu12==10.3.5.147 (from torch>=1.7.1->grad-
cam)
  Downloading nvidia_curand_cu12-10.3.5.147-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Collecting nvidia-cusolver-cu12==11.6.1.9 (from torch>=1.7.1->grad-
cam)
  Downloading nvidia_cusolver_cu12-11.6.1.9-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
Collecting nvidia-cusparse-cu12==12.3.1.170 (from torch>=1.7.1->grad-
cam)
  Downloading nvidia_cusparse_cu12-12.3.1.170-py3-none-
manylinux2014_x86_64.whl.metadata (1.6 kB)
Requirement already satisfied: nvidia-cusparseelt-cu12==0.6.2 in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(0.6.2)
Requirement already satisfied: nvidia-nccl-cu12==2.21.5 in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(2.21.5)
Requirement already satisfied: nvidia-nvtx-cu12==12.4.127 in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(12.4.127)
Collecting nvidia-nvjitlink-cu12==12.4.127 (from torch>=1.7.1->grad-
cam)
  Downloading nvidia_nvjitlink_cu12-12.4.127-py3-none-
manylinux2014_x86_64.whl.metadata (1.5 kB)
Requirement already satisfied: triton==3.2.0 in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(3.2.0)
Requirement already satisfied: sympy==1.13.1 in
/usr/local/lib/python3.11/dist-packages (from torch>=1.7.1->grad-cam)
(1.13.1)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
/usr/local/lib/python3.11/dist-packages (from sympy==1.13.1-
>torch>=1.7.1->grad-cam) (1.3.0)
Requirement already satisfied: contourpy>=1.0.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->grad-cam)
(1.3.2)
Requirement already satisfied: cycler>=0.10 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->grad-cam)
(0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->grad-cam)
(4.58.4)
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Requirement already satisfied: kiwisolver>=1.0.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->grad-cam)
(1.4.8)
Requirement already satisfied: packaging>=20.0 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->grad-cam)
(25.0)
Requirement already satisfied: pyparsing<3.1,>=2.3.1 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->grad-cam)
(3.0.9)
Requirement already satisfied: python-dateutil>=2.7 in
/usr/local/lib/python3.11/dist-packages (from matplotlib->grad-cam)
(2.9.0.post0)
Requirement already satisfied: mkl_fft in
/usr/local/lib/python3.11/dist-packages (from numpy->grad-cam) (1.3.8)
Requirement already satisfied: mkl_random in
/usr/local/lib/python3.11/dist-packages (from numpy->grad-cam) (1.2.4)
Requirement already satisfied: mkl_umath in
/usr/local/lib/python3.11/dist-packages (from numpy->grad-cam) (0.1.1)
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packages (from numpy->grad-cam) (2025.2.0)
Requirement already satisfied: tbb4py in
/usr/local/lib/python3.11/dist-packages (from numpy->grad-cam)
(2022.2.0)
Requirement already satisfied: mkl-service in
/usr/local/lib/python3.11/dist-packages (from numpy->grad-cam) (2.4.1)
Requirement already satisfied: scipy>=1.3.2 in
/usr/local/lib/python3.11/dist-packages (from scikit-learn->grad-cam)
(1.15.3)
Requirement already satisfied: joblib>=1.1.1 in
/usr/local/lib/python3.11/dist-packages (from scikit-learn->grad-cam)
(1.5.1)
Requirement already satisfied: threadpoolctl>=2.0.0 in
/usr/local/lib/python3.11/dist-packages (from scikit-learn->grad-cam)
(3.6.0)
Requirement already satisfied: six>=1.5 in
/usr/local/lib/python3.11/dist-packages (from python-dateutil>=2.7-
>matplotlib->grad-cam) (1.17.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.11/dist-packages (from jinja2->torch>=1.7.1-
>grad-cam) (3.0.2)
Requirement already satisfied: intel-openmp<2026,>=2024 in
/usr/local/lib/python3.11/dist-packages (from mkl->numpy->grad-cam)
(2024.2.0)
Requirement already satisfied: tbb==2022.* in
/usr/local/lib/python3.11/dist-packages (from mkl->numpy->grad-cam)
(2022.2.0)
Requirement already satisfied: tcmlib==1.* in
/usr/local/lib/python3.11/dist-packages (from tbb==2022.*->mkl->numpy-
>grad-cam) (1.4.0)
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Requirement already satisfied: intel-cmplr-lib-rt in
/usr/local/lib/python3.11/dist-packages (from mkl_umath->numpy->grad-
cam) (2024.2.0)
Requirement already satisfied: intel-cmplr-lib-ur==2024.2.0 in
/usr/local/lib/python3.11/dist-packages (from intel-
openmp<2026,>=2024->mkl->numpy->grad-cam) (2024.2.0)
Downloading nvidia_cublas_cu12-12.4.5.8-py3-none-
manylinux2014_x86_64.whl (363.4 MB) ━━━━━━━━ 363.4/363.4 MB 4.6 MB/s eta
0:00:00:00:0100:01
anylinux2014_x86_64.whl (13.8 MB) ━━━━━━━━ 13.8/13.8 MB 103.1 MB/s eta
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anylinux2014_x86_64.whl (24.6 MB) ━━━━━━━━ 24.6/24.6 MB 71.9 MB/s eta
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e_cu12-12.4.127-py3-none-manylinux2014_x86_64.whl (883 kB) ━━━━━━ 883.7/883.7 kB 48.6 MB/s eta
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anylinux2014_x86_64.whl (211.5 MB) ━━━━━━━━ 211.5/211.5 MB 6.1 MB/s eta
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anylinux2014_x86_64.whl (56.3 MB) ━━━━━━ 56.3/56.3 MB 30.6 MB/s eta
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anylinux2014_x86_64.whl (127.9 MB) ━━━━━━ 127.9/127.9 MB 13.3 MB/s eta
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anylinux2014_x86_64.whl (207.5 MB) ━━━━━━ 207.5/207.5 MB 2.0 MB/s eta
0:00:00:00:0100:01
anylinux2014_x86_64.whl (21.1 MB) ━━━━━━ 21.1/21.1 MB 84.5 MB/s eta
0:00:00:00:0100:01

Building wheel for grad-cam (pyproject.toml) ... :
filename=grad_cam-1.5.5-py3-none-any.whl size=44284
sha256=d9af0bafb38f6d25756b950a54a8f5860fe2aeeead782f0eb865d5186038597
9
Stored in directory:
/root/.cache/pip/wheels/bc/52/78/893c3b94279ef238f43a9e89608af648de401
b96415bebbd1f
Successfully built grad-cam
Installing collected packages: ttach, nvidia-nvjitlink-cu12, nvidia-
curand-cu12, nvidia-cufft-cu12, nvidia-cuda-runtime-cu12, nvidia-cuda-
nvrtc-cu12, nvidia-cuda-cupti-cu12, nvidia-cublas-cu12, nvidia-
```

```
cusparse-cu12, nvidia-cudnn-cu12, nvidia-cusolver-cu12, grad-cam
Attempting uninstall: nvidia-nvjitlink-cu12
    Found existing installation: nvidia-nvjitlink-cu12 12.5.82
    Uninstalling nvidia-nvjitlink-cu12-12.5.82:
        Successfully uninstalled nvidia-nvjitlink-cu12-12.5.82
Attempting uninstall: nvidia-curand-cu12
    Found existing installation: nvidia-curand-cu12 10.3.6.82
    Uninstalling nvidia-curand-cu12-10.3.6.82:
        Successfully uninstalled nvidia-curand-cu12-10.3.6.82
Attempting uninstall: nvidia-cufft-cu12
    Found existing installation: nvidia-cufft-cu12 11.2.3.61
    Uninstalling nvidia-cufft-cu12-11.2.3.61:
        Successfully uninstalled nvidia-cufft-cu12-11.2.3.61
Attempting uninstall: nvidia-cuda-runtime-cu12
    Found existing installation: nvidia-cuda-runtime-cu12 12.5.82
    Uninstalling nvidia-cuda-runtime-cu12-12.5.82:
        Successfully uninstalled nvidia-cuda-runtime-cu12-12.5.82
Attempting uninstall: nvidia-cuda-nvrtc-cu12
    Found existing installation: nvidia-cuda-nvrtc-cu12 12.5.82
    Uninstalling nvidia-cuda-nvrtc-cu12-12.5.82:
        Successfully uninstalled nvidia-cuda-nvrtc-cu12-12.5.82
Attempting uninstall: nvidia-cuda-cupti-cu12
    Found existing installation: nvidia-cuda-cupti-cu12 12.5.82
    Uninstalling nvidia-cuda-cupti-cu12-12.5.82:
        Successfully uninstalled nvidia-cuda-cupti-cu12-12.5.82
Attempting uninstall: nvidia-cublas-cu12
    Found existing installation: nvidia-cublas-cu12 12.5.3.2
    Uninstalling nvidia-cublas-cu12-12.5.3.2:
        Successfully uninstalled nvidia-cublas-cu12-12.5.3.2
Attempting uninstall: nvidia-cusparse-cu12
    Found existing installation: nvidia-cusparse-cu12 12.5.1.3
    Uninstalling nvidia-cusparse-cu12-12.5.1.3:
        Successfully uninstalled nvidia-cusparse-cu12-12.5.1.3
Attempting uninstall: nvidia-cudnn-cu12
    Found existing installation: nvidia-cudnn-cu12 9.3.0.75
    Uninstalling nvidia-cudnn-cu12-9.3.0.75:
        Successfully uninstalled nvidia-cudnn-cu12-9.3.0.75
Attempting uninstall: nvidia-cusolver-cu12
    Found existing installation: nvidia-cusolver-cu12 11.6.3.83
    Uninstalling nvidia-cusolver-cu12-11.6.3.83:
        Successfully uninstalled nvidia-cusolver-cu12-11.6.3.83
Successfully installed grad-cam-1.5.5 nvidia-cublas-cu12-12.4.5.8
nvidia-cuda-cupti-cu12-12.4.127 nvidia-cuda-nvrtc-cu12-12.4.127
nvidia-cuda-runtime-cu12-12.4.127 nvidia-cudnn-cu12-9.1.0.70 nvidia-
cufft-cu12-11.2.1.3 nvidia-curand-cu12-10.3.5.147 nvidia-cusolver-
cu12-11.6.1.9 nvidia-cusparse-cu12-12.3.1.170 nvidia-nvjitlink-cu12-
12.4.127 ttach-0.0.3
```

"""

Cleaned EfficientNet XAI Visualization

Fixes: quarter circle artifact, redundant code, better heatmap processing

```

"""
import torch
import torch.nn as nn
import torch.nn.functional as F
from torchvision import models, transforms
from PIL import Image
import numpy as np
import matplotlib.pyplot as plt
import cv2

from pytorch_grad_cam import GradCAM, GradCAMPlusPlus, LayerCAM
from pytorch_grad_cam.utils.image import show_cam_on_image
from pytorch_grad_cam.utils.model_targets import
ClassifierOutputTarget

# =====
# CONFIGURATION
# =====
MODEL_PATH =
"/kaggle/input/trained-efficient-net-weights/best_efficientnet.pth"
IMAGE_PATH = "/kaggle/input/covidx-cxr2/train/sub-S326737_ses-
E53636_run-1_bp-chest_vp-ap_cr-corrected.png"

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
class_names = ['COVID-19', 'Cardiomegaly', 'Normal',
               'Pleural Effusion', 'Pneumonia', 'Tuberculosis']
IMG_SIZE = 380

print("=*70)
print("EFFICIENTNET XAI VISUALIZATION")
print("=*70)

# =====
# LOAD MODEL
# =====
def load_model():
    model = models.efficientnet_b4(weights=None)
    num_features = model.classifier[1].in_features
    model.classifier = nn.Sequential(
        nn.Dropout(0.4),
        nn.Linear(num_features, 6)
    )
    state_dict = torch.load(MODEL_PATH, map_location=device)
    model.load_state_dict(state_dict)
    model.to(device)
    model.eval()
    return model

```

```

model = load_model()
print("Model loaded")

# =====
# PROCESS IMAGE - FIX FOR QUARTER CIRCLE
# =====
def prepare_image(image_path, size=IMG_SIZE):
    """Prepare image ensuring proper dimensions"""
    original_pil = Image.open(image_path).convert("RGB")

    # Resize for model
    resized_pil = original_pil.resize((size, size),
Image.Resampling.BILINEAR)

    # Create numpy array for visualization (0-1 range)
    img_np = np.array(resized_pil).astype(np.float32) / 255.0

    # Create tensor for model
    transform = transforms.Compose([
        transforms.ToTensor(),
        transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,
0.225])
    ])
    img_tensor = transform(resized_pil).unsqueeze(0).to(device)

    return img_np, img_tensor

img_rgb, input_tensor = prepare_image(IMAGE_PATH)
print(f"Image processed: shape={img_rgb.shape}")

# =====
# GET PREDICTION
# =====
with torch.no_grad():
    output = model(input_tensor)
    probs = F.softmax(output, dim=1)[0]
    pred_class = probs.argmax().item()
    confidence = probs[pred_class].item()

print(f"Prediction: {class_names[pred_class]} ({confidence*100:.2f} %)")

# =====
# FIND BEST LAYER
# =====
def evaluate_layers(model, input_tensor, pred_class):
    """Test multiple layers and find the best one"""
    layer_configs = [
        ("features[8] (Last)", model.features[8]),

```

```

        ("features[7]", model.features[7]),
        ("features[6]", model.features[6]),
        ("features[5]", model.features[5]),
    ]

targets = [ClassifierOutputTarget(pred_class)]
results = {}

print("\nLayer Analysis:")
print("-" * 70)

for name, target_layer in layer_configs:
    try:
        cam = LayerCAM(model=model, target_layers=[target_layer])
        grayscale_cam = cam(input_tensor=input_tensor,
targets=targets)[0, :]

        # Calculate metrics
        active_ratio = (grayscale_cam > 0.1).mean()
        mean_val = grayscale_cam.mean()
        std_val = grayscale_cam.std()

        score = active_ratio * std_val # Balance coverage and
variation

        results[name] = {
            'cam': grayscale_cam,
            'layer': target_layer,
            'score': score,
            'active_ratio': active_ratio,
            'mean': mean_val,
            'std': std_val
        }

        print(f"{name:20s} | Active: {active_ratio:.1%} | "
              f"Mean: {mean_val:.3f} | Std: {std_val:.3f} | Score: "
{score:.3f})"

    except Exception as e:
        print(f"{name:20s} | Failed: {str(e)[:50]}")

# Find best layer by score
best_name = max(results.keys(), key=lambda x: results[x]['score'])
print(f"\n Best layer: {best_name} (score: {results[best_name]
['score']:.3f})")

return results[best_name]

best_result = evaluate_layers(model, input_tensor, pred_class)

```

```

# =====
# ENHANCED HEATMAP PROCESSING - FIXES ARTIFACTS
# =====
def enhance_heatmap(heatmap, percentile_low=20, percentile_high=99):
    """
    Enhanced heatmap processing to remove artifacts
    """

    # Remove low-value noise
    threshold_low = np.percentile(heatmap, percentile_low)
    threshold_high = np.percentile(heatmap, percentile_high)

    enhanced = heatmap.copy()
    enhanced[enhanced < threshold_low] = 0

    # Clip extreme values (helps with artifacts)
    enhanced = np.clip(enhanced, 0, threshold_high)

    # Normalize to 0-1
    if enhanced.max() > 0:
        enhanced = (enhanced - enhanced.min()) / (enhanced.max() -
enhanced.min())

    # Apply gamma correction for better visibility
    enhanced = np.power(enhanced, 0.7)

    return enhanced

heatmap_enhanced = enhance_heatmap(best_result['cam'])

# =====
# CREATE OVERLAY - FIX FOR PROPER ALIGNMENT
# =====
def create_overlay(img_rgb, heatmap, alpha=0.5):
    """
    Create overlay ensuring proper size alignment
    # Ensure heatmap is same size as image
    if heatmap.shape != img_rgb.shape[:2]:
        heatmap = cv2.resize(heatmap, (img_rgb.shape[1],
img_rgb.shape[0]))

    # Create colored heatmap
    heatmap_colored = cv2.applyColorMap(
        (heatmap * 255).astype(np.uint8),
        cv2.COLORMAP_JET
    )
    heatmap_colored = cv2.cvtColor(heatmap_colored, cv2.COLOR_BGR2RGB) /
255.0

    # Blend
    overlay = heatmap_colored * alpha + img_rgb * (1 - alpha)

```

```

    overlay = np.clip(overlay, 0, 1)

    return overlay

overlay = create_overlay(img_rgb, heatmap_enhanced)

# =====
# CLEAN VISUALIZATION
# =====
fig = plt.figure(figsize=(20, 10))
gs = fig.add_gridspec(2, 4, hspace=0.3, wspace=0.3)

# Row 1: Main visualizations
ax1 = fig.add_subplot(gs[0, 0])
ax1.imshow(img_rgb)
ax1.set_title('(A) Original X-Ray', fontsize=14, fontweight='bold')
ax1.axis('off')

ax2 = fig.add_subplot(gs[0, 1])
im = ax2.imshow(heatmap_enhanced, cmap='jet',
interpolation='bilinear')
ax2.set_title('(B) Attention Heatmap\n(Enhanced)', fontsize=14,
fontweight='bold')
ax2.axis('off')
plt.colorbar(im, ax=ax2, fraction=0.046, pad=0.04)

ax3 = fig.add_subplot(gs[0, 2])
ax3.imshow(overlay)
ax3.set_title(f'(C) Overlay\n{class_names[pred_class]}\n({confidence*100:.1f}%)',
              fontsize=14, fontweight='bold')
ax3.axis('off')

ax4 = fig.add_subplot(gs[0, 3])
colors = ['darkgreen' if i == pred_class else 'steelblue' for i in
range(len(class_names))]
ax4.bart(class_names, probs.cpu().numpy(), color=colors)
ax4.set_xlim([0, 1])
ax4.set_xlabel('Confidence', fontsize=12, fontweight='bold')
ax4.set_title('(D) Predictions', fontsize=14, fontweight='bold')
ax4.grid(axis='x', alpha=0.3)

# Row 2: Additional views
ax5 = fig.add_subplot(gs[1, 0])
ax5.imshow(img_rgb)
ax5.contour(heatmap_enhanced, levels=5, colors='red', linewidths=1.5,
alpha=0.6)
ax5.set_title('(E) Contour View', fontsize=14, fontweight='bold')
ax5.axis('off')

```

```

ax6 = fig.add_subplot(gs[1, 1])
# Thresholded view
threshold_mask = heatmap_enhanced > 0.5
ax6.imshow(img_rgb)
ax6.imshow(threshold_mask, cmap='Reds', alpha=0.4)
ax6.set_title('(F) High Attention Regions\n(threshold > 0.5)', fontsize=14, fontweight='bold')
ax6.axis('off')

ax7 = fig.add_subplot(gs[1, 2])
# Side-by-side
combined = np.hstack([img_rgb, overlay])
ax7.imshow(combined)
ax7.set_title('(G) Comparison', fontsize=14, fontweight='bold')
ax7.axis('off')

# Statistics box
ax8 = fig.add_subplot(gs[1, 3])
top3_idx = probs.argsort(descending=True)[:3]
stats_text = f"""
MODEL: EfficientNet-B4

PREDICTION:
{class_names[pred_class]}: {confidence*100:.1f}%

TOP 3:
"""
for i, idx in enumerate(top3_idx, 1):
    stats_text += f" {i}. {class_names[idx]}: {probs[idx]*100:.1f}%\n"
stats_text += f"""

HEATMAP:
Active area: {best_result['active_ratio']:.1%}
Mean activation: {best_result['mean']:.3f}
Variation: {best_result['std']:.3f}

Red/yellow = high attention
Blue/dark = low attention
"""

ax8.text(0.05, 0.5, stats_text, fontsize=11,
         verticalalignment='center', family='monospace',
         bbox=dict(boxstyle='round', facecolor='lightgray',
alpha=0.3))
ax8.axis('off')

plt.suptitle(f'Explainable AI: {class_names[pred_class]} Detection',
             fontsize=16, fontweight='bold')
plt.savefig('xai_efficientnet_clean.png', dpi=300,

```

```
bbox_inches='tight', facecolor='white')
plt.show()

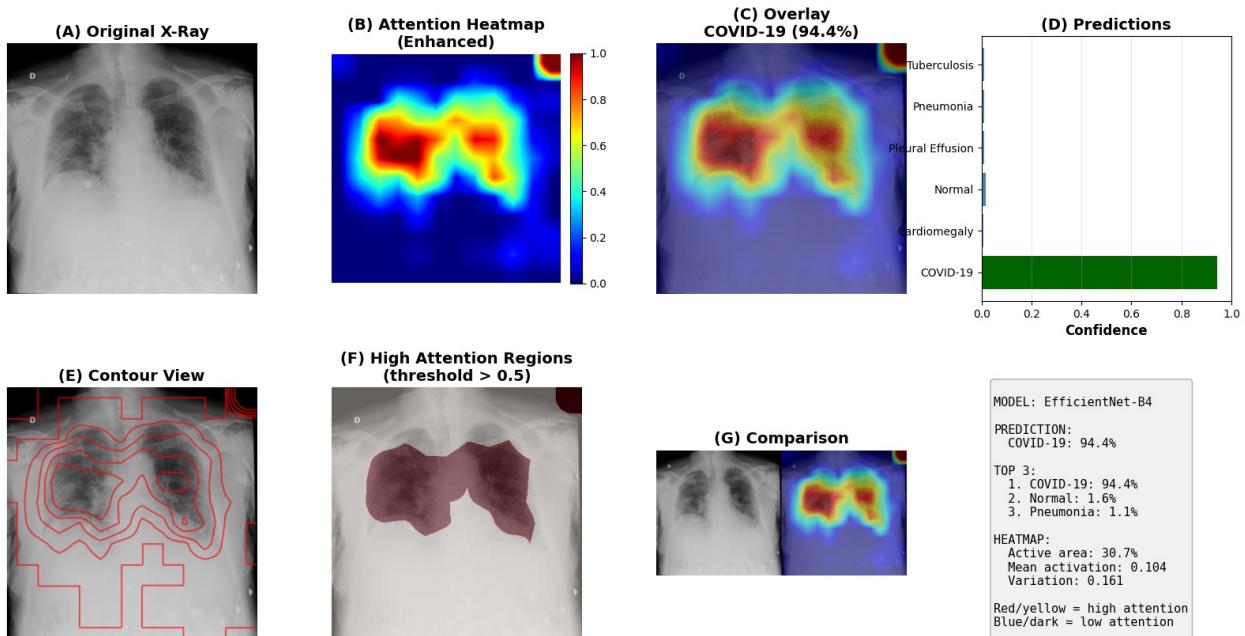
print("\n" + "*70)
print("SUMMARY")
print("*70)
print(f"\t Visualization saved: xai_efficientnet_clean.png")
print(f"\t Prediction: {class_names[pred_class]} ({confidence*100:.2f} %)")
print(f"\t Active attention area: {best_result['active_ratio']:.1%}")
print("*70)

=====
EFFICIENTNET XAI VISUALIZATION
=====
[] Model loaded
[] Image processed: shape=(380, 380, 3)
[] Prediction: COVID-19 (94.41%)

Layer Analysis:
-----
features[8] (Last) | Active: 1.3% | Mean: 0.010 | Std: 0.069 |
Score: 0.001
features[7]         | Active: 30.7% | Mean: 0.104 | Std: 0.161 |
Score: 0.049
features[6]         | Active: 3.5% | Mean: 0.024 | Std: 0.098 |
Score: 0.003
features[5]         | Active: 21.8% | Mean: 0.076 | Std: 0.130 |
Score: 0.028

[] Best layer: features[7] (score: 0.049)
```

Explainable AI: COVID-19 Detection



SUMMARY

- Visualization saved: xai_efficientnet_clean.png
- Prediction: COVID-19 (94.41%)
- Active attention area: 30.7%

'''

Cleaned EfficientNet XAI Visualization

Fixes: quarter circle artifact, redundant code, better heatmap processing

'''

```
import torch
import torch.nn as nn
import torch.nn.functional as F
from torchvision import models, transforms
from PIL import Image
import numpy as np
import matplotlib.pyplot as plt
import cv2

from pytorch_grad_cam import GradCAM, GradCAMPlusPlus, LayerCAM
from pytorch_grad_cam.utils.image import show_cam_on_image
from pytorch_grad_cam.utils.model_targets import
ClassifierOutputTarget
```

```

# =====
# CONFIGURATION
# =====
MODEL_PATH =
"/kaggle/input/trained-efficient-net-weights/best_efficientnet.pth"
IMAGE_PATH = "/kaggle/input/covidx-cxr2/train/fd060e38-c89d-4bef-b9aa-
427a97a1cf9a.png"

device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
class_names = ['COVID-19', 'Cardiomegaly', 'Normal',
               'Pleural Effusion', 'Pneumonia', 'Tuberculosis']
IMG_SIZE = 380

print("*"*70)
print("EFFICIENTNET XAI VISUALIZATION")
print("*"*70)

# =====
# LOAD MODEL
# =====
def load_model():
    model = models.efficientnet_b4(weights=None)
    num_features = model.classifier[1].in_features
    model.classifier = nn.Sequential(
        nn.Dropout(0.4),
        nn.Linear(num_features, 6)
    )
    state_dict = torch.load(MODEL_PATH, map_location=device)
    model.load_state_dict(state_dict)
    model.to(device)
    model.eval()
    return model

model = load_model()
print("Model loaded")

# =====
# PROCESS IMAGE - FIX FOR QUARTER CIRCLE
# =====
def prepare_image(image_path, size=IMG_SIZE):
    """Prepare image ensuring proper dimensions"""
    original_pil = Image.open(image_path).convert("RGB")

    # Resize for model
    resized_pil = original_pil.resize((size, size),
                                      Image.Resampling.BILINEAR)

    # Create numpy array for visualization (0-1 range)
    img_np = np.array(resized_pil).astype(np.float32) / 255.0

```

```

# Create tensor for model
transform = transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize([0.485, 0.456, 0.406], [0.229, 0.224,
0.225])
])
img_tensor = transform(resized_pil).unsqueeze(0).to(device)

return img_np, img_tensor

img_rgb, input_tensor = prepare_image(IMAGE_PATH)
print(f"\u25b6 Image processed: shape={img_rgb.shape}")

# =====
# GET PREDICTION
# =====
with torch.no_grad():
    output = model(input_tensor)
    probs = F.softmax(output, dim=1)[0]
    pred_class = probs.argmax().item()
    confidence = probs[pred_class].item()

print(f"\u25b6 Prediction: {class_names[pred_class]} ({confidence*100:.2f} %)")

# =====
# FIND BEST LAYER
# =====
def evaluate_layers(model, input_tensor, pred_class):
    """Test multiple layers and find the best one"""
    layer_configs = [
        ("features[8] (Last)", model.features[8]),
        ("features[7]", model.features[7]),
        ("features[6]", model.features[6]),
        ("features[5]", model.features[5]),
    ]
    targets = [ClassifierOutputTarget(pred_class)]
    results = {}

    print("\nLayer Analysis:")
    print("-" * 70)

    for name, target_layer in layer_configs:
        try:
            cam = LayerCAM(model=model, target_layers=[target_layer])
            grayscale_cam = cam(input_tensor=input_tensor,
targets=targets)[0, :]
        
```

Calculate metrics

```

active_ratio = (grayscale_cam > 0.1).mean()
mean_val = grayscale_cam.mean()
std_val = grayscale_cam.std()

score = active_ratio * std_val # Balance coverage and
variation

results[name] = {
    'cam': grayscale_cam,
    'layer': target_layer,
    'score': score,
    'active_ratio': active_ratio,
    'mean': mean_val,
    'std': std_val
}

print(f"\n{name:20s} | Active: {active_ratio:.1%} | "
      f"Mean: {mean_val:.3f} | Std: {std_val:.3f} | Score: "
{score:.3f})"

except Exception as e:
    print(f"\n{name:20s} | Failed: {str(e)[:50]}")

# Find best layer by score
best_name = max(results.keys(), key=lambda x: results[x]['score'])
print(f"\nBest layer: {best_name} (score: {results[best_name]"
['score']:.3f}))"

return results[best_name]

best_result = evaluate_layers(model, input_tensor, pred_class)

# =====
# ENHANCED HEATMAP PROCESSING - FIXES ARTIFACTS
# =====
def enhance_heatmap(heatmap, percentile_low=20, percentile_high=99):
    """
    Enhanced heatmap processing to remove artifacts
    """
    # Remove low-value noise
    threshold_low = np.percentile(heatmap, percentile_low)
    threshold_high = np.percentile(heatmap, percentile_high)

    enhanced = heatmap.copy()
    enhanced[enhanced < threshold_low] = 0

    # Clip extreme values (helps with artifacts)
    enhanced = np.clip(enhanced, 0, threshold_high)

```

```

# Normalize to 0-1
if enhanced.max() > 0:
    enhanced = (enhanced - enhanced.min()) / (enhanced.max() -
enhanced.min())

# Apply gamma correction for better visibility
enhanced = np.power(enhanced, 0.7)

return enhanced

heatmap_enhanced = enhance_heatmap(best_result['cam'])

# =====
# CREATE OVERLAY - FIX FOR PROPER ALIGNMENT
# =====
def create_overlay(img_rgb, heatmap, alpha=0.5):
    """Create overlay ensuring proper size alignment"""
    # Ensure heatmap is same size as image
    if heatmap.shape != img_rgb.shape[:2]:
        heatmap = cv2.resize(heatmap, (img_rgb.shape[1],
img_rgb.shape[0]))

    # Create colored heatmap
    heatmap_colored = cv2.applyColorMap(
        (heatmap * 255).astype(np.uint8),
        cv2.COLORMAP_JET
    )
    heatmap_colored = cv2.cvtColor(heatmap_colored, cv2.COLOR_BGR2RGB)
/ 255.0

    # Blend
    overlay = heatmap_colored * alpha + img_rgb * (1 - alpha)
    overlay = np.clip(overlay, 0, 1)

    return overlay

overlay = create_overlay(img_rgb, heatmap_enhanced)

# =====
# CLEAN VISUALIZATION
# =====
fig = plt.figure(figsize=(20, 10))
gs = fig.add_gridspec(2, 4, hspace=0.3, wspace=0.3)

# Row 1: Main visualizations
ax1 = fig.add_subplot(gs[0, 0])
ax1.imshow(img_rgb)
ax1.set_title('(A) Original X-Ray', fontsize=14, fontweight='bold')
ax1.axis('off')

```

```

ax2 = fig.add_subplot(gs[0, 1])
im = ax2.imshow(heatmap_enhanced, cmap='jet',
interpolation='bilinear')
ax2.set_title('(B) Attention Heatmap\n(Enhanced)', fontsize=14,
fontweight='bold')
ax2.axis('off')
plt.colorbar(im, ax=ax2, fraction=0.046, pad=0.04)

ax3 = fig.add_subplot(gs[0, 2])
ax3.imshow(overlay)
ax3.set_title(f'(C) Overlay\n{class_names[pred_class]}\n({confidence*100:.1f}%)',
              fontsize=14, fontweight='bold')
ax3.axis('off')

ax4 = fig.add_subplot(gs[0, 3])
colors = ['darkgreen' if i == pred_class else 'steelblue' for i in
range(len(class_names))]
ax4.bach(class_names, probs.cpu().numpy(), color=colors)
ax4.set_xlim([0, 1])
ax4.set_xlabel('Confidence', fontsize=12, fontweight='bold')
ax4.set_title('(D) Predictions', fontsize=14, fontweight='bold')
ax4.grid(axis='x', alpha=0.3)

# Row 2: Additional views
ax5 = fig.add_subplot(gs[1, 0])
ax5.imshow(img_rgb)
ax5.contour(heatmap_enhanced, levels=5, colors='red', linewidths=1.5,
alpha=0.6)
ax5.set_title('(E) Contour View', fontsize=14, fontweight='bold')
ax5.axis('off')

ax6 = fig.add_subplot(gs[1, 1])
# Thresholded view
threshold_mask = heatmap_enhanced > 0.5
ax6.imshow(img_rgb)
ax6.imshow(threshold_mask, cmap='Reds', alpha=0.4)
ax6.set_title('(F) High Attention Regions\n(threshold > 0.5)',
              fontsize=14, fontweight='bold')
ax6.axis('off')

ax7 = fig.add_subplot(gs[1, 2])
# Side-by-side
combined = np.hstack([img_rgb, overlay])
ax7.imshow(combined)
ax7.set_title('(G) Comparison', fontsize=14, fontweight='bold')
ax7.axis('off')

# Statistics box
ax8 = fig.add_subplot(gs[1, 3])

```

```

top3_idx = probs.argsort(descending=True)[:3]
stats_text = """
MODEL: EfficientNet-B4

PREDICTION:
{class_names[pred_class]}: {confidence*100:.1f}%

TOP 3:
"""
for i, idx in enumerate(top3_idx, 1):
    stats_text += f" {i}. {class_names[idx]}: {probs[idx]*100:.1f}%\n"

stats_text += """
HEATMAP:
Active area: {best_result['active_ratio']:.1%}
Mean activation: {best_result['mean']:.3f}
Variation: {best_result['std']:.3f}

Red/yellow = high attention
Blue/dark = low attention
"""

ax8.text(0.05, 0.5, stats_text, fontsize=11,
         verticalalignment='center', family='monospace',
         bbox=dict(boxstyle='round', facecolor='lightgray',
alpha=0.3))
ax8.axis('off')

plt.suptitle(f'Explainable AI: {class_names[pred_class]} Detection',
             fontsize=16, fontweight='bold')
plt.savefig('xai_efficientnet_clean.png', dpi=300,
bbox_inches='tight', facecolor='white')
plt.show()

print("\n" + "="*70)
print("SUMMARY")
print("="*70)
print(f" Visualization saved: xai_efficientnet_clean.png")
print(f" Prediction: {class_names[pred_class]} ({confidence*100:.2f}%)")
print(f" Active attention area: {best_result['active_ratio']:.1%}")
print("="*70)

=====
EFFICIENTNET XAI VISUALIZATION
=====

Model loaded
Image processed: shape=(380, 380, 3)
Prediction: Normal (77.77%)

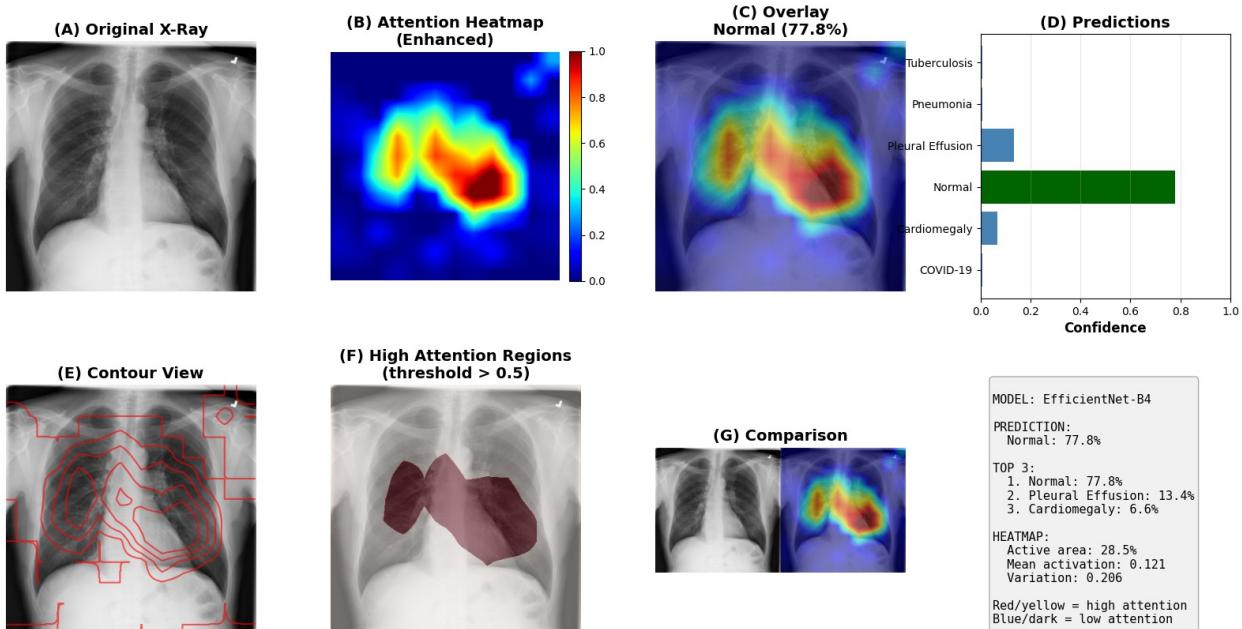
```

Layer Analysis:

```
features[8] (Last) | Active: 18.3% | Mean: 0.056 | Std: 0.120 |
Score: 0.022
features[7]         | Active: 28.5% | Mean: 0.121 | Std: 0.206 |
Score: 0.059
features[6]         | Active: 18.3% | Mean: 0.057 | Std: 0.117 |
Score: 0.021
features[5]         | Active: 14.3% | Mean: 0.047 | Std: 0.086 |
Score: 0.012
```

□ Best layer: features[7] (score: 0.059)

Explainable AI: Normal Detection



SUMMARY

- Visualization saved: xai_efficientnet_clean.png
- Prediction: Normal (77.77%)
- Active attention area: 28.5%