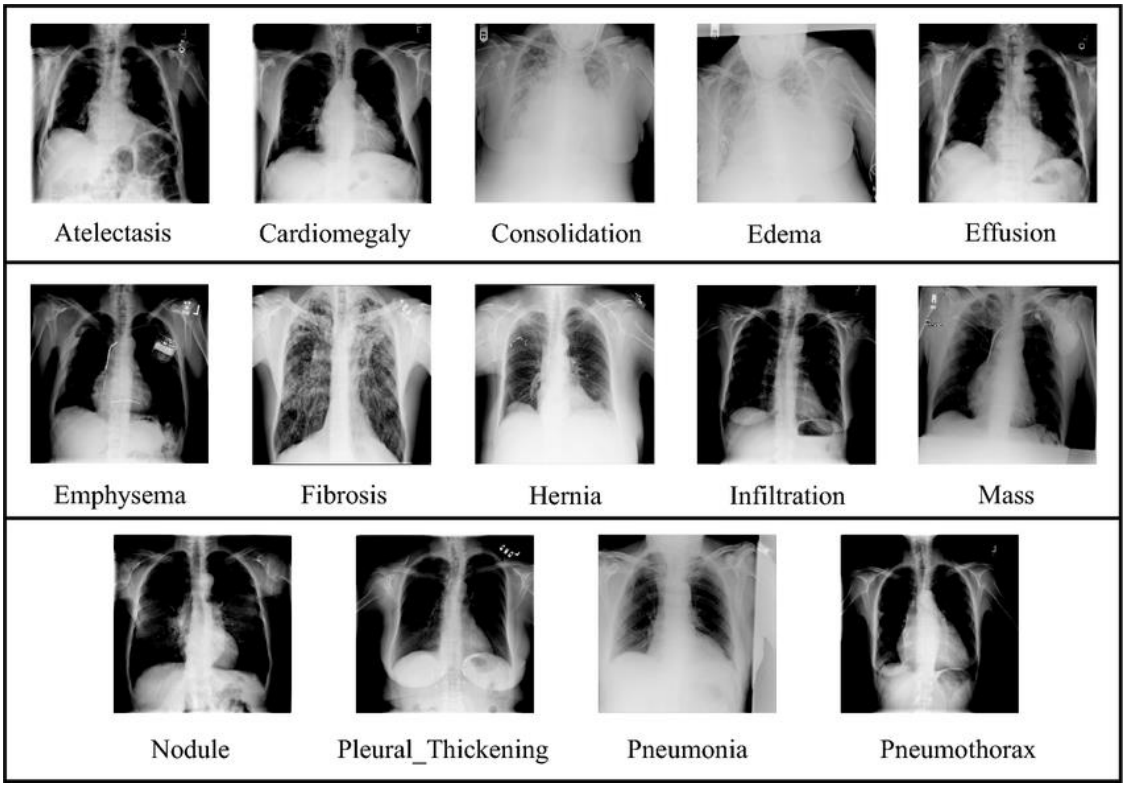
Chest X Ray Classification using DenseNet121 and Swin Transformer

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import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import cv2
import seaborn as sns
import os
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
import torchvision.models as models
import torchvision.transforms as transforms
from torch.utils.data import DataLoader, Dataset
from torch.cuda.amp import autocast, GradScaler
from sklearn.metrics import roc_auc_score, roc_curve
from sklearn.model_selection import train_test_split
from pathlib import Path
from scipy.optimize import differential_evolution, LinearConstraint
import timm
import warnings
warnings.filterwarnings("ignore")
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class CFG:
    CLASS_NAMES = [
        "Atelectasis", "Cardiomegaly", "Effusion", "Infiltration", "Mass",
        "Nodule", "Pneumonia", "Pneumothorax", "Consolidation", "Edema",
        "Emphysema", "Fibrosis", "Pleural_Thickening", "Hernia"
    ]
    BASE_PATH = Path("/kaggle/input/nih-chest-x-ray-14-224x224-
resized/images-224/images-224")
    DATA_PATH = Path("/kaggle/input/nih-chest-x-ray-14-224x224-resized")
    OUTPUT_PATH = Path("/kaggle/working")
    BEST_MODEL_PATH = "models/best_model.pt"

    EPOCHS = 5
    BATCH_SIZE = 16
    DEVICE = torch.device("cuda" if torch.cuda.is_available() else "cpu")
    COLOR_MODE = 'rgb'
    TARGET_SIZE = (224, 224)

    CHECKPOINT_PATH_DENSENET = 'model/DenseNet121_val_auc.pt'
    CHECKPOINT_PATH_SWIN = 'model/SwinTransformer_val_auc.pt'
    CHECKPOINT_DIR = os.path.dirname(CHECKPOINT_PATH_DENSENET)

os.makedirs(CFG.OUTPUT_PATH / "model", exist_ok=True)

data_entry_df = pd.read_csv(f'{CFG.DATA_PATH}/Data_Entry_2017.csv')
with open(f'{CFG.DATA_PATH}/train_val_list_NIH.txt', 'r') as f:
    train_val_list = [line.strip() for line in f]
with open(f'{CFG.DATA_PATH}/test_list_NIH.txt', 'r') as f:
    test_list = [line.strip() for line in f]

train_val_df = data_entry_df[data_entry_df['Image
Index'].isin(train_val_list)]
test_df = data_entry_df[data_entry_df['Image Index'].isin(test_list)]

train_val_df['full_path'] = train_val_df['Image Index'].apply(lambda x:
str(CFG.BASE_PATH / x))
test_df['full_path'] = test_df['Image Index'].apply(lambda x:
str(CFG.BASE_PATH / x))

for cls in CFG.CLASS_NAMES:
    train_val_df[cls] = train_val_df['Finding Labels'].apply(lambda x: 1 if
cls in x.split('|') else 0)
    test_df[cls] = test_df['Finding Labels'].apply(lambda x: 1 if cls in
x.split('|') else 0)

sampled_dfs = []
for cls in CFG.CLASS_NAMES:
    class_df = train_val_df[train_val_df[cls] == 1]
    if len(class_df) >= 100:
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        sampled_df = class_df.sample(n=100, random_state=42)
    else:
        sampled_df = class_df
    sampled_dfs.append(sampled_df)

train_val_df = pd.concat(sampled_dfs).drop_duplicates(subset='Image Index')
train_val_df = train_val_df[train_val_df['full_path'].apply(os.path.exists)]

train_df, val_df = train_test_split(train_val_df, test_size=0.125,
random_state=42)

sampled_test_dfs = []
for cls in CFG.CLASS_NAMES:
    class_df = test_df[test_df[cls] == 1]
    if len(class_df) >= 100:
        sampled_df = class_df.sample(n=100, random_state=42)
    else:
        sampled_df = class_df
    sampled_test_dfs.append(sampled_df)
test_df = pd.concat(sampled_test_dfs).drop_duplicates(subset='Image Index')
test_df = test_df[test_df['full_path'].apply(os.path.exists)]

train_df.to_csv(f'{CFG.OUTPUT_PATH}/train_100_per_class.csv', index=False)
val_df.to_csv(f'{CFG.OUTPUT_PATH}/validation_100_per_class.csv', index=False)
test_df.to_csv(f'{CFG.OUTPUT_PATH}/test.csv', index=False)

print(f"Train set size: {len(train_df)} images")
print(f"Validation set size: {len(val_df)} images")
print(f"Test set size: {len(test_df)} images")
print("Train class distribution:")
print(train_df[CFG.CLASS_NAMES].sum())

class ChestXRayDataset(Dataset):
    def __init__(self, dataframe, transform=None):
        self.dataframe = dataframe
        self.transform = transform
        self.class_names = CFG.CLASS_NAMES

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

    def __getitem__(self, idx):
        img_path = self.dataframe.iloc[idx]['full_path']
        image = cv2.imread(img_path)
        image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)
        image = apply_clahe(image)
        image = (image / 255.0 - np.array([0.485, 0.456, 0.406])) /
np.array([0.229, 0.224, 0.225])
        image = image.transpose((2, 0, 1))
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        image = torch.tensor(image, dtype=torch.float32)

        if self.transform:
            image = self.transform(image)

        labels =
self.dataframe.iloc[idx][self.class_names].values.astype(np.float32)
        return image, torch.tensor(labels, dtype=torch.float32), img_path

def apply_clahe(image):
    if len(image.shape) == 3:
        gray = cv2.cvtColor(image, cv2.COLOR_RGB2GRAY)
    else:
        gray = image
    gray = np.uint8(gray)
    clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8, 8))
    cl = clahe.apply(gray)
    if len(image.shape) == 3:
        clahe_img = cv2.cvtColor(cl, cv2.COLOR_GRAY2RGB)
    else:
        clahe_img = cl
    return clahe_img

train_transform = transforms.Compose([
    transforms.ToPILImage(),
    transforms.RandomHorizontalFlip(p=0.5),
    transforms.RandomRotation(10),
    transforms.RandomAffine(degrees=0, translate=(0.1, 0.05), scale=(0.95,
1.05), shear=0.1),
    transforms.ToTensor()
])

val_transform = transforms.Compose([
    transforms.ToPILImage(),
    transforms.ToTensor()
])

train_dataset = ChestXRayDataset(train_df, transform=train_transform)
val_dataset = ChestXRayDataset(val_df, transform=val_transform)
test_dataset = ChestXRayDataset(test_df, transform=val_transform)

train_loader = DataLoader(train_dataset, batch_size=CFG.BATCH_SIZE,
shuffle=True, drop_last=True)
val_loader = DataLoader(val_dataset, batch_size=CFG.BATCH_SIZE,
shuffle=False)
test_loader = DataLoader(test_dataset, batch_size=CFG.BATCH_SIZE,
shuffle=False)

def compute_class_weights(df, class_names):
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    pos_ratios = df[class_names].mean()
    weights = torch.zeros(len(class_names))
    for i, cls in enumerate(class_names):
        rho = pos_ratios[cls]
        weights[i] = torch.exp(torch.tensor(1 - rho))
    return weights.to(CFG.DEVICE)

class CombinedLoss(nn.Module):
    def __init__(self, gamma1=1.0, gamma2=4.0, margin=0.05):
        super(CombinedLoss, self).__init__()
        self.gamma1 = gamma1
        self.gamma2 = gamma2
        self.margin = margin

    def forward(self, inputs, targets, weights):
        if inputs.shape != targets.shape:
            raise ValueError(f"Inputs shape {inputs.shape} does not match
targets shape {targets.shape}")
        if inputs.shape[1] != len(CFG.CLASS_NAMES):
            raise ValueError(f"Expected {len(CFG.CLASS_NAMES)} classes, got
{inputs.shape[1]}")
        inputs = torch.clamp(inputs, 0, 1)
        inputs_m = torch.clamp(inputs - self.margin, min=0)
        loss = -torch.sum(
            weights[None, :] * (
                (1 - inputs) ** self.gamma1 * targets * torch.log(inputs +
1e-10) +
                inputs_m ** self.gamma2 * (1 - targets) * torch.log(1 -
inputs_m + 1e-10)
            ), dim=1
        )
        return loss.mean()

class DenseNet121Model(nn.Module):
    def __init__(self, num_classes=len(CFG.CLASS_NAMES)):
        super(DenseNet121Model, self).__init__()
        self.densenet = models.densenet121(pretrained=True)
        num_ftrs = self.densenet.classifier.in_features
        self.densenet.classifier = nn.Linear(num_ftrs, num_classes)
        self.sigmoid = nn.Sigmoid()

    def forward(self, x, return_features=False):
        features = self.densenet.features(x)
        out = F.relu(features, inplace=True)
        out = F.adaptive_avg_pool2d(out, (1, 1)).view(features.size(0), -1)
        out = self.densenet.classifier(out)
        out = self.sigmoid(out)
        if return_features:
            return out, features
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        return out

class SwinTransformerModel(nn.Module):
    def __init__(self, num_classes=len(CFG.CLASS_NAMES)):
        super(SwinTransformerModel, self).__init__()
        self.swin = timm.create_model('swin_base_patch4_window7_224',
pretrained=True, num_classes=0)
        self.head = nn.Linear(1024, num_classes)
        self.sigmoid = nn.Sigmoid()

    def forward(self, x, return_features=False):
        features = self.swin(x)
        out = self.head(features)
        out = self.sigmoid(out)
        if return_features:
            return out, features
        return out

densenet_model =
DenseNet121Model(num_classes=len(CFG.CLASS_NAMES)).to(CFG.DEVICE)
swin_model =
SwinTransformerModel(num_classes=len(CFG.CLASS_NAMES)).to(CFG.DEVICE)

criterion = CombinedLoss(gamma1=1.0, gamma2=4.0, margin=0.05)
optimizer_densenet = optim.AdamW(densenet_model.parameters(), lr=1e-4,
weight_decay=1e-4)
optimizer_swin = optim.AdamW(swin_model.parameters(), lr=1e-4,
weight_decay=1e-4)

scaler = GradScaler()

class_weights = compute_class_weights(train_df, CFG.CLASS_NAMES)

class EarlyStopping:
    def __init__(self, patience=5, delta=0):
        self.patience = patience
        self.delta = delta
        self.best_score = None
        self.early_stop = False
        self.counter = 0
        self.best_loss = np.inf

    def __call__(self, val_loss):
        score = -val_loss
        if self.best_score is None:
            self.best_score = score
            self.best_loss = val_loss
        elif score < self.best_score + self.delta:
            self.counter += 1
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            if self.counter >= self.patience:
                self.early_stop = True
        else:
            self.best_score = score
            self.best_loss = val_loss
            self.counter = 0

def train_model(model, train_loader, val_loader, criterion, optimizer,
num_epochs, checkpoint_path, model_name):
    early_stopping = EarlyStopping(patience=5)
    best_auc = 0.0
    scheduler = optim.lr_scheduler.ReduceLROnPlateau(optimizer, mode='min',
factor=0.5, patience=2, verbose=True)

    for epoch in range(num_epochs):
        model.train()
        running_loss = 0.0
        for images, labels, _ in train_loader:
            images, labels = images.to(CFG.DEVICE), labels.to(CFG.DEVICE)
            optimizer.zero_grad()
            with autocast():
                outputs = model(images)
                loss = criterion(outputs, labels, class_weights)
            scaler.scale(loss).backward()
            scaler.step(optimizer)
            scaler.update()
            running_loss += loss.item() * images.size(0)

        epoch_loss = running_loss / len(train_loader.dataset)

        model.eval()
        val_preds, val_labels = [], []
        val_loss = 0.0
        with torch.no_grad():
            for images, labels, _ in val_loader:
                images, labels = images.to(CFG.DEVICE), labels.to(CFG.DEVICE)
                with autocast():
                    outputs = model(images)
                    val_loss += criterion(outputs, labels,
class_weights).item() * images.size(0)
                val_preds.append(outputs.cpu().numpy())
                val_labels.append(labels.cpu().numpy())

        val_loss = val_loss / len(val_loader.dataset)
        val_preds = np.concatenate(val_preds)
        val_labels = np.concatenate(val_labels)
        auc_scores = [roc_auc_score(val_labels[:, i], val_preds[:, i]) for i
in range(len(CFG.CLASS_NAMES))]
        mean_auc = np.mean(auc_scores)
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        print(f'Epoch {epoch+1}/{num_epochs}, {model_name} - Train Loss:
{epoch_loss:.4f}, Val Loss: {val_loss:.4f}, Mean AUC: {mean_auc:.4f}')

        if mean_auc > best_auc:
            best_auc = mean_auc
            torch.save(model.state_dict(), checkpoint_path)

        early_stopping(val_loss)
        scheduler.step(val_loss)
        if early_stopping.early_stop:
            print(f"Early stopping triggered for {model_name}")
            break

    torch.cuda.empty_cache()

def ensemble_predict(densenet_model, swin_model, loader, weights):
    densenet_model.eval()
    swin_model.eval()
    all_preds, all_labels = [], []
    with torch.no_grad():
        for images, labels, _ in loader:
            images, labels = images.to(CFG.DEVICE), labels.to(CFG.DEVICE)
            with autocast():
                densenet_preds = densenet_model(images)
                swin_preds = swin_model(images)
                ensemble_preds = weights[0] * densenet_preds + weights[1] *
swin_preds
            all_preds.append(ensemble_preds.cpu().numpy())
            all_labels.append(labels.cpu().numpy())
    return np.concatenate(all_preds), np.concatenate(all_labels)

def objective_function(weights, densenet_model, swin_model, val_loader):
    weights = np.array(weights) / np.sum(weights)
    val_preds, val_labels = ensemble_predict(densenet_model, swin_model,
val_loader, weights)
    auc_scores = [roc_auc_score(val_labels[:, i], val_preds[:, i]) for i in
range(len(CFG.CLASS_NAMES))]
    return -np.mean(auc_scores)

train_model(densenet_model, train_loader, val_loader, criterion,
optimizer_densenet, CFG.EPOCHS, CFG.CHECKPOINT_PATH_DENSENET, "DenseNet121")
torch.cuda.empty_cache()
train_model(swin_model, train_loader, val_loader, criterion, optimizer_swin,
CFG.EPOCHS, CFG.CHECKPOINT_PATH_SWIN, "SwinTransformer")

densenet_model.load_state_dict(torch.load(CFG.CHECKPOINT_PATH_DENSENET))
swin_model.load_state_dict(torch.load(CFG.CHECKPOINT_PATH_SWIN))
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bounds = [(0, 1), (0, 1)]
constraints = LinearConstraint(np.ones(2), lb=1, ub=1)
result = differential_evolution(
    lambda w: objective_function(w, densenet_model, swin_model, val_loader),
    bounds,
    constraints=constraints,
    maxiter=100
)
optimal_weights = result.x / np.sum(result.x)
print(f"Optimal ensemble weights: DenseNet={optimal_weights[0]:.4f},
SwinTransformer={optimal_weights[1]:.4f}")

test_preds, test_labels = ensemble_predict(densenet_model, swin_model,
test_loader, optimal_weights)
auc_scores = [roc_auc_score(test_labels[:, i], test_preds[:, i]) for i in
range(len(CFG.CLASS_NAMES))]
mean_auc = np.mean(auc_scores)
print(f"Test Mean AUC: {mean_auc:.4f}")
for cls, auc in zip(CFG.CLASS_NAMES, auc_scores):
    print(f"{cls}: AUC = {auc:.4f}")

plt.figure(figsize=(10, 8))
for i, cls in enumerate(CFG.CLASS_NAMES):
    fpr, tpr, _ = roc_curve(test_labels[:, i], test_preds[:, i])
    plt.plot(fpr, tpr, label=f'{cls} (AUC = {auc_scores[i]:.4f})')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curves for CheX-DS')
plt.legend()
plt.savefig(f'{CFG.OUTPUT_PATH}/roc_curves.png')
plt.show()

np.save(f'{CFG.OUTPUT_PATH}/test_predictions.npy', test_preds)
np.save(f'{CFG.OUTPUT_PATH}/test_labels.npy', test_labels)

Train set size: 1209 images
Validation set size: 173 images
Test set size: 1349 images
Train class distribution:
Atelectasis           268
Cardiomegaly          114
Effusion              283
Infiltration          338
Mass                  182
Nodule                152
Pneumonia              96
Pneumothorax          124
Consolidation         150
Edema                 119
Emphysema             114
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Fibrosis              108
Pleural_Thickening    148
Hernia                 94
dtype: int64
Epoch 1/5, DenseNet121 - Train Loss: 2.3531, Val Loss: 2.2826, Mean AUC:
0.5623
Epoch 2/5, DenseNet121 - Train Loss: 2.0696, Val Loss: 2.2544, Mean AUC:
0.5840
Epoch 3/5, DenseNet121 - Train Loss: 1.9548, Val Loss: 2.2879, Mean AUC:
0.5987
Epoch 4/5, DenseNet121 - Train Loss: 1.8423, Val Loss: 2.3280, Mean AUC:
0.5951
Epoch 5/5, DenseNet121 - Train Loss: 1.7293, Val Loss: 2.3448, Mean AUC:
0.6051
Epoch 1/5, SwinTransformer - Train Loss: 2.1966, Val Loss: 2.2037, Mean AUC:
0.5861
Epoch 2/5, SwinTransformer - Train Loss: 2.1437, Val Loss: 2.1586, Mean AUC:
0.6103
Epoch 3/5, SwinTransformer - Train Loss: 2.1312, Val Loss: 2.1350, Mean AUC:
0.6333
Epoch 4/5, SwinTransformer - Train Loss: 2.1137, Val Loss: 2.1473, Mean AUC:
0.6395
Epoch 5/5, SwinTransformer - Train Loss: 2.0771, Val Loss: 2.0997, Mean AUC:
0.6497
Optimal ensemble weights: DenseNet=0.1202, SwinTransformer=0.8798
Test Mean AUC: 0.6624
Atelectasis: AUC = 0.6323
Cardiomegaly: AUC = 0.7392
Effusion: AUC = 0.6728
Infiltration: AUC = 0.6334
Mass: AUC = 0.5849
Nodule: AUC = 0.6103
Pneumonia: AUC = 0.5596
Pneumothorax: AUC = 0.6312
Consolidation: AUC = 0.6599
Edema: AUC = 0.7721
Emphysema: AUC = 0.5607
Fibrosis: AUC = 0.7209
Pleural_Thickening: AUC = 0.6374
Hernia: AUC = 0.8592
```