Capstone Project

August 5, 2025

[42]:
```
import zipfile
import os

zip_path = 'Chest Xray Dataset.zip'
extract_to = 'chest_xray_data'

with zipfile.ZipFile(zip_path, 'r') as zip_ref:
    zip_ref.extractall(extract_to)

print("Dataset unzipped successfully!")
```

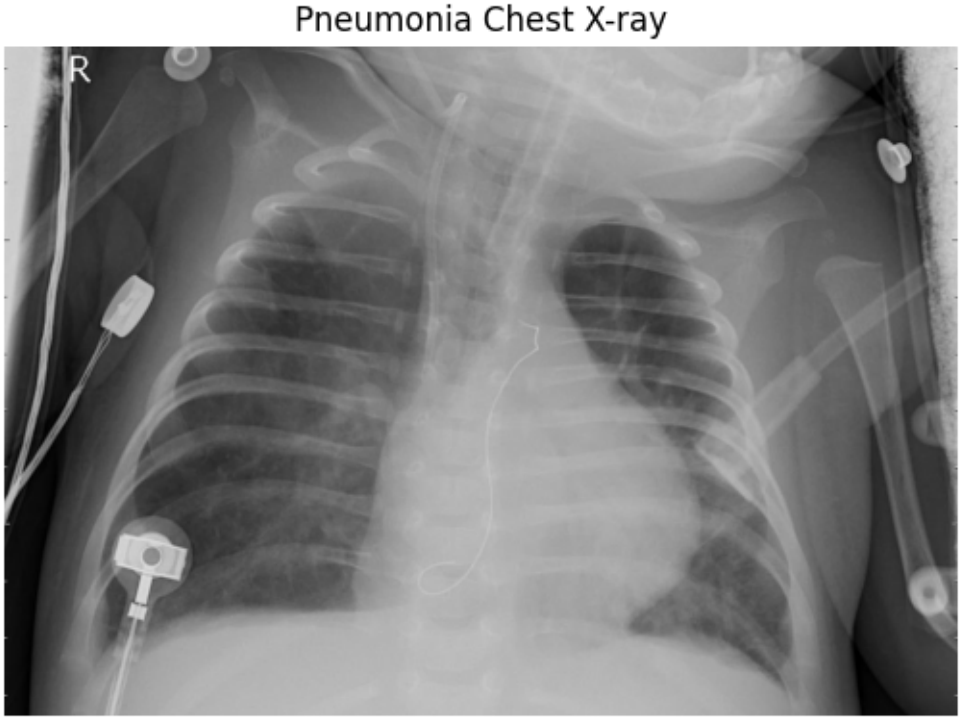
```
Dataset unzipped successfully!
```

[43]:
```
import os

os.getcwd()
os.listdir('chest_xray_data')

import os
import shutil
from sklearn.model_selection import train_test_split

original_dir = 'chest_xray_data/chest_xray/train'
custom_train_dir = 'chest_xray_data/custom/train'
custom_val_dir = 'chest_xray_data/custom/val'

classes = ['NORMAL', 'PNEUMONIA']

for cls in classes:
    images = os.listdir(os.path.join(original_dir, cls))
    train_imgs, val_imgs = train_test_split(images, test_size=0.2,␣
 ↪random_state=42)

    os.makedirs(os.path.join(custom_train_dir, cls), exist_ok=True)
    os.makedirs(os.path.join(custom_val_dir, cls), exist_ok=True)

    for img in train_imgs:
```

```
        shutil.copy(os.path.join(original_dir, cls, img), os.path.
↪join(custom_train_dir, cls, img))
    for img in val_imgs:
        shutil.copy(os.path.join(original_dir, cls, img), os.path.
↪join(custom_val_dir, cls, img))

print("Custom training and validation sets created.")
```

```
Custom training and validation sets created.
```

[44]:
```
from PIL import Image
import matplotlib.pyplot as plt

base_path = 'chest_xray_data/chest_xray'

# Get path to one pneumonia image
pneumonia_img = os.listdir(os.path.join(base_path, 'train', 'PNEUMONIA'))[0]
img_path = os.path.join(base_path, 'train', 'PNEUMONIA', pneumonia_img)

# Display the image
img = Image.open(img_path)
plt.imshow(img, cmap='gray')
plt.title("Pneumonia Chest X-ray")
plt.axis('off')
plt.show()
```



[45]:
```
!pip install tensorflow
```

```
Requirement already satisfied: tensorflow in /opt/anaconda3/lib/python3.12/site-
packages (2.19.0)
Requirement already satisfied: absl-py>=1.0.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (2.3.0)
Requirement already satisfied: astunparse>=1.6.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers>=24.3.25 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (25.2.10)
Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (0.6.0)
Requirement already satisfied: google-pasta>=0.1.1 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (0.2.0)
Requirement already satisfied: libclang>=13.0.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (18.1.1)
Requirement already satisfied: opt-einsum>=2.3.2 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.4.0)
Requirement already satisfied: packaging in /opt/anaconda3/lib/python3.12/site-
packages (from tensorflow) (24.1)
Requirement already satisfied:
protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<6.0.0dev,>=3.20.3
in /opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.20.3)
Requirement already satisfied: requests<3,>=2.21.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (2.32.3)
Requirement already satisfied: setuptools in /opt/anaconda3/lib/python3.12/site-
packages (from tensorflow) (72.1.0)
Requirement already satisfied: six>=1.12.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.1.0)
Requirement already satisfied: typing-extensions>=3.6.6 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (4.11.0)
Requirement already satisfied: wrapt>=1.11.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.14.1)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.73.0)
Requirement already satisfied: tensorboard~=2.19.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (2.19.0)
Requirement already satisfied: keras>=3.5.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.10.0)
Requirement already satisfied: numpy<2.2.0,>=1.26.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (1.26.4)
Requirement already satisfied: h5py>=3.11.0 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (3.11.0)
```

```
Requirement already satisfied: ml-dtypes<1.0.0,>=0.5.1 in
/opt/anaconda3/lib/python3.12/site-packages (from tensorflow) (0.5.1)
Requirement already satisfied: wheel<1.0,>=0.23.0 in
/opt/anaconda3/lib/python3.12/site-packages (from astunparse>=1.6.0->tensorflow)
(0.43.0)
Requirement already satisfied: rich in /opt/anaconda3/lib/python3.12/site-
packages (from keras>=3.5.0->tensorflow) (13.7.1)
Requirement already satisfied: namex in /opt/anaconda3/lib/python3.12/site-
packages (from keras>=3.5.0->tensorflow) (0.1.0)
Requirement already satisfied: optree in /opt/anaconda3/lib/python3.12/site-
packages (from keras>=3.5.0->tensorflow) (0.16.0)
Requirement already satisfied: charset-normalizer<4,>=2 in
/opt/anaconda3/lib/python3.12/site-packages (from
requests<3,>=2.21.0->tensorflow) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in
/opt/anaconda3/lib/python3.12/site-packages (from
requests<3,>=2.21.0->tensorflow) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/opt/anaconda3/lib/python3.12/site-packages (from
requests<3,>=2.21.0->tensorflow) (2.2.2)
Requirement already satisfied: certifi>=2017.4.17 in
/opt/anaconda3/lib/python3.12/site-packages (from
requests<3,>=2.21.0->tensorflow) (2024.8.30)
Requirement already satisfied: markdown>=2.6.8 in
/opt/anaconda3/lib/python3.12/site-packages (from
tensorboard~=2.19.0->tensorflow) (3.4.1)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in
/opt/anaconda3/lib/python3.12/site-packages (from
tensorboard~=2.19.0->tensorflow) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in
/opt/anaconda3/lib/python3.12/site-packages (from
tensorboard~=2.19.0->tensorflow) (3.0.3)
Requirement already satisfied: MarkupSafe>=2.1.1 in
/opt/anaconda3/lib/python3.12/site-packages (from
werkzeug>=1.0.1->tensorboard~=2.19.0->tensorflow) (2.1.3)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/opt/anaconda3/lib/python3.12/site-packages (from
rich->keras>=3.5.0->tensorflow) (2.2.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
/opt/anaconda3/lib/python3.12/site-packages (from
rich->keras>=3.5.0->tensorflow) (2.15.1)
Requirement already satisfied: mdurl~=0.1 in /opt/anaconda3/lib/python3.12/site-
packages (from markdown-it-py>=2.2.0->rich->keras>=3.5.0->tensorflow) (0.1.0)
```

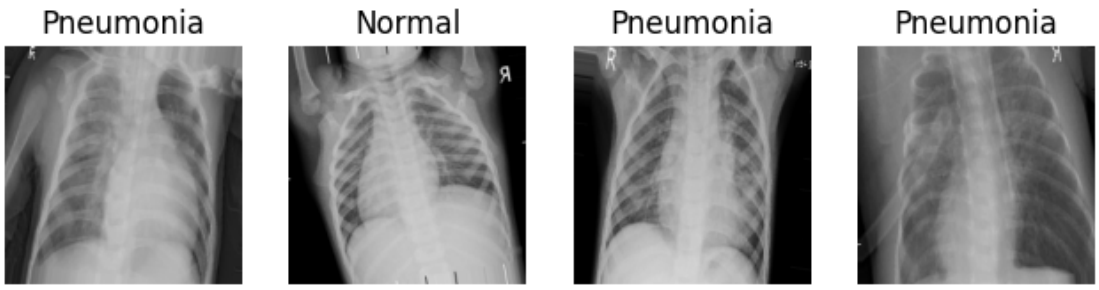
[94]:
```
from tensorflow.keras.preprocessing.image import ImageDataGenerator

# Data augmentation for training
```

```
train_datagen = ImageDataGenerator(
    rescale=1./255,
    rotation_range=10,
    zoom_range=0.1,
    horizontal_flip=True
)

# No augmentation for validation/test
test_datagen = ImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory(
    'chest_xray_data/custom/train',
    target_size=(224, 224),
    color_mode='rgb',
    batch_size=32,
    class_mode='binary'
)

val_generator = test_datagen.flow_from_directory(
    'chest_xray_data/custom/train',
    target_size=(224, 224),
    color_mode='rgb',
    batch_size=32,
    class_mode='binary'
)

test_generator = test_datagen.flow_from_directory(
    'chest_xray_data/chest_xray/test',
    target_size=(224, 224),
    color_mode='rgb',
    batch_size=32,
    class_mode='binary',
    shuffle=False
)
```

```
Found 4172 images belonging to 2 classes.
Found 4172 images belonging to 2 classes.
Found 624 images belonging to 2 classes.
```

[96]:
```
import matplotlib.pyplot as plt

x_batch, y_batch = next(train_generator)

plt.figure(figsize=(10, 5))
for i in range(4):
    plt.subplot(1, 5, i + 1)
    plt.imshow(x_batch[i].squeeze(), cmap='gray')
```

```
    plt.title("Pneumonia" if y_batch[i] == 1 else "Normal")
    plt.axis('off')
plt.show()
```



[102]:
```
from tensorflow.keras.applications import EfficientNetB0, ResNet50
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Dense, Dropout, GlobalAveragePooling2D,␣
 ↪Input
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.losses import BinaryFocalCrossentropy
from tensorflow.keras.metrics import AUC, Recall
from tensorflow.keras.callbacks import EarlyStopping, ReduceLROnPlateau
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from sklearn.utils import class_weight
import numpy as np

# =====================
# 1. Model Definition
# =====================
from tensorflow.keras.applications import EfficientNetV2B0

base_model = ResNet50(include_top=False, weights='imagenet', input_shape=(224,␣
 ↪224, 3))
base_model.trainable = True
for layer in base_model.layers[:-50]:
    layer.trainable = False

x = base_model.output
x = GlobalAveragePooling2D()(x)
x = Dropout(0.5)(x)
x = Dense(128, activation='relu')(x)
x = Dropout(0.3)(x)
output = Dense(1, activation='sigmoid')(x)

model = Model(inputs=base_model.input, outputs=output)
```

```
# =====================
# 2. Data Generators
# =====================
train_datagen = LungCroppedImageDataGenerator(
    rescale=1./255,
    rotation_range=20,
    zoom_range=0.2,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.1,
    horizontal_flip=True,
    fill_mode='nearest'
)

val_datagen = LungCroppedImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory(
    'chest_xray_data/custom/train',
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary',
    shuffle=True
)

val_generator = val_datagen.flow_from_directory(
    'chest_xray_data/custom/val',
    target_size=(224, 224),
    batch_size=32,
    class_mode='binary',
    shuffle=False
)

# =====================
# 3. Class Weights
# =====================
class_weights = class_weight.compute_class_weight(
    class_weight='balanced',
    classes=np.unique(train_generator.classes),
    y=train_generator.classes
)
class_weights = dict(enumerate(class_weights))

# =====================
# 4. Compile Model
```

```
# =====================
model.compile(
    optimizer=Adam(learning_rate=1e-5),
    loss=BinaryFocalCrossentropy(gamma=2.0),
    metrics=['accuracy', AUC(name='auc'), Recall(name='recall')]
)

# =====================
# 5. Callbacks
# =====================
early_stop = EarlyStopping(monitor='val_loss', patience=3,␣
 ↪restore_best_weights=True, verbose=1)
reduce_lr = ReduceLROnPlateau(monitor='val_loss', patience=2, factor=0.2,␣
 ↪verbose=1)

# =====================
# 6. Train Model
# =====================
history = model.fit(
    train_generator,
    validation_data=val_generator,
    epochs=15,
    class_weight=class_weights,
    verbose=1,
    callbacks=[early_stop, reduce_lr]
)

# =====================
# 7. Model Summary
# =====================
model.summary()

from sklearn.metrics import precision_recall_curve

probs = model.predict(val_generator)
probs = probs.flatten()
precision, recall, thresholds = precision_recall_curve(val_generator.classes,␣
 ↪probs)
```

```
Found 4172 images belonging to 2 classes.
Found 1044 images belonging to 2 classes.
```

```
/opt/anaconda3/lib/python3.12/site-
packages/keras/src/trainers/data_adapters/py_dataset_adapter.py:121:
UserWarning: Your `PyDataset` class should call `super().__init__(**kwargs)` in
its constructor. `**kwargs` can include `workers`, `use_multiprocessing`,
`max_queue_size`. Do not pass these arguments to `fit()`, as they will be
ignored.
```

```
  self._warn_if_super_not_called()
Epoch 1/15
131/131             191s 1s/step -
accuracy: 0.6972 - auc: 0.7653 - loss: 0.1629 - recall: 0.7048 - val_accuracy:
0.2577 - val_auc: 0.8754 - val_loss: 0.1950 - val_recall: 0.0000e+00 -
learning_rate: 1.0000e-05
Epoch 2/15
131/131             186s 1s/step -
accuracy: 0.8162 - auc: 0.8995 - loss: 0.1077 - recall: 0.8034 - val_accuracy:
0.8764 - val_auc: 0.9406 - val_loss: 0.0864 - val_recall: 0.9252 -
learning_rate: 1.0000e-05
Epoch 3/15
131/131             188s 1s/step -
accuracy: 0.8234 - auc: 0.9069 - loss: 0.0997 - recall: 0.8047 - val_accuracy:
0.8381 - val_auc: 0.9515 - val_loss: 0.0953 - val_recall: 0.7935 -
learning_rate: 1.0000e-05
Epoch 4/15
131/131             0s 1s/step -
accuracy: 0.8410 - auc: 0.9182 - loss: 0.0935 - recall: 0.8301
Epoch 4: ReduceLROnPlateau reducing learning rate to 1.9999999494757505e-06.
131/131             195s 1s/step -
accuracy: 0.8410 - auc: 0.9182 - loss: 0.0935 - recall: 0.8301 - val_accuracy:
0.4703 - val_auc: 0.9580 - val_loss: 0.3387 - val_recall: 0.2865 -
learning_rate: 1.0000e-05
Epoch 5/15
131/131             192s 1s/step -
accuracy: 0.8480 - auc: 0.9299 - loss: 0.0860 - recall: 0.8243 - val_accuracy:
0.8554 - val_auc: 0.9561 - val_loss: 0.0840 - val_recall: 0.8129 -
learning_rate: 2.0000e-06
Epoch 6/15
131/131             212s 2s/step -
accuracy: 0.8487 - auc: 0.9284 - loss: 0.0884 - recall: 0.8375 - val_accuracy:
0.7586 - val_auc: 0.9591 - val_loss: 0.1232 - val_recall: 0.6787 -
learning_rate: 2.0000e-06
Epoch 7/15
131/131             0s 1s/step -
accuracy: 0.8518 - auc: 0.9309 - loss: 0.0819 - recall: 0.8321
Epoch 7: ReduceLROnPlateau reducing learning rate to 3.999999989900971e-07.
131/131             204s 2s/step -
accuracy: 0.8519 - auc: 0.9309 - loss: 0.0819 - recall: 0.8322 - val_accuracy:
0.7193 - val_auc: 0.9613 - val_loss: 0.1464 - val_recall: 0.6258 -
learning_rate: 2.0000e-06
Epoch 8/15
131/131             213s 2s/step -
accuracy: 0.8449 - auc: 0.9353 - loss: 0.0810 - recall: 0.8193 - val_accuracy:
0.7615 - val_auc: 0.9613 - val_loss: 0.1246 - val_recall: 0.6826 -
learning_rate: 4.0000e-07
```

```
Epoch 8: early stopping
Restoring model weights from the end of the best epoch: 5.
```

Model: "functional_22"

Layer (type)	Output Shape	Param #	Connected to
input_layer_12 (InputLayer)	(None, 224, 224, 3)	0	-
conv1_pad (ZeroPadding2D)	(None, 230, 230, 3)	0	input_layer_12[0…
conv1_conv (Conv2D)	(None, 112, 112, 64)	9,472	conv1_pad[0][0]
conv1_bn (BatchNormalizatio…	(None, 112, 112, 64)	256	conv1_conv[0][0]
conv1_relu (Activation)	(None, 112, 112, 64)	0	conv1_bn[0][0]
pool1_pad (ZeroPadding2D)	(None, 114, 114, 64)	0	conv1_relu[0][0]
pool1_pool (MaxPooling2D)	(None, 56, 56, 64)	0	pool1_pad[0][0]
conv2_block1_1_conv (Conv2D)	(None, 56, 56, 64)	4,160	pool1_pool[0][0]
conv2_block1_1_bn (BatchNormalizatio…	(None, 56, 56, 64)	256	conv2_block1_1_c…
conv2_block1_1_relu (Activation)	(None, 56, 56, 64)	0	conv2_block1_1_b…
conv2_block1_2_conv (Conv2D)	(None, 56, 56, 64)	36,928	conv2_block1_1_r…
conv2_block1_2_bn (BatchNormalizatio…	(None, 56, 56, 64)	256	conv2_block1_2_c…
conv2_block1_2_relu (Activation)	(None, 56, 56, 64)	0	conv2_block1_2_b…
conv2_block1_0_conv	(None, 56, 56,	16,640	pool1_pool[0][0]

```
(Conv2D)                256)

conv2_block1_3_conv     (None, 56, 56,          16,640   conv2_block1_2_r…
(Conv2D)                256)

conv2_block1_0_bn       (None, 56, 56,           1,024   conv2_block1_0_c…
(BatchNormalizatio…     256)

conv2_block1_3_bn       (None, 56, 56,           1,024   conv2_block1_3_c…
(BatchNormalizatio…     256)

conv2_block1_add        (None, 56, 56,               0   conv2_block1_0_b…
(Add)                   256)                             conv2_block1_3_b…

conv2_block1_out        (None, 56, 56,               0   conv2_block1_add…
(Activation)            256)

conv2_block2_1_conv     (None, 56, 56,          16,448   conv2_block1_out…
(Conv2D)                64)

conv2_block2_1_bn       (None, 56, 56,             256   conv2_block2_1_c…
(BatchNormalizatio…     64)

conv2_block2_1_relu     (None, 56, 56,               0   conv2_block2_1_b…
(Activation)            64)

conv2_block2_2_conv     (None, 56, 56,          36,928   conv2_block2_1_r…
(Conv2D)                64)

conv2_block2_2_bn       (None, 56, 56,             256   conv2_block2_2_c…
(BatchNormalizatio…     64)

conv2_block2_2_relu     (None, 56, 56,               0   conv2_block2_2_b…
(Activation)            64)

conv2_block2_3_conv     (None, 56, 56,          16,640   conv2_block2_2_r…
(Conv2D)                256)

conv2_block2_3_bn       (None, 56, 56,           1,024   conv2_block2_3_c…
(BatchNormalizatio…     256)

conv2_block2_add        (None, 56, 56,               0   conv2_block1_out…
(Add)                   256)                             conv2_block2_3_b…

conv2_block2_out        (None, 56, 56,               0   conv2_block2_add…
(Activation)            256)

conv2_block3_1_conv     (None, 56, 56,          16,448   conv2_block2_out…
```

```
(Conv2D)                 64)

conv2_block3_1_bn        (None, 56, 56,             256   conv2_block3_1_c…
(BatchNormalizatio…      64)

conv2_block3_1_relu      (None, 56, 56,               0   conv2_block3_1_b…
(Activation)             64)

conv2_block3_2_conv      (None, 56, 56,          36,928   conv2_block3_1_r…
(Conv2D)                 64)

conv2_block3_2_bn        (None, 56, 56,             256   conv2_block3_2_c…
(BatchNormalizatio…      64)

conv2_block3_2_relu      (None, 56, 56,               0   conv2_block3_2_b…
(Activation)             64)

conv2_block3_3_conv      (None, 56, 56,          16,640   conv2_block3_2_r…
(Conv2D)                 256)

conv2_block3_3_bn        (None, 56, 56,           1,024   conv2_block3_3_c…
(BatchNormalizatio…      256)

conv2_block3_add         (None, 56, 56,               0   conv2_block2_out…
(Add)                    256)                             conv2_block3_3_b…

conv2_block3_out         (None, 56, 56,               0   conv2_block3_add…
(Activation)             256)

conv3_block1_1_conv      (None, 28, 28,          32,896   conv2_block3_out…
(Conv2D)                 128)

conv3_block1_1_bn        (None, 28, 28,             512   conv3_block1_1_c…
(BatchNormalizatio…      128)

conv3_block1_1_relu      (None, 28, 28,               0   conv3_block1_1_b…
(Activation)             128)

conv3_block1_2_conv      (None, 28, 28,         147,584   conv3_block1_1_r…
(Conv2D)                 128)

conv3_block1_2_bn        (None, 28, 28,             512   conv3_block1_2_c…
(BatchNormalizatio…      128)

conv3_block1_2_relu      (None, 28, 28,               0   conv3_block1_2_b…
(Activation)             128)

conv3_block1_0_conv      (None, 28, 28,         131,584   conv2_block3_out…
```

```
(Conv2D)                    512)

conv3_block1_3_conv         (None, 28, 28,          66,048   conv3_block1_2_r…
(Conv2D)                    512)

conv3_block1_0_bn           (None, 28, 28,           2,048   conv3_block1_0_c…
(BatchNormalizatio…         512)

conv3_block1_3_bn           (None, 28, 28,           2,048   conv3_block1_3_c…
(BatchNormalizatio…         512)

conv3_block1_add            (None, 28, 28,               0   conv3_block1_0_b…
(Add)                       512)                             conv3_block1_3_b…

conv3_block1_out            (None, 28, 28,               0   conv3_block1_add…
(Activation)                512)

conv3_block2_1_conv         (None, 28, 28,          65,664   conv3_block1_out…
(Conv2D)                    128)

conv3_block2_1_bn           (None, 28, 28,             512   conv3_block2_1_c…
(BatchNormalizatio…         128)

conv3_block2_1_relu         (None, 28, 28,               0   conv3_block2_1_b…
(Activation)                128)

conv3_block2_2_conv         (None, 28, 28,         147,584   conv3_block2_1_r…
(Conv2D)                    128)

conv3_block2_2_bn           (None, 28, 28,             512   conv3_block2_2_c…
(BatchNormalizatio…         128)

conv3_block2_2_relu         (None, 28, 28,               0   conv3_block2_2_b…
(Activation)                128)

conv3_block2_3_conv         (None, 28, 28,          66,048   conv3_block2_2_r…
(Conv2D)                    512)

conv3_block2_3_bn           (None, 28, 28,           2,048   conv3_block2_3_c…
(BatchNormalizatio…         512)

conv3_block2_add            (None, 28, 28,               0   conv3_block1_out…
(Add)                       512)                             conv3_block2_3_b…

conv3_block2_out            (None, 28, 28,               0   conv3_block2_add…
(Activation)                512)

conv3_block3_1_conv         (None, 28, 28,          65,664   conv3_block2_out…
```

```
(Conv2D)                 128)

conv3_block3_1_bn        (None, 28, 28,             512   conv3_block3_1_c…
(BatchNormalizatio…      128)

conv3_block3_1_relu      (None, 28, 28,               0   conv3_block3_1_b…
(Activation)             128)

conv3_block3_2_conv      (None, 28, 28,         147,584   conv3_block3_1_r…
(Conv2D)                 128)

conv3_block3_2_bn        (None, 28, 28,             512   conv3_block3_2_c…
(BatchNormalizatio…      128)

conv3_block3_2_relu      (None, 28, 28,               0   conv3_block3_2_b…
(Activation)             128)

conv3_block3_3_conv      (None, 28, 28,          66,048   conv3_block3_2_r…
(Conv2D)                 512)

conv3_block3_3_bn        (None, 28, 28,           2,048   conv3_block3_3_c…
(BatchNormalizatio…      512)

conv3_block3_add         (None, 28, 28,               0   conv3_block2_out…
(Add)                    512)                             conv3_block3_3_b…

conv3_block3_out         (None, 28, 28,               0   conv3_block3_add…
(Activation)             512)

conv3_block4_1_conv      (None, 28, 28,          65,664   conv3_block3_out…
(Conv2D)                 128)

conv3_block4_1_bn        (None, 28, 28,             512   conv3_block4_1_c…
(BatchNormalizatio…      128)

conv3_block4_1_relu      (None, 28, 28,               0   conv3_block4_1_b…
(Activation)             128)

conv3_block4_2_conv      (None, 28, 28,         147,584   conv3_block4_1_r…
(Conv2D)                 128)

conv3_block4_2_bn        (None, 28, 28,             512   conv3_block4_2_c…
(BatchNormalizatio…      128)

conv3_block4_2_relu      (None, 28, 28,               0   conv3_block4_2_b…
(Activation)             128)

conv3_block4_3_conv      (None, 28, 28,          66,048   conv3_block4_2_r…
```

```
(Conv2D)                 512)

conv3_block4_3_bn        (None, 28, 28,           2,048   conv3_block4_3_c…
(BatchNormalizatio…      512)

conv3_block4_add         (None, 28, 28,               0   conv3_block3_out…
(Add)                    512)                             conv3_block4_3_b…

conv3_block4_out         (None, 28, 28,               0   conv3_block4_add…
(Activation)             512)

conv4_block1_1_conv      (None, 14, 14,         131,328   conv3_block4_out…
(Conv2D)                 256)

conv4_block1_1_bn        (None, 14, 14,           1,024   conv4_block1_1_c…
(BatchNormalizatio…      256)

conv4_block1_1_relu      (None, 14, 14,               0   conv4_block1_1_b…
(Activation)             256)

conv4_block1_2_conv      (None, 14, 14,         590,080   conv4_block1_1_r…
(Conv2D)                 256)

conv4_block1_2_bn        (None, 14, 14,           1,024   conv4_block1_2_c…
(BatchNormalizatio…      256)

conv4_block1_2_relu      (None, 14, 14,               0   conv4_block1_2_b…
(Activation)             256)

conv4_block1_0_conv      (None, 14, 14,         525,312   conv3_block4_out…
(Conv2D)                 1024)

conv4_block1_3_conv      (None, 14, 14,         263,168   conv4_block1_2_r…
(Conv2D)                 1024)

conv4_block1_0_bn        (None, 14, 14,           4,096   conv4_block1_0_c…
(BatchNormalizatio…      1024)

conv4_block1_3_bn        (None, 14, 14,           4,096   conv4_block1_3_c…
(BatchNormalizatio…      1024)

conv4_block1_add         (None, 14, 14,               0   conv4_block1_0_b…
(Add)                    1024)                            conv4_block1_3_b…

conv4_block1_out         (None, 14, 14,               0   conv4_block1_add…
(Activation)             1024)

conv4_block2_1_conv      (None, 14, 14,         262,400   conv4_block1_out…
```

```
(Conv2D)              256)

conv4_block2_1_bn     (None, 14, 14,          1,024   conv4_block2_1_c…
(BatchNormalizatio…   256)

conv4_block2_1_relu   (None, 14, 14,              0   conv4_block2_1_b…
(Activation)          256)

conv4_block2_2_conv   (None, 14, 14,        590,080   conv4_block2_1_r…
(Conv2D)              256)

conv4_block2_2_bn     (None, 14, 14,          1,024   conv4_block2_2_c…
(BatchNormalizatio…   256)

conv4_block2_2_relu   (None, 14, 14,              0   conv4_block2_2_b…
(Activation)          256)

conv4_block2_3_conv   (None, 14, 14,        263,168   conv4_block2_2_r…
(Conv2D)              1024)

conv4_block2_3_bn     (None, 14, 14,          4,096   conv4_block2_3_c…
(BatchNormalizatio…   1024)

conv4_block2_add      (None, 14, 14,              0   conv4_block1_out…
(Add)                 1024)                           conv4_block2_3_b…

conv4_block2_out      (None, 14, 14,              0   conv4_block2_add…
(Activation)          1024)

conv4_block3_1_conv   (None, 14, 14,        262,400   conv4_block2_out…
(Conv2D)              256)

conv4_block3_1_bn     (None, 14, 14,          1,024   conv4_block3_1_c…
(BatchNormalizatio…   256)

conv4_block3_1_relu   (None, 14, 14,              0   conv4_block3_1_b…
(Activation)          256)

conv4_block3_2_conv   (None, 14, 14,        590,080   conv4_block3_1_r…
(Conv2D)              256)

conv4_block3_2_bn     (None, 14, 14,          1,024   conv4_block3_2_c…
(BatchNormalizatio…   256)

conv4_block3_2_relu   (None, 14, 14,              0   conv4_block3_2_b…
(Activation)          256)

conv4_block3_3_conv   (None, 14, 14,        263,168   conv4_block3_2_r…
```

(Conv2D)	1024)		
conv4_block3_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block3_3_c…
conv4_block3_add (Add)	(None, 14, 14, 1024)	0	conv4_block2_out… conv4_block3_3_b…
conv4_block3_out (Activation)	(None, 14, 14, 1024)	0	conv4_block3_add…
conv4_block4_1_conv (Conv2D)	(None, 14, 14, 256)	262,400	conv4_block3_out…
conv4_block4_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block4_1_c…
conv4_block4_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_block4_1_b…
conv4_block4_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block4_1_r…
conv4_block4_2_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block4_2_c…
conv4_block4_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block4_2_b…
conv4_block4_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block4_2_r…
conv4_block4_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block4_3_c…
conv4_block4_add (Add)	(None, 14, 14, 1024)	0	conv4_block3_out… conv4_block4_3_b…
conv4_block4_out (Activation)	(None, 14, 14, 1024)	0	conv4_block4_add…
conv4_block5_1_conv (Conv2D)	(None, 14, 14, 256)	262,400	conv4_block4_out…
conv4_block5_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block5_1_c…
conv4_block5_1_relu	(None, 14, 14,	0	conv4_block5_1_b…

(Activation)	256)		
conv4_block5_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block5_1_r…
conv4_block5_2_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block5_2_c…
conv4_block5_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block5_2_b…
conv4_block5_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block5_2_r…
conv4_block5_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block5_3_c…
conv4_block5_add (Add)	(None, 14, 14, 1024)	0	conv4_block4_out… conv4_block5_3_b…
conv4_block5_out (Activation)	(None, 14, 14, 1024)	0	conv4_block5_add…
conv4_block6_1_conv (Conv2D)	(None, 14, 14, 256)	262,400	conv4_block5_out…
conv4_block6_1_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block6_1_c…
conv4_block6_1_relu (Activation)	(None, 14, 14, 256)	0	conv4_block6_1_b…
conv4_block6_2_conv (Conv2D)	(None, 14, 14, 256)	590,080	conv4_block6_1_r…
conv4_block6_2_bn (BatchNormalizatio…	(None, 14, 14, 256)	1,024	conv4_block6_2_c…
conv4_block6_2_relu (Activation)	(None, 14, 14, 256)	0	conv4_block6_2_b…
conv4_block6_3_conv (Conv2D)	(None, 14, 14, 1024)	263,168	conv4_block6_2_r…
conv4_block6_3_bn (BatchNormalizatio…	(None, 14, 14, 1024)	4,096	conv4_block6_3_c…
conv4_block6_add	(None, 14, 14,	0	conv4_block5_out…

(Add)	1024)		conv4_block6_3_b…
conv4_block6_out (Activation)	(None, 14, 14, 1024)	0	conv4_block6_add…
conv5_block1_1_conv (Conv2D)	(None, 7, 7, 512)	524,800	conv4_block6_out…
conv5_block1_1_bn (BatchNormalizatio…	(None, 7, 7, 512)	2,048	conv5_block1_1_c…
conv5_block1_1_relu (Activation)	(None, 7, 7, 512)	0	conv5_block1_1_b…
conv5_block1_2_conv (Conv2D)	(None, 7, 7, 512)	2,359,808	conv5_block1_1_r…
conv5_block1_2_bn (BatchNormalizatio…	(None, 7, 7, 512)	2,048	conv5_block1_2_c…
conv5_block1_2_relu (Activation)	(None, 7, 7, 512)	0	conv5_block1_2_b…
conv5_block1_0_conv (Conv2D)	(None, 7, 7, 2048)	2,099,200	conv4_block6_out…
conv5_block1_3_conv (Conv2D)	(None, 7, 7, 2048)	1,050,624	conv5_block1_2_r…
conv5_block1_0_bn (BatchNormalizatio…	(None, 7, 7, 2048)	8,192	conv5_block1_0_c…
conv5_block1_3_bn (BatchNormalizatio…	(None, 7, 7, 2048)	8,192	conv5_block1_3_c…
conv5_block1_add (Add)	(None, 7, 7, 2048)	0	conv5_block1_0_b… conv5_block1_3_b…
conv5_block1_out (Activation)	(None, 7, 7, 2048)	0	conv5_block1_add…
conv5_block2_1_conv (Conv2D)	(None, 7, 7, 512)	1,049,088	conv5_block1_out…
conv5_block2_1_bn (BatchNormalizatio…	(None, 7, 7, 512)	2,048	conv5_block2_1_c…
conv5_block2_1_relu	(None, 7, 7, 512)	0	conv5_block2_1_b…

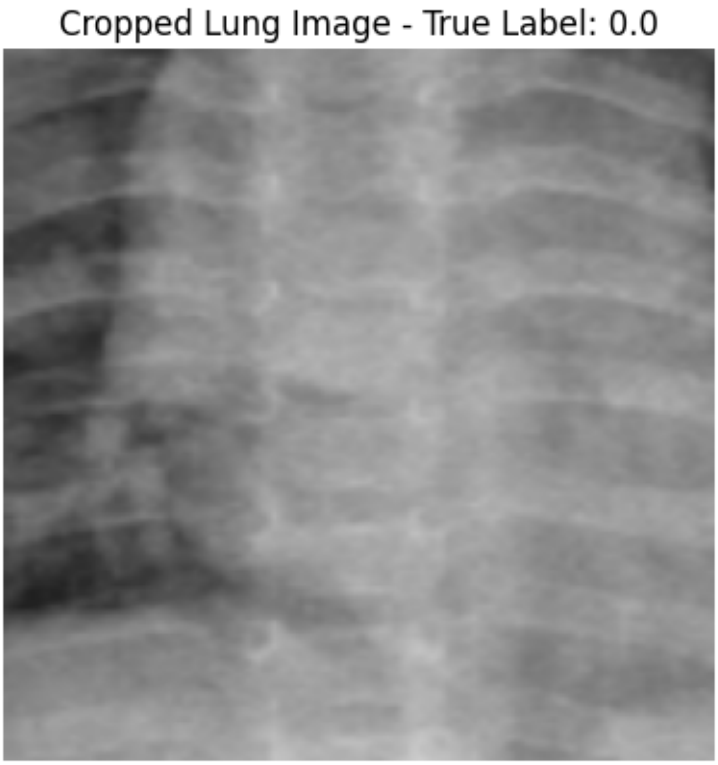
```
(Activation)

conv5_block2_2_conv   (None, 7, 7, 512)    2,359,808   conv5_block2_1_r…
(Conv2D)

conv5_block2_2_bn     (None, 7, 7, 512)        2,048   conv5_block2_2_c…
(BatchNormalizatio…

conv5_block2_2_relu   (None, 7, 7, 512)            0   conv5_block2_2_b…
(Activation)

conv5_block2_3_conv   (None, 7, 7,         1,050,624   conv5_block2_2_r…
(Conv2D)              2048)

conv5_block2_3_bn     (None, 7, 7,             8,192   conv5_block2_3_c…
(BatchNormalizatio…   2048)

conv5_block2_add      (None, 7, 7,                 0   conv5_block1_out…
(Add)                 2048)                            conv5_block2_3_b…

conv5_block2_out      (None, 7, 7,                 0   conv5_block2_add…
(Activation)          2048)

conv5_block3_1_conv   (None, 7, 7, 512)    1,049,088   conv5_block2_out…
(Conv2D)

conv5_block3_1_bn     (None, 7, 7, 512)        2,048   conv5_block3_1_c…
(BatchNormalizatio…

conv5_block3_1_relu   (None, 7, 7, 512)            0   conv5_block3_1_b…
(Activation)

conv5_block3_2_conv   (None, 7, 7, 512)    2,359,808   conv5_block3_1_r…
(Conv2D)

conv5_block3_2_bn     (None, 7, 7, 512)        2,048   conv5_block3_2_c…
(BatchNormalizatio…

conv5_block3_2_relu   (None, 7, 7, 512)            0   conv5_block3_2_b…
(Activation)

conv5_block3_3_conv   (None, 7, 7,         1,050,624   conv5_block3_2_r…
(Conv2D)              2048)

conv5_block3_3_bn     (None, 7, 7,             8,192   conv5_block3_3_c…
(BatchNormalizatio…   2048)

conv5_block3_add      (None, 7, 7,                 0   conv5_block2_out…
```

```
(Add)                 2048)                                  conv5_block3_3_b…

conv5_block3_out      (None, 7, 7,                 0         conv5_block3_add…
(Activation)          2048)

global_average_poo…   (None, 2048)                 0         conv5_block3_out…
(GlobalAveragePool…

dropout_24            (None, 2048)                 0         global_average_p…
(Dropout)

dense_24 (Dense)      (None, 128)            262,272         dropout_24[0][0]

dropout_25            (None, 128)                  0         dense_24[0][0]
(Dropout)

dense_25 (Dense)      (None, 1)                  129         dropout_25[0][0]


 Total params: 58,275,973 (222.31 MB)

 Trainable params: 17,212,929 (65.66 MB)

 Non-trainable params: 6,637,184 (25.32 MB)

 Optimizer params: 34,425,860 (131.32 MB)

WARNING:tensorflow:5 out of the last 42 calls to <function
TensorFlowTrainer.make_predict_function.<locals>.one_step_on_data_distributed at
0x3751d5800> triggered tf.function retracing. Tracing is expensive and the
excessive number of tracings could be due to (1) creating @tf.function
repeatedly in a loop, (2) passing tensors with different shapes, (3) passing
Python objects instead of tensors. For (1), please define your @tf.function
outside of the loop. For (2), @tf.function has reduce_retracing=True option that
can avoid unnecessary retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.
33/33             26s 783ms/step
```

[104]:
```
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
import cv2

def crop_lungs_fixed(img):
```

```
    """
    Crops the image to a central lung region.
    Assumes input shape (H, W, 3) and returns resized (224, 224, 3) image.
    """
    h, w = img.shape[:2]
    # Empirically determined crop region (adjustable)
    top = int(h * 0.15)
    bottom = int(h * 0.90)
    left = int(w * 0.20)
    right = int(w * 0.80)

    cropped = img[top:bottom, left:right]
    resized = cv2.resize(cropped, (224, 224))
    return resized

# Get a batch of images from validation generator
img_batch, label_batch = val_generator[0]
original_img = img_batch[0]  # shape: (224, 224, 3)

# Apply the crop
lung_cropped_img = crop_lungs_fixed(original_img)

# Show it
import matplotlib.pyplot as plt
plt.imshow(lung_cropped_img)
plt.title(f"Cropped Lung Image - True Label: {label_batch[0]}")
plt.axis('off')
plt.show()

class LungCroppedImageDataGenerator(ImageDataGenerator):
    def standardize(self, x):
        x = super().standardize(x)
        return crop_lungs_fixed(x)

def get_gradcam_heatmap(model, image_array,␣
 ↪last_conv_layer_name='conv5_block3_out'):
    grad_model = tf.keras.models.Model(
        [model.inputs],
        [model.get_layer(last_conv_layer_name).output, model.output]
    )

    with tf.GradientTape() as tape:
        conv_outputs, predictions = grad_model(image_array)
        loss = predictions[:, 0]

    grads = tape.gradient(loss, conv_outputs)[0]
    conv_outputs = conv_outputs[0]
```

```
    weights = tf.reduce_mean(grads, axis=(0, 1))

    cam = np.zeros(conv_outputs.shape[0:2], dtype=np.float32)
    for i, w in enumerate(weights):
        cam += w * conv_outputs[:, :, i]

    cam = np.maximum(cam, 0)
    cam = cam / np.max(cam)
    return cam



def overlay_heatmap_on_image(img, heatmap, alpha=0.4):
    heatmap_resized = cv2.resize(heatmap, (img.shape[1], img.shape[0]))
    heatmap_color = cv2.applyColorMap(np.uint8(255 * heatmap_resized), cv2.
 ↪COLORMAP_JET)
    img_rgb = np.uint8(img * 255)
    superimposed_img = cv2.addWeighted(heatmap_color, alpha, img_rgb, 1 -␣
 ↪alpha, 0)
    return superimposed_img



img_batch, label_batch = val_generator[0]
img = img_batch[0]
label = label_batch[0]
img_array = np.expand_dims(img, axis=0)

heatmap = get_gradcam_heatmap(model, img_array)
overlay = overlay_heatmap_on_image(img, heatmap)

plt.imshow(cv2.cvtColor(overlay, cv2.COLOR_BGR2RGB))
plt.title(f"True label: {int(label)} | Pred: {model.predict(img_array)[0][0]:.
 ↪2f}")
plt.axis('off')
plt.show()
```



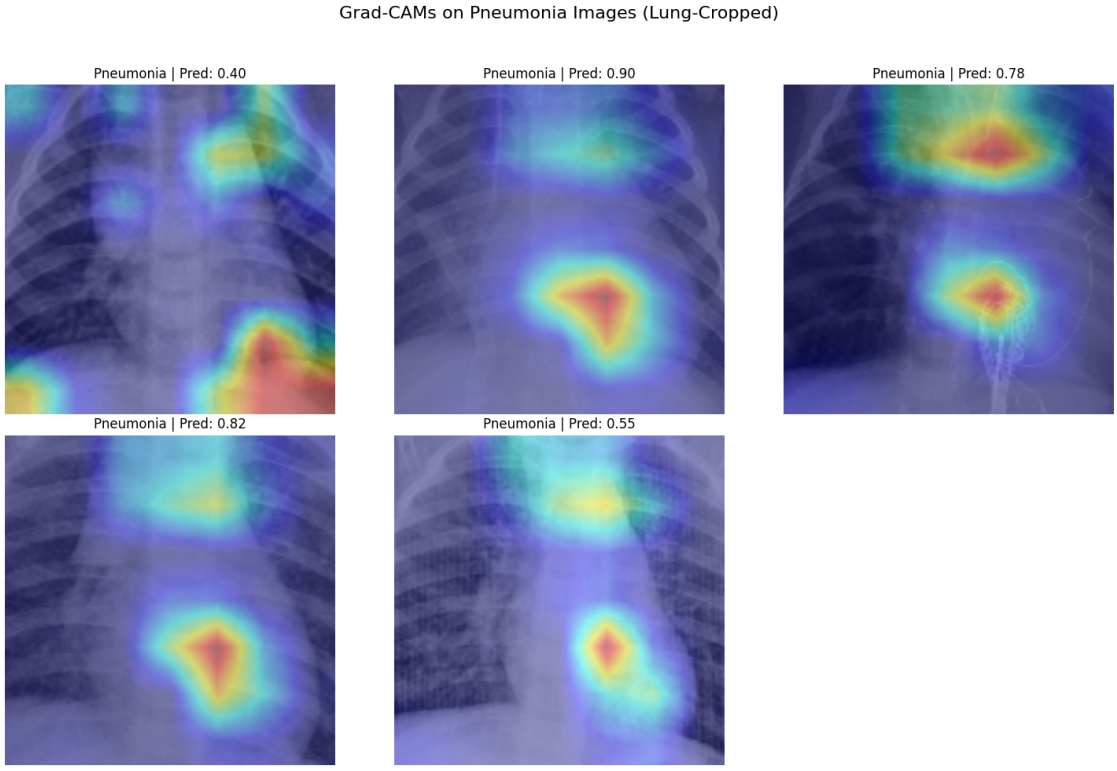

```
/opt/anaconda3/lib/python3.12/site-packages/keras/src/models/functional.py:241:
UserWarning: The structure of `inputs` doesn't match the expected structure.
Expected: [['keras_tensor_2823']]
Received: inputs=Tensor(shape=(1, 224, 224, 3))
  warnings.warn(msg)
```

```
1/1             0s 489ms/step
```

[113]:
```
# Get all validation images and labels
x_val, y_val = [], []

for i in range(len(val_generator)):
    x_batch, y_batch = val_generator[i]
    x_val.extend(x_batch)
    y_val.extend(y_batch)

x_val = np.array(x_val)
y_val = np.array(y_val)

import random

# Find indices of pneumonia cases
pneumonia_indices = np.where(y_val == 1)[0]
selected_indices = random.sample(list(pneumonia_indices), 5)  # Pick 5 at random

x_samples = x_val[selected_indices]
y_samples = y_val[selected_indices]

def get_gradcam_heatmap(model, image_array,␣
 ↪last_conv_layer_name='conv5_block3_out'):
```

```
    grad_model = tf.keras.models.Model(
        [model.inputs],
        [model.get_layer(last_conv_layer_name).output, model.output]
    )
    with tf.GradientTape() as tape:
        conv_outputs, predictions = grad_model(image_array)
        loss = predictions[:, 0]

    grads = tape.gradient(loss, conv_outputs)[0]
    conv_outputs = conv_outputs[0]
    weights = tf.reduce_mean(grads, axis=(0, 1))
    cam = np.zeros(conv_outputs.shape[0:2], dtype=np.float32)

    for i, w in enumerate(weights):
        cam += w * conv_outputs[:, :, i]

    cam = np.maximum(cam, 0)
    cam = cam / np.max(cam)
    return cam

def overlay_heatmap_on_image(img, heatmap, alpha=0.4):
    heatmap_resized = cv2.resize(heatmap, (img.shape[1], img.shape[0]))
    heatmap_color = cv2.applyColorMap(np.uint8(255 * heatmap_resized), cv2.
 ↪COLORMAP_JET)
    img_rgb = np.uint8(img * 255)
    return cv2.addWeighted(heatmap_color, alpha, img_rgb, 1 - alpha, 0)

import matplotlib.pyplot as plt

plt.figure(figsize=(15, 10))

for i, img in enumerate(x_samples):
    img_array = np.expand_dims(img, axis=0)
    heatmap = get_gradcam_heatmap(model, img_array)
    overlay = overlay_heatmap_on_image(img, heatmap)

    pred = model.predict(img_array)[0][0]

    plt.subplot(2, 3, i+1)
    plt.imshow(cv2.cvtColor(overlay, cv2.COLOR_BGR2RGB))
    plt.title(f"Pneumonia | Pred: {pred:.2f}")
    plt.axis('off')

plt.tight_layout()
plt.suptitle("Grad-CAMs on Pneumonia Images (Lung-Cropped)", fontsize=16)
plt.subplots_adjust(top=0.88)
plt.show()
```

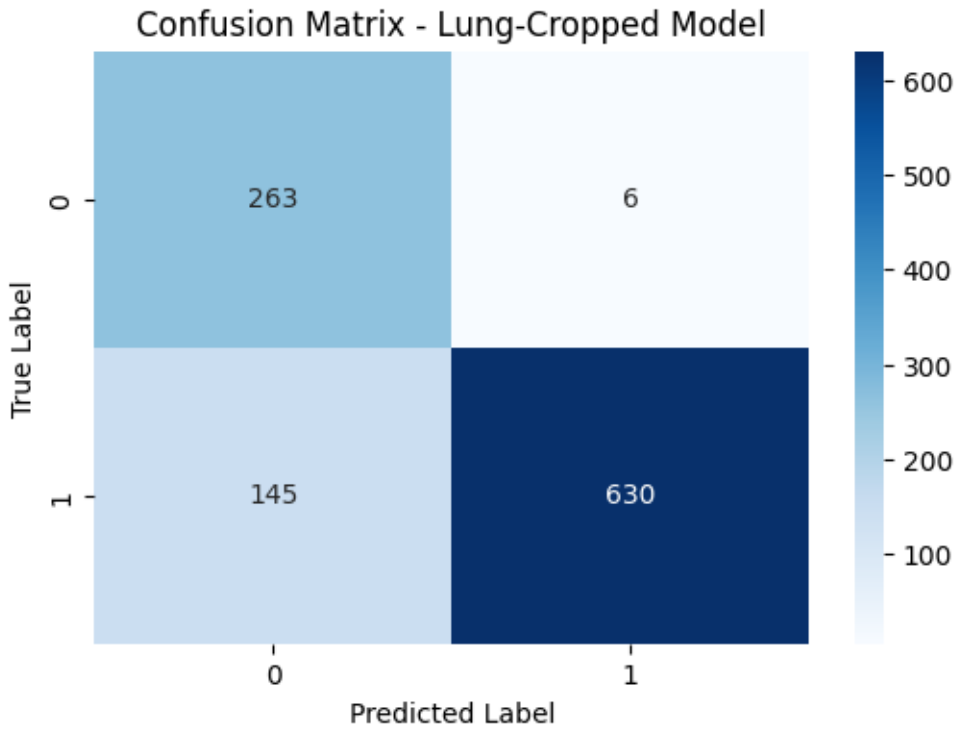
```
1/1             0s 120ms/step
1/1             0s 46ms/step
1/1             0s 46ms/step
1/1             0s 42ms/step
1/1             0s 46ms/step
```



[115]:
```python
y_true = val_generator.classes
y_probs = model.predict(val_generator).flatten()
y_pred = (y_probs > 0.5).astype(int)

from sklearn.metrics import confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt

cm = confusion_matrix(y_true, y_pred)

plt.figure(figsize=(6, 4))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues')
plt.xlabel("Predicted Label")
plt.ylabel("True Label")
plt.title("Confusion Matrix - Lung-Cropped Model")
plt.show()
```

```
from sklearn.metrics import classification_report

print(classification_report(y_true, y_pred, target_names=["Normal",␣
 ↪"Pneumonia"]))
```

```
33/33              23s 697ms/step
```

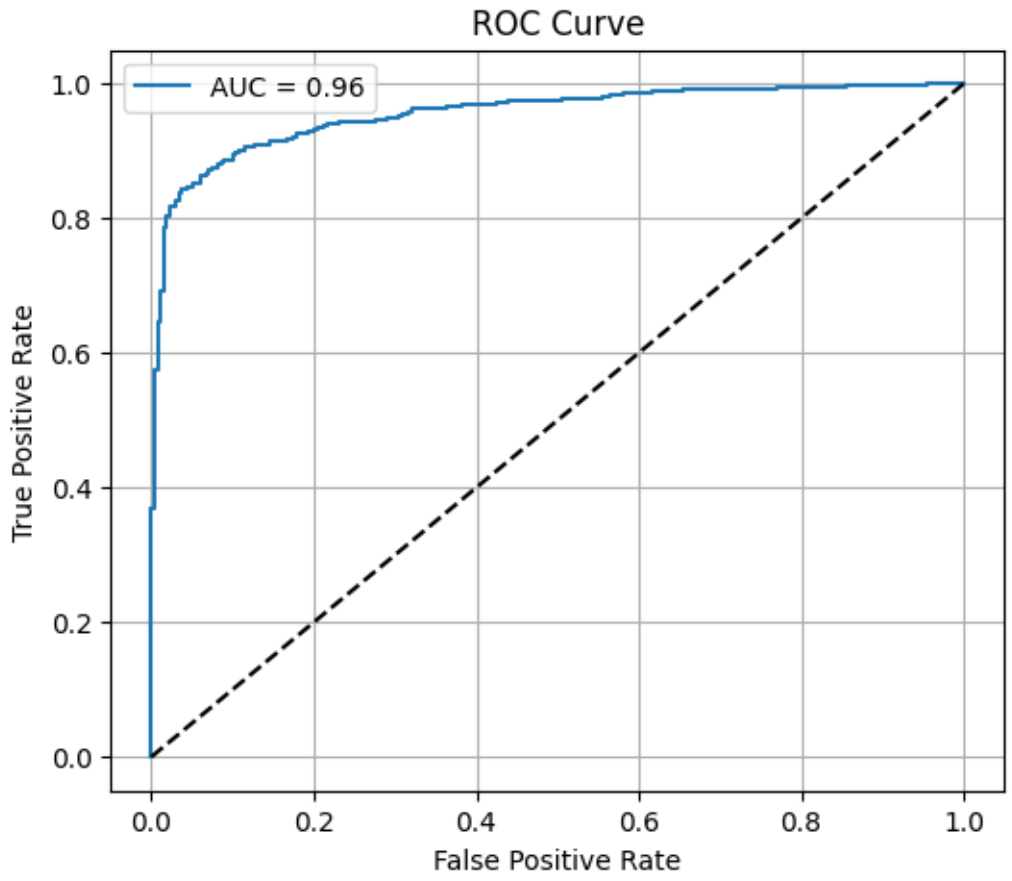


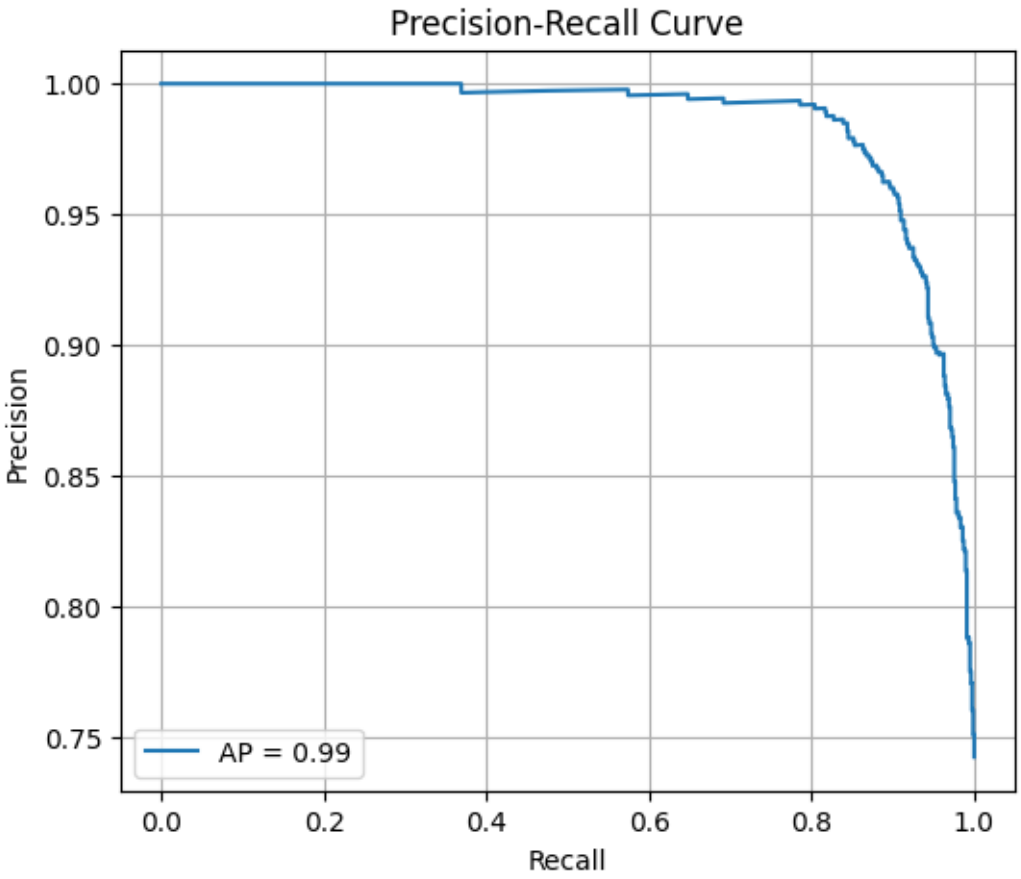
	precision	recall	f1-score	support
Normal	0.64	0.98	0.78	269
Pneumonia	0.99	0.81	0.89	775
accuracy			0.86	1044
macro avg	0.82	0.90	0.83	1044
weighted avg	0.90	0.86	0.86	1044

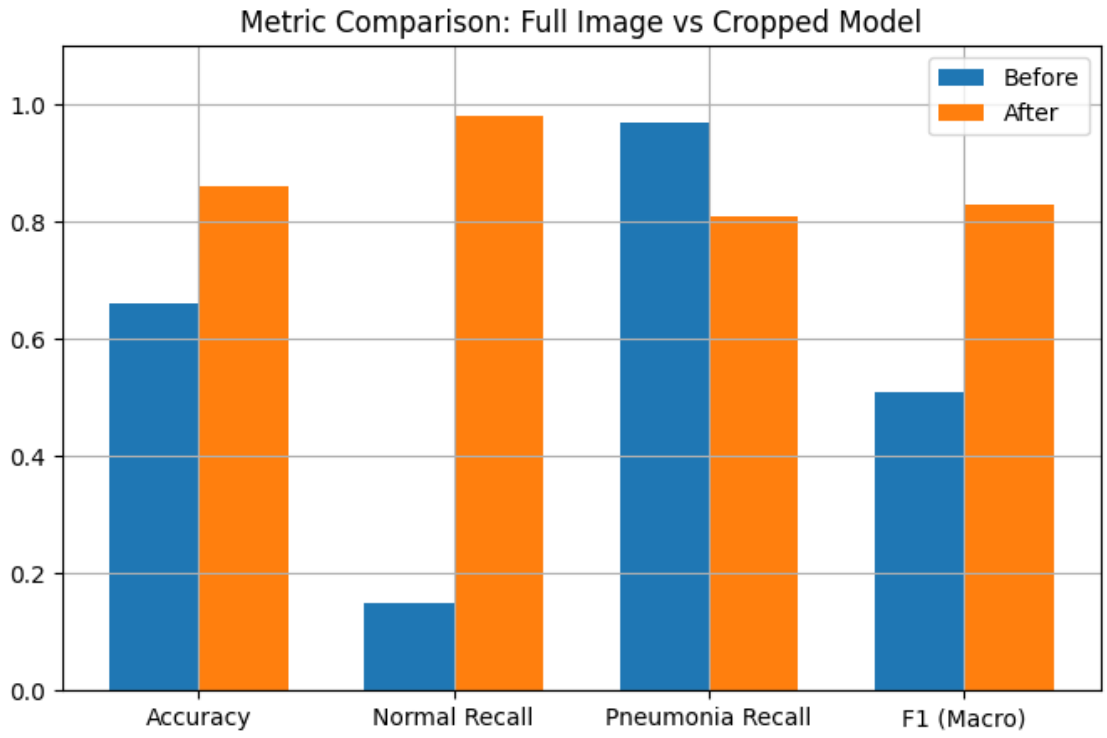
[119]:
```
def plot_training_curves(history):
    metrics = ['accuracy', 'loss', 'auc', 'recall']
    plt.figure(figsize=(16, 8))

    for i, metric in enumerate(metrics):
        plt.subplot(2, 2, i+1)
        plt.plot(history.history[metric], label=f'Train {metric}')
```

```
        plt.plot(history.history[f'val_{metric}'], label=f'Val {metric}')
        plt.title(f"{metric.title()} over Epochs")
        plt.xlabel("Epoch")
        plt.ylabel(metric.title())
        plt.legend()
        plt.grid(True)

    plt.tight_layout()
    plt.suptitle("Training Metrics", fontsize=16, y=1.02)
    plt.show()


from sklearn.metrics import roc_curve, auc

fpr, tpr, _ = roc_curve(y_true, y_probs)
roc_auc = auc(fpr, tpr)

plt.figure(figsize=(6, 5))
plt.plot(fpr, tpr, label=f'AUC = {roc_auc:.2f}')
plt.plot([0, 1], [0, 1], 'k--')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve')
plt.legend()
plt.grid()
plt.show()


from sklearn.metrics import precision_recall_curve, average_precision_score

precision, recall, _ = precision_recall_curve(y_true, y_probs)
avg_prec = average_precision_score(y_true, y_probs)

plt.figure(figsize=(6, 5))
plt.plot(recall, precision, label=f'AP = {avg_prec:.2f}')
plt.xlabel('Recall')
plt.ylabel('Precision')
plt.title('Precision-Recall Curve')
plt.grid()
plt.legend()
plt.show()



import numpy as np

labels = ['Accuracy', 'Normal Recall', 'Pneumonia Recall', 'F1 (Macro)']
```

```
before = [0.66, 0.15, 0.97, 0.51]
after = [0.86, 0.98, 0.81, 0.83]

x = np.arange(len(labels))
width = 0.35

plt.figure(figsize=(8, 5))
plt.bar(x - width/2, before, width, label='Before')
plt.bar(x + width/2, after, width, label='After')
plt.xticks(x, labels)
plt.ylim(0, 1.1)
plt.title("Metric Comparison: Full Image vs Cropped Model")
plt.legend()
plt.grid(True)
plt.show()
```




Precision-Recall Curve
Precision
Recall
1.00
0.95
0.90
0.85
0.80
0.75
0.0
0.2
0.4
0.6
0.8
1.0
AP = 0.99



[75]:
```
!pip install opencv-python
```

```
Collecting opencv-python
  Downloading opencv_python-4.12.0.88-cp37-abi3-macosx_13_0_arm64.whl.metadata
(19 kB)
Collecting numpy<2.3.0,>=2 (from opencv-python)
  Downloading numpy-2.2.6-cp312-cp312-macosx_14_0_arm64.whl.metadata (62 kB)
Downloading opencv_python-4.12.0.88-cp37-abi3-macosx_13_0_arm64.whl (37.9 MB)
                         37.9/37.9 MB
7.3 MB/s eta 0:00:0000:0100:01
Downloading numpy-2.2.6-cp312-cp312-macosx_14_0_arm64.whl (5.1 MB)
                         5.1/5.1 MB
12.8 MB/s eta 0:00:00a 0:00:01
Installing collected packages: numpy, opencv-python
  Attempting uninstall: numpy
    Found existing installation: numpy 1.26.4
    Uninstalling numpy-1.26.4:
      Successfully uninstalled numpy-1.26.4
```

```
ERROR: pip's dependency resolver does not currently take into account all
the packages that are installed. This behaviour is the source of the following
dependency conflicts.
gensim 4.3.3 requires numpy<2.0,>=1.18.5, but you have numpy 2.2.6 which is
incompatible.
contourpy 1.2.0 requires numpy<2.0,>=1.20, but you have numpy 2.2.6 which is
incompatible.
numba 0.60.0 requires numpy<2.1,>=1.22, but you have numpy 2.2.6 which is
incompatible.
tensorflow 2.19.0 requires numpy<2.2.0,>=1.26.0, but you have numpy 2.2.6 which
is incompatible.
pywavelets 1.5.0 requires numpy<2.0,>=1.22.4, but you have numpy 2.2.6 which is
incompatible.
Successfully installed numpy-2.2.6 opencv-python-4.12.0.88
```

[ ]: