

group-8-notebook

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PNEUMONIA DETECTION USING DEEP LEARNING METHODOLOGY

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#Business Understanding

#Introduction Pneumonia is an infection that inflames the air sacs in one or both lungs. The air sacs may fill with fluid or pus (purulent material), causing cough with phlegm or pus, fever, chills, and difficulty breathing. A variety of organisms, including bacteria, viruses and fungi, can cause pneumonia. Chest X-ray, blood tests, and culture of the sputum may help confirm the diagnosis. The disease may be classified by where it was acquired, such as community- or hospital-acquired or healthcare-associated pneumonia.

The rapid advancement of Artificial Intelligence (AI) has brought significant benefits across various industries, including healthcare. Traditionally, diagnosing pneumonia requires time-consuming physical examinations and lab tests, often necessitating multiple doctor visits. To address this issue, we aim to develop a deep learning model capable of accurately detecting pneumonia from chest x-ray images. Such a tool holds immense value for healthcare professionals and patients, enabling quicker and more precise diagnoses. Radiologists and other specialists can leverage this technology to enhance their diagnostic accuracy, ultimately leading to better patient care and treatment outcomes.

#Picture depicting a normal, bacterial and viral pneumonia lungs

The normal chest X-ray(left panel) depicts clear lungs without any areas of abnormal opacification in the image. Bacterial pneumonia(middle panel) typically exhibits a focal lobar consolidation, in

this case in the right upper lobe(white arrows),whereas viral pneumonia(right panel) manifest with a more diffuse ” interstitial” pattern in both lungs

#Problem Statement

What is the contemporary context or the exiting situation(Context)

Early detection and treatment of pneumonia are essential for avoiding complications and enhancing clinical results. Detecting pneumonia is not only a medical necessity but also a humanitarian imperative and a technological frontier. Chest X-rays are a frequently used imaging modality for diagnosing pneumonia.

What is the problem being tackled(Issue)

According to the World Health Organization, Pneumonia accounts for 14% of all deaths of children under 5 years old, killing 740 180 children in 2019. Chest X-ray imaging serves as a prevalent diagnostic tool for pneumonia, offering insights such as increased lung opacity. Nevertheless, interpreting chest X-rays poses challenges due to the subtle nature of pneumonia symptoms and their potential overlap with other respiratory conditions. Analyzing radiological images, including chest X-rays and CT scans, demands specialized expertise and can consume significant time in the diagnostic process

What problem are we trying to solve.(Relevance)

This project aims to develop a deep learning model capable of accurately detecting pneumonia from chest x-ray images. Such a tool holds immense value for healthcare professionals and patients, enabling quicker and more precise diagnoses. Radiologists and other specialists can leverage this technology to enhance their diagnostic accuracy, ultimately leading to better patient care and treatment outcomes.

Objectives

- 1.The main objective of this project is to leverage deep learning techniques to develop an automated system capable of accurately diagnosing pneumonia from chest X-ray images.
- 2.Preprocess the chest X-ray images to standardize resolution, orientation, and contrast, optimizing them for input into the deep learning model.
- 3.Explore and implement various deep learning architectures suitable for image classification tasks, such as convolutional neural networks (CNNs), to identify the most effective model for pneumonia detection.
- 4.Train the selected deep learning model using the prepared dataset, employing techniques like data augmentation to enhance model generalization and prevent overfitting.
- 5.Evaluate the trained model’s performance using appropriate metrics such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic (ROC) curve, validating its effectiveness in pneumonia detection.
- 6.Fine-tune the model parameters and architecture based on evaluation results, iteratively improving its performance and robustness.

#Stakeholders

Key stakeholders interested in leveraging deep learning for medical imaging include healthcare professionals, patients, hospitals, medical device manufacturers, and insurance companies. For

instance, hospitals can optimize resource allocation and improve treatment efficacy, while medical device manufacturers can enhance product development for more accurate diagnoses. Additionally, researchers and government agencies stand to benefit from these advancements, using the models to deepen disease understanding and ensure regulatory compliance.

#Specific Goals

1.Data Understanding and Preparation

Load, explore, and preprocess the Chest X-Ray Images (Pneumonia) dataset to ensure it is suitable for model training. Implement data augmentation techniques to enhance the training dataset and improve model generalization

2.Model Development

Build and train a baseline convolutional neural network (CNN) model to classify chest X-ray images as 'PNEUMONIA' or 'NORMAL'. Experiment with different model architectures and layers to improve performance.

3.Hyperparameter Tuning

Utilize Keras Tuner to perform hyperparameter optimization, focusing on key parameters such as learning rate, batch size, and network depth

4.Model Evaluation

Evaluate the model's performance using accuracy, precision, recall, and F1-score on validation and test datasets. Ensure the model's robustness and ability to generalize to new, unseen data.

5.Result Analysis and Evaluation

Analyze and visualize the training history, including loss and accuracy curves, to understand the model's learning dynamics. Compare training, validation, and test performance to detect and address potential overfitting or underfitting

6.Clinical Intergration

Propose a strategy for integrating the developed model into clinical workflows to assist in the diagnosis of pneumonia

Research Questions 1: Can a convolutional neural network (CNN) accurately classify chest X-ray images as 'PNEUMONIA' or 'NORMAL'? What are the optimal hyperparameters for achieving the highest diagnostic accuracy in the CNN model? 2:How well does the model generalize to new, unseen chest X-ray images? 3:What are the practical considerations for integrating this model into clinical settings?

Significance Developing an automated pneumonia detection system has significant potential to:

Enhance the speed and accuracy of pneumonia diagnosis, leading to timely and effective treatment. Support healthcare providers in areas with limited access to trained radiologists. Reduce the burden on medical professionals by providing a reliable second opinion.

Data Preprocessing Resizing: Images were resized to 224x224 pixels to maintain uniformity. Normalization: Pixel values were rescaled to a range of 0 to 1 to facilitate faster convergence during training. Augmentation: Data augmentation techniques, such as rotation and flipping, were applied to the training set to enhance model generalization.

Dataset Description

Source: Kaggle's Chest X-Ray Images (Pneumonia) dataset. **Structure:** The dataset is organized into three primary directories: **train:** Contains training images categorized into 'PNEUMONIA' and 'NORMAL'. **val:** Contains validation images for model tuning and performance evaluation. **test:** Contains test images for final model evaluation.

Downloading and Extracting Dataset from Kaggle

```
[ ]: # Install Kaggle
!pip install kaggle

# Make a directory for Kaggle and move kaggle.json there
!mkdir -p ~/.kaggle
!cp kaggle.json ~/.kaggle/

# Set permissions for the kaggle.json file
!chmod 600 ~/.kaggle/kaggle.json

# Download the dataset
!kaggle datasets download -d paultimothymooney/chest-xray-pneumonia

# Unzip the downloaded dataset
!unzip chest-xray-pneumonia.zip -d chest_xray
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[illegible]

[illegible]

[illegible]

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```

IMPORTING DESIRED LIBRARIES

```
[ ]: import pandas as pd
import numpy as np

import tensorflow as tf
import pathlib

import os

import matplotlib.pyplot as plt
import matplotlib.image as mpimg

from PIL import Image
```

```

from tensorflow.keras.preprocessing.image import ImageDataGenerator

from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense,
↳Dropout

import datetime

import tensorflow as tf

```

```

[ ]: # Define the path to the dataset
data_dir = pathlib.Path("chest_xray/chest_xray")

```

LOADING DATASET

```

[ ]: # Load the dataset
image_count = len(list(data_dir.glob('*/*.jpeg')))
print(f'Total number of images: {image_count}')

```

Total number of images: 5856

```

[ ]: batch_size = 32
img_height = 180
img_width = 180

train_ds = tf.keras.utils.image_dataset_from_directory(
    data_dir / 'train',
    image_size=(img_height, img_width),
    batch_size=batch_size)

val_ds = tf.keras.utils.image_dataset_from_directory(
    data_dir / 'val',
    image_size=(img_height, img_width),
    batch_size=batch_size)

test_ds = tf.keras.utils.image_dataset_from_directory(
    data_dir / 'test',
    image_size=(img_height, img_width),
    batch_size=batch_size)

```

Found 5216 files belonging to 2 classes.
Found 16 files belonging to 2 classes.
Found 624 files belonging to 2 classes.

```
[ ]: # Print the class names
class_names = train_ds.class_names
print(f'Class names: {class_names}')
```

Class names: ['NORMAL', 'PNEUMONIA']

UNDERSTANDING THE DATASET

To understand the structure of the dataset first we examined the directory structure and counted the number of images in each class for training, validation, and testing sets.

```
[ ]: # Define paths to the dataset directories
train_dir = pathlib.Path("chest_xray/chest_xray/train")
val_dir = pathlib.Path("chest_xray/chest_xray/val")
test_dir = pathlib.Path("chest_xray/chest_xray/test")
```

```
[ ]: # Function to count images in each subdirectory
def count_images(directory):
    normal_count = len(list(directory.glob('NORMAL/*')))
    pneumonia_count = len(list(directory.glob('PNEUMONIA/*')))
    return normal_count, pneumonia_count
```

```
[ ]: #Count images in train, validation, and test sets
train_normal_count, train_pneumonia_count = count_images(train_dir)
val_normal_count, val_pneumonia_count = count_images(val_dir)
test_normal_count, test_pneumonia_count = count_images(test_dir)

print(f"Training set: {train_normal_count} NORMAL, {train_pneumonia_count} PNEUMONIA")
print(f"Validation set: {val_normal_count} NORMAL, {val_pneumonia_count} PNEUMONIA")
print(f"Test set: {test_normal_count} NORMAL, {test_pneumonia_count} PNEUMONIA")
```

Training set: 1341 NORMAL, 3875 PNEUMONIA

Validation set: 8 NORMAL, 8 PNEUMONIA

Test set: 234 NORMAL, 390 PNEUMONIA

Exploring the dataset

By exploring the dataset in these steps, we gain insights into its structure, sample images, class distribution, and image properties. This understanding helps in making informed decisions when preprocessing the data and training our model.

```
[ ]: def show_samples(image_paths, title):
    plt.figure(figsize=(10, 10))
    for i, img_path in enumerate(image_paths[:9]):
        plt.subplot(3, 3, i + 1)
        img = mpimg.imread(img_path)
        plt.imshow(img, cmap='gray')
```

```
plt.axis('off')
plt.suptitle(title)
plt.show()
```

```
# Show samples of Normal and Pneumonia images from the training set
```

```
train_normal_images = list(train_dir.glob('NORMAL/*'))
```

```
train_pneumonia_images = list(train_dir.glob('PNEUMONIA/*'))
```

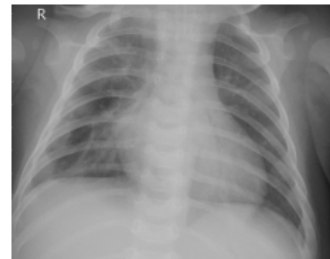
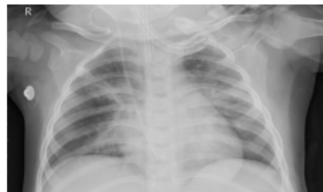
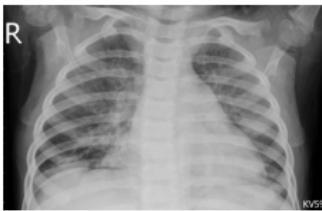
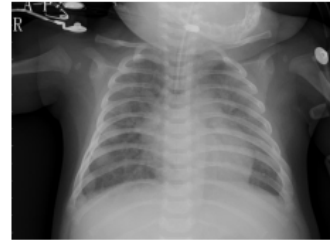
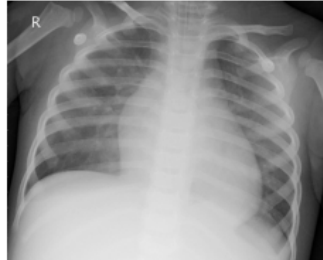
```
show_samples(train_normal_images, "Normal Images")
```

```
show_samples(train_pneumonia_images, "Pneumonia Images")
```

Normal Images



Pneumonia Images



Visualizing a sample of images

Visualizing a few sample images from each class can provide insights into the data. The displayed images are from both the NORMAL and PNEUMONIA classes for the training set.

Checking for class imbalance

```
[ ]: # Creating a DataFrame to summarize the counts
data_summary = pd.DataFrame({
    'Set': ['Training', 'Validation', 'Test'],
```



```

    'Normal': [train_normal_count, val_normal_count, test_normal_count],
    'Pneumonia': [train_pneumonia_count, val_pneumonia_count,
↪test_pneumonia_count]
})

```

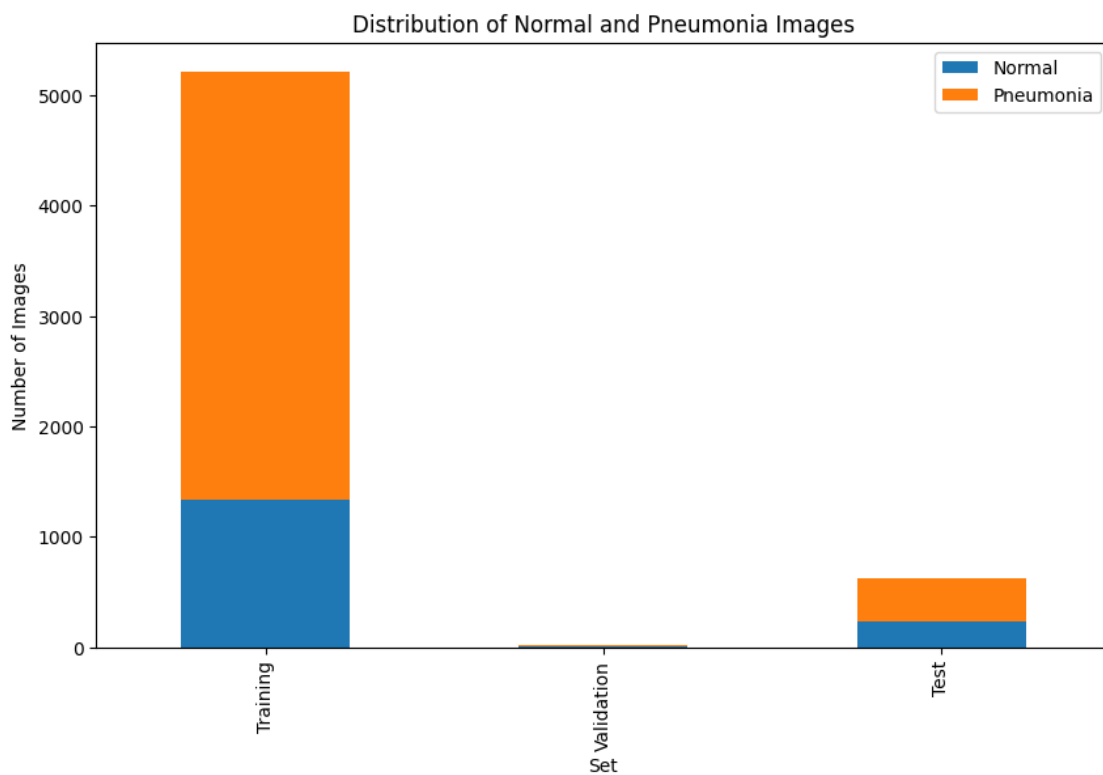
```
[ ]: print(data_summary)
```

	Set	Normal	Pneumonia
0	Training	1341	3875
1	Validation	8	8
2	Test	234	390

```

[ ]: # Plot the distribution
data_summary.plot(kind='bar', x='Set', stacked=True, figsize=(10, 6))
plt.title('Distribution of Normal and Pneumonia Images')
plt.ylabel('Number of Images')
plt.show()

```



We compared the number of images in each class as it displayed on the above histogram so as to see if class imbalance will affect the models performance

Displaying Images Dimensions

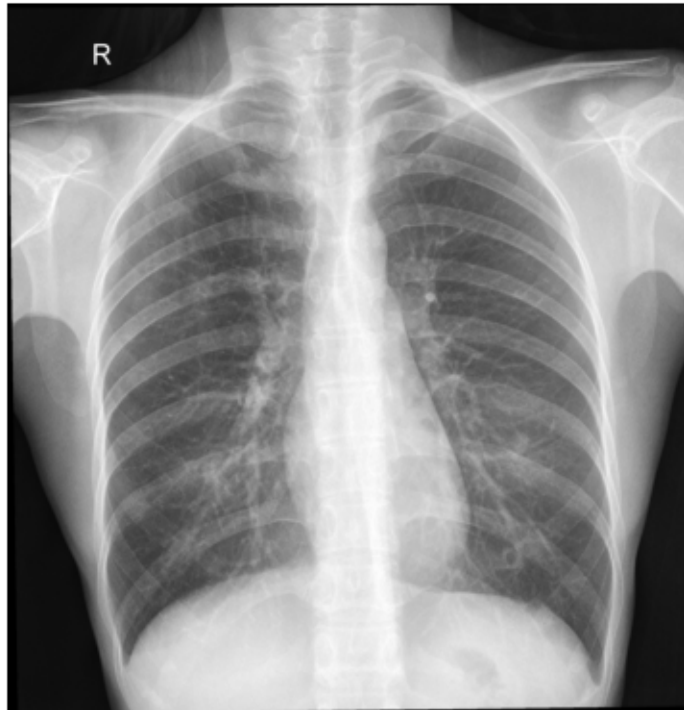
We tried to understand the dimensions and pixel values of images in order to perform preprocessing.

```
[ ]: def display_image_info(image_paths, title):
    # Load an image
    img_path = image_paths[0]
    img = Image.open(img_path)
    img_array = np.array(img)

    # Display image info
    print(f"{title} Image:")
    print(f"Dimensions: {img.size}")
    print(f"Pixel range: {img_array.min()} - {img_array.max()}")
    plt.imshow(img, cmap='gray')
    plt.axis('off')
    plt.show()

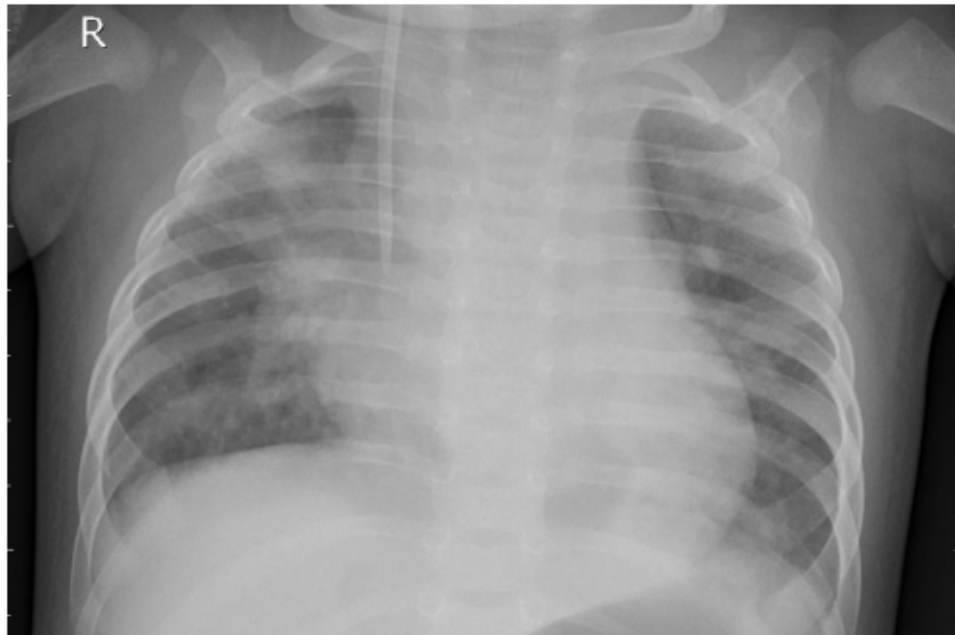
    # Display information for a sample image from each class
    display_image_info(train_normal_images, "Normal")
    display_image_info(train_pneumonia_images, "Pneumonia")
```

Normal Image:
Dimensions: (2288, 2363)
Pixel range: 0 - 255



Pneumonia Image:
Dimensions: (920, 608)

Pixel range: 0 - 255



The displayed images shows the chest of a normal personal while the second images shows the chest of a person who has been affected by pneumonia

PREPROCESSING

This step involves preparing the data for the model an also includes tasks like resizing images, normalizing pixel values, data augmentation, and splitting the data into training and validation.

Resizing the Images and Normalizaton

The main reason for resizing the image is to ensure that they are of the same size

Normalization is a fundamental preprocessing step when working with image data in machine learning models. By dividing pixel values by 255, we ensure that the pixel values are within a manageable range for the model to learn effectively. This process helps in stabilizing the training process and often leads to better model performance.

Data augmentation introduces variations of training images (such as rotations, flips, and zooms), which can help the model generalize better to new data. It's typically applied only to the training set.

```
[ ]: #Performing resizing process  
      #Define image size and batch size  
      IMG_SIZE = (224, 224)  
      BATCH_SIZE = 3  
  
      #Performing Augmentation Process
```

```

# Create ImageDataGenerator instances
train_datagen = ImageDataGenerator(
    rescale=1./255,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True,
    brightness_range=[0.5,2.0],
    width_shift_range = 0.2,
    rotation_range=20,
    fill_mode = 'nearest'
)
#Performing Normalization Process
val_test_datagen = ImageDataGenerator(rescale=1./255)

# Create generators for training, validation, and testing sets
train_generator = train_datagen.flow_from_directory(
    train_dir,
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='binary' # Assuming binary classification (NORMAL vs PNEUMONIA)
)

val_generator = val_test_datagen.flow_from_directory(
    val_dir,
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='binary'
)

test_generator = val_test_datagen.flow_from_directory(
    test_dir,
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='binary'
)

```

Found 5216 images belonging to 2 classes.

Found 16 images belonging to 2 classes.

Found 624 images belonging to 2 classes.

The two ImageDataGenerator objects, Image_gen and val_Datagen, which are in charge of data augmentation and normalization, were initialized above. Normalization is carried out by the Image_gen object by rescaling the pixel values to the interval [0, 1]. It also incorporates augmentation methods like rotation, shearing, zooming, flipping both horizontally and vertically, brightness modifications, width shifting, and nearest fill mode. These additions contribute to the training data's increased robustness and diversity, which in turn strengthens the model's capacity for generalization. To ensure consistency with the training procedure, the val_Datagen object, on the other

hand, only uses rescaling for normalization to the validation data.

MODEL ARCHITECTURE

Building a Convolutional Neural Network (CNN) model. A simple model might consist of several convolutional layers followed by pooling layers and a few dense layers.

Evaluate the model on the validation and test sets to assess its performance. Monitor metrics such as accuracy, loss, precision, recall, and F1-score.

Compiling the model

Compiling the model with an appropriate optimizer, loss function, and metrics. This step configures the model for training.

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

def train_and_evaluate_model(model, train_generator, validation_generator,
    ↪test_generator, epochs=30):
    """
    Train the model, evaluate on validation and test sets, plot training
    ↪history (loss and accuracy),
    and plot train vs test accuracy and train vs test loss.
    """
    start = datetime.datetime.now()

    # Train the model
    history = model.fit(
        train_generator,
        epochs=epochs,
        validation_data=validation_generator,
        verbose=1
    )

    # Record the training duration
    end = datetime.datetime.now()
    training_duration = end - start
    print(f"Training completed in: {training_duration}")

    # Evaluate on validation set
    validation_loss, validation_accuracy = model.evaluate(validation_generator)
    print("Validation Loss:", validation_loss)
    print("Validation Accuracy:", validation_accuracy)

    # Evaluate on test set
    test_loss, test_accuracy = model.evaluate(test_generator)
    print("Test Loss:", test_loss)
    print("Test Accuracy:", test_accuracy)

    # Plot training history (loss and accuracy)
```

```

plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
plt.plot(history.history['loss'], label='Training Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.title('Training and Validation Loss')
plt.legend()

plt.subplot(1, 2, 2)
plt.plot(history.history['accuracy'], label='Training Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Training and Validation Accuracy')
plt.legend()

plt.show()

# Plot train vs test accuracy
plt.figure(figsize=(8, 6))
plt.plot(history.history['accuracy'], label='Training Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.axhline(y=test_accuracy, color='r', linestyle='--', label='Test_
↪Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Train vs Test Accuracy')
plt.legend()
plt.show()

# Plot train vs test loss
plt.figure(figsize=(8, 6))
plt.plot(history.history['loss'], label='Training Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.axhline(y=test_loss, color='r', linestyle='--', label='Test Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.title('Train vs Test Loss')
plt.legend()
plt.show()

return history

```

To incorporate timing functionality to measure the duration of the model training process, we used the datetime module to record the start and end times.

```
[ ]: from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense,
↳ Dropout

def cnn_model(input_shape):
    model = Sequential([
        Conv2D(32, (3, 3), activation='relu', input_shape=input_shape),
        MaxPooling2D((2, 2)),
        Conv2D(64, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Conv2D(128, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Flatten(),
        Dense(128, activation='relu'),
        Dropout(0.5),
        Dense(1, activation='sigmoid')
    ])
    return model
```

cnn_model Function:

this function defines a basic CNN architecture suitable for image classification tasks. It starts with convolutional layers followed by max-pooling to reduce spatial dimensions, flattens the output, adds dense layers for classification, and includes dropout for regularization.

```
[ ]: # Define input shape based on your image dimensions (e.g., (height, width,
↳ channels))
input_shape = (224, 224, 3)

# Create the baseline CNN model
baseline_model = cnn_model(input_shape)
```

Input Shape: We define input_shape as (224, 224, 3), Our images are 224x224 pixels with 3 channels (RGB).

```
[ ]: baseline_model.compile(optimizer='adam', loss='binary_crossentropy',
↳ metrics=['accuracy'])
```

Model Compilation: Compiled the model using the Adam optimizer, binary cross-entropy loss (suitable for binary classification), and accuracy metric for evaluation.

```
[ ]: baseline_model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 222, 222, 32)	896

max_pooling2d (MaxPooling2D)	(None, 111, 111, 32)	0
conv2d_1 (Conv2D)	(None, 109, 109, 64)	18496
max_pooling2d_1 (MaxPooling2D)	(None, 54, 54, 64)	0
conv2d_2 (Conv2D)	(None, 52, 52, 128)	73856
max_pooling2d_2 (MaxPooling2D)	(None, 26, 26, 128)	0
flatten (Flatten)	(None, 86528)	0
dense (Dense)	(None, 128)	11075712
dropout (Dropout)	(None, 128)	0
dense_1 (Dense)	(None, 1)	129

```
=====
Total params: 11169089 (42.61 MB)
Trainable params: 11169089 (42.61 MB)
Non-trainable params: 0 (0.00 Byte)
```

Model Summary: Print a summary of the model architecture, showing the layer types, output shapes, and number of parameters.

The baseline model architecture comprises a total of 11,169,089 parameters, with all parameters being trainable. The model's size is approximately 42.61 MB. There are no non-trainable parameters in this architecture, showing that all parameters are updated during the training process.

Creating Data Generator

```
[ ]: # Set up data generators
train_datagen = ImageDataGenerator(rescale=1./255)
val_datagen = ImageDataGenerator(rescale=1./255)
test_datagen = ImageDataGenerator(rescale=1./255)

train_generator = train_datagen.flow_from_directory('chest_xray/chest_xray/
↳train', target_size=(224, 224), batch_size=32, class_mode='binary')
validation_generator = val_datagen.flow_from_directory('chest_xray/chest_xray/
↳val', target_size=(224, 224), batch_size=32, class_mode='binary')
test_generator = test_datagen.flow_from_directory('chest_xray/chest_xray/test',
↳target_size=(224, 224), batch_size=32, class_mode='binary')

# Train and evaluate the model
```



```
history = train_and_evaluate_model(baseline_model, train_generator, validation_generator, test_generator, epochs=30)
```

Found 5216 images belonging to 2 classes.

Found 16 images belonging to 2 classes.

Found 624 images belonging to 2 classes.

Epoch 1/30

163/163 [=====] - 558s 3s/step - loss: 0.2486 - accuracy: 0.8967 - val_loss: 0.4518 - val_accuracy: 0.7500

Epoch 2/30

163/163 [=====] - 542s 3s/step - loss: 0.1263 - accuracy: 0.9538 - val_loss: 0.4372 - val_accuracy: 0.8125

Epoch 3/30

163/163 [=====] - 539s 3s/step - loss: 0.0881 - accuracy: 0.9688 - val_loss: 0.3227 - val_accuracy: 0.7500

Epoch 4/30

163/163 [=====] - 532s 3s/step - loss: 0.0806 - accuracy: 0.9670 - val_loss: 0.2801 - val_accuracy: 0.8750

Epoch 5/30

163/163 [=====] - 531s 3s/step - loss: 0.0685 - accuracy: 0.9772 - val_loss: 1.0018 - val_accuracy: 0.6875

Epoch 6/30

163/163 [=====] - 535s 3s/step - loss: 0.0485 - accuracy: 0.9803 - val_loss: 0.4052 - val_accuracy: 0.7500

Epoch 7/30

163/163 [=====] - 534s 3s/step - loss: 0.0424 - accuracy: 0.9829 - val_loss: 0.8838 - val_accuracy: 0.6250

Epoch 8/30

163/163 [=====] - 532s 3s/step - loss: 0.0377 - accuracy: 0.9872 - val_loss: 0.2116 - val_accuracy: 0.8750

Epoch 9/30

163/163 [=====] - 533s 3s/step - loss: 0.0324 - accuracy: 0.9887 - val_loss: 0.0344 - val_accuracy: 1.0000

Epoch 10/30

163/163 [=====] - 535s 3s/step - loss: 0.0310 - accuracy: 0.9881 - val_loss: 0.3437 - val_accuracy: 0.8750

Epoch 11/30

163/163 [=====] - 533s 3s/step - loss: 0.0306 - accuracy: 0.9887 - val_loss: 0.6850 - val_accuracy: 0.8125

Epoch 12/30

163/163 [=====] - 531s 3s/step - loss: 0.0203 - accuracy: 0.9925 - val_loss: 0.1560 - val_accuracy: 0.9375

Epoch 13/30

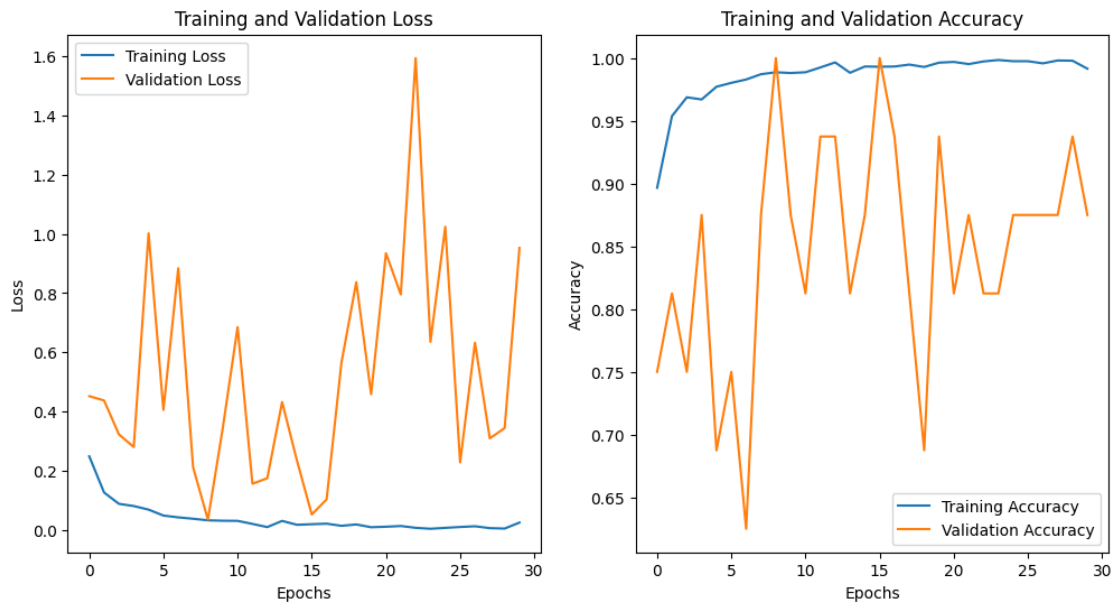
163/163 [=====] - 533s 3s/step - loss: 0.0095 - accuracy: 0.9965 - val_loss: 0.1745 - val_accuracy: 0.9375

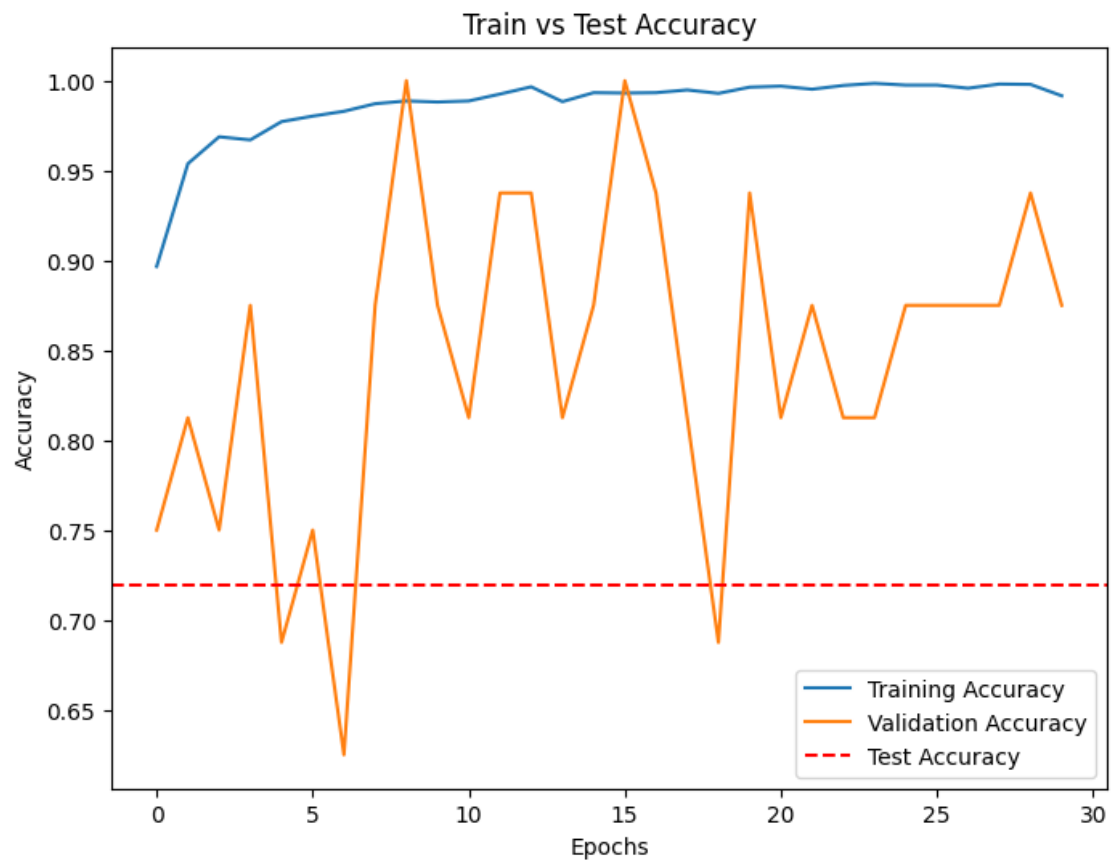
Epoch 14/30

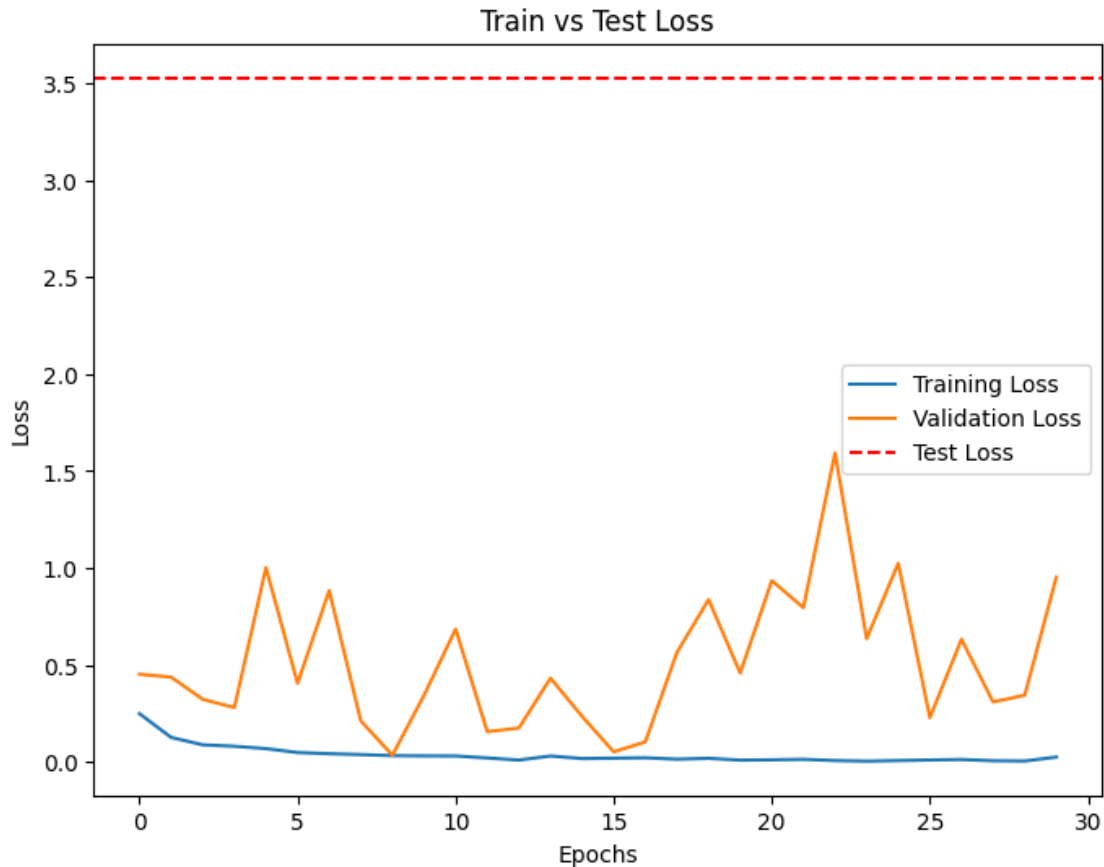
163/163 [=====] - 535s 3s/step - loss: 0.0304 -

accuracy: 0.9883 - val_loss: 0.4319 - val_accuracy: 0.8125
Epoch 15/30
163/163 [=====] - 532s 3s/step - loss: 0.0172 -
accuracy: 0.9933 - val_loss: 0.2346 - val_accuracy: 0.8750
Epoch 16/30
163/163 [=====] - 562s 3s/step - loss: 0.0193 -
accuracy: 0.9931 - val_loss: 0.0520 - val_accuracy: 1.0000
Epoch 17/30
163/163 [=====] - 535s 3s/step - loss: 0.0210 -
accuracy: 0.9933 - val_loss: 0.1032 - val_accuracy: 0.9375
Epoch 18/30
163/163 [=====] - 534s 3s/step - loss: 0.0138 -
accuracy: 0.9948 - val_loss: 0.5648 - val_accuracy: 0.8125
Epoch 19/30
163/163 [=====] - 532s 3s/step - loss: 0.0184 -
accuracy: 0.9929 - val_loss: 0.8370 - val_accuracy: 0.6875
Epoch 20/30
163/163 [=====] - 533s 3s/step - loss: 0.0090 -
accuracy: 0.9964 - val_loss: 0.4584 - val_accuracy: 0.9375
Epoch 21/30
163/163 [=====] - 533s 3s/step - loss: 0.0107 -
accuracy: 0.9969 - val_loss: 0.9347 - val_accuracy: 0.8125
Epoch 22/30
163/163 [=====] - 536s 3s/step - loss: 0.0132 -
accuracy: 0.9952 - val_loss: 0.7953 - val_accuracy: 0.8750
Epoch 23/30
163/163 [=====] - 533s 3s/step - loss: 0.0070 -
accuracy: 0.9973 - val_loss: 1.5938 - val_accuracy: 0.8125
Epoch 24/30
163/163 [=====] - 533s 3s/step - loss: 0.0039 -
accuracy: 0.9985 - val_loss: 0.6353 - val_accuracy: 0.8125
Epoch 25/30
163/163 [=====] - 532s 3s/step - loss: 0.0070 -
accuracy: 0.9975 - val_loss: 1.0241 - val_accuracy: 0.8750
Epoch 26/30
163/163 [=====] - 541s 3s/step - loss: 0.0098 -
accuracy: 0.9975 - val_loss: 0.2280 - val_accuracy: 0.8750
Epoch 27/30
163/163 [=====] - 532s 3s/step - loss: 0.0123 -
accuracy: 0.9958 - val_loss: 0.6322 - val_accuracy: 0.8750
Epoch 28/30
163/163 [=====] - 535s 3s/step - loss: 0.0060 -
accuracy: 0.9981 - val_loss: 0.3091 - val_accuracy: 0.8750
Epoch 29/30
163/163 [=====] - 532s 3s/step - loss: 0.0046 -
accuracy: 0.9979 - val_loss: 0.3439 - val_accuracy: 0.9375
Epoch 30/30
163/163 [=====] - 537s 3s/step - loss: 0.0248 -

accuracy: 0.9916 - val_loss: 0.9526 - val_accuracy: 0.8750
Training completed in: 4:28:44.670540
1/1 [=====] - 1s 596ms/step - loss: 0.9526 - accuracy:
0.8750
Validation Loss: 0.9525676965713501
Validation Accuracy: 0.875
20/20 [=====] - 22s 1s/step - loss: 3.5283 - accuracy:
0.7196
Test Loss: 3.528272867202759
Test Accuracy: 0.7195512652397156







From the above output the validation accuracy was 0.875 and Test Accuracy of 0.720 bad, We tried to improve the model performance by by reducing overfitting,we did this by trying to modify different achtectures.

Building CNN TUNED BASELINE MODEL

This is a machine learning model that has undergone hyperparameter optimization to improve its performance. Hyperparameters are settings that influence how the model is trained and evaluated, such as learning rate, batch size, number of layers, number of neurons per layer, and dropout rate. Tuning these parameters helps in finding the most effective model

```
[ ]: pip install keras-tuner
```

Collecting keras-tuner

Downloading keras_tuner-1.4.7-py3-none-any.whl (129 kB)
129.1/129.1

kB 3.3 MB/s eta 0:00:00

Requirement already satisfied: keras in /usr/local/lib/python3.10/dist-packages (from keras-tuner) (2.15.0)

Requirement already satisfied: packaging in /usr/local/lib/python3.10/dist-

```

packages (from keras-tuner) (24.1)
Requirement already satisfied: requests in /usr/local/lib/python3.10/dist-
packages (from keras-tuner) (2.31.0)
Collecting kt-legacy (from keras-tuner)
  Downloading kt_legacy-1.0.5-py3-none-any.whl (9.6 kB)
Requirement already satisfied: charset-normalizer<4,>=2 in
/usr/local/lib/python3.10/dist-packages (from requests->keras-tuner) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.10/dist-
packages (from requests->keras-tuner) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/usr/local/lib/python3.10/dist-packages (from requests->keras-tuner) (2.0.7)
Requirement already satisfied: certifi>=2017.4.17 in
/usr/local/lib/python3.10/dist-packages (from requests->keras-tuner) (2024.6.2)
Installing collected packages: kt-legacy, keras-tuner
Successfully installed keras-tuner-1.4.7 kt-legacy-1.0.5

```

```

[ ]: from kerastuner.tuners import RandomSearch
from kerastuner.engine.hyperparameters import HyperParameters

# Define the function to find the best hyperparameters and build a new model
↳ architecture
def tune_model(hp):
    model = Sequential([
        Conv2D(32, (3, 3), activation='relu', input_shape=input_shape),
        MaxPooling2D((2, 2)),
        Conv2D(64, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Conv2D(128, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Flatten(),
        Dense(128, activation='relu'),
        Dropout(0.5),
        Dense(1, activation='sigmoid')
    ])
    # Tune the learning rate
    hp_learning_rate = hp.Choice('learning_rate', values=[1e-2, 1e-3, 1e-4])
    model.compile(optimizer=tf.keras.optimizers.
↳ Adam(learning_rate=hp_learning_rate),
                    loss='binary_crossentropy',
                    metrics=['accuracy'])
    return model

# Define input shape based on your image dimensions (e.g., (height, width,
↳ channels))
input_shape = (224, 224, 3)

# Data preparation

```

```

train_datagen = ImageDataGenerator(
    rescale=1./255,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True,
    validation_split=0.2) # Using 20% of the data for validation

val_test_datagen = ImageDataGenerator(
    rescale=1./255
)

# Create generators for training, validation, and testing sets
train_generator = train_datagen.flow_from_directory(
    train_dir,
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='binary' # Assuming binary classification (e.g., NORMAL vs.
    ↪ PNEUMONIA)
)

val_generator = val_test_datagen.flow_from_directory(
    val_dir,
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='binary'
)

test_generator = val_test_datagen.flow_from_directory(
    test_dir,
    target_size=IMG_SIZE,
    batch_size=BATCH_SIZE,
    class_mode='binary'
)

# Define the function to find the best hyperparameters and build a new model
    ↪ architecture
def tune_model(hp):
    model = Sequential([
        Conv2D(32, (3, 3), activation='relu', input_shape=input_shape),
        MaxPooling2D((2, 2)),
        Conv2D(64, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Conv2D(128, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Flatten(),
        Dense(128, activation='relu'),
        Dropout(0.5),

```

```

        Dense(1, activation='sigmoid')
    ])

    # Tune the learning rate
    hp_learning_rate = hp.Choice('learning_rate', values=[1e-2, 1e-3, 1e-4])
    model.compile(optimizer=tf.keras.optimizers.
↳Adam(learning_rate=hp_learning_rate),
                loss='binary_crossentropy',
                metrics=['accuracy'])

    return model

# Instantiate the tuner
tuner = RandomSearch(
    tune_model,
    objective='val_accuracy',
    max_trials=3, # Increase this value for more trials
    executions_per_trial=1,
    directory='hyperparameter_tuning',
    project_name='tuned_baseline_cnn'
)

# Start the search for the best hyperparameters
tuner.search(train_generator, validation_data=val_generator, epochs=10)

# Get the best hyperparameters
best_hps = tuner.get_best_hyperparameters(num_trials=1)[0]
print(f"Best learning rate: {best_hps.get('learning_rate')}")

# Build the model with the best hyperparameters
best_model = tuner.get_best_models(num_models=1)[0]

end = datetime.datetime.now()

```

Trial 3 Complete [02h 42m 18s]
val_accuracy: 0.8125

Best val_accuracy So Far: 0.875
Total elapsed time: 08h 29m 44s
Best learning rate: 0.0001

We tried 3 trial to search for the best parameter, the first trial resulted to 0.5 Accuracy for validation which took almost 3hrs to compute, The second trial the accuracy was increased to 0.875 which means that accuracy might continue to be better as execution continues. The second trial result was 0.8125 hence the best val accuracy was produced by the second trial which was 0.875

Applying Early Stopping Technique

The main purpose of applying early stopping technique is to train the model on early stopping to prevent overfitting and also to evaluate the model on the validation set and print the results.


```
[ ]: from tensorflow.keras.callbacks import EarlyStopping
import matplotlib.pyplot as plt

def train_and_evaluate_model_es(model, train_generator, validation_generator,
    ↪test_generator, epochs=30):
    """
    Train the model, evaluate on validation and test sets, plot training
    ↪history (loss and accuracy),
    and plot train vs test accuracy and train vs test loss.
    """
    # Define early stopping callback
    early_stopping = EarlyStopping(monitor='val_loss', patience=3,
    ↪restore_best_weights=True)

    # Train the model
    history = model.fit(
        train_generator,
        epochs=epochs,
        validation_data=validation_generator,
        callbacks=[early_stopping], # Pass the early stopping callback
        verbose=1
    )

    # Evaluate on validation set
    validation_loss, validation_accuracy = model.evaluate(validation_generator,
    ↪verbose=0)
    print("Validation Loss:", validation_loss)
    print("Validation Accuracy:", validation_accuracy)

    # Evaluate on test set
    test_loss, test_accuracy = model.evaluate(test_generator, verbose=0)
    print("Test Loss:", test_loss)
    print("Test Accuracy:", test_accuracy)

    # Plot training history (loss and accuracy)
    plt.figure(figsize=(12, 6))
    plt.subplot(1, 2, 1)
    plt.plot(history.history['loss'], label='Training Loss')
    plt.plot(history.history['val_loss'], label='Validation Loss')
    plt.xlabel('Epochs')
    plt.ylabel('Loss')
    plt.title('Training and Validation Loss')
    plt.legend()

    plt.subplot(1, 2, 2)
    plt.plot(history.history['accuracy'], label='Training Accuracy')
    plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
```

```

plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Training and Validation Accuracy')
plt.legend()

plt.show()

# Plot train vs test accuracy
plt.figure(figsize=(8, 6))
plt.plot(history.history['accuracy'], label='Training Accuracy')
plt.plot(history.history['val_accuracy'], label='Validation Accuracy')
plt.axhline(y=test_accuracy, color='r', linestyle='--', label='Test_
↪Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.title('Train vs Test Accuracy')
plt.legend()
plt.show()

# Plot train vs test loss
plt.figure(figsize=(8, 6))
plt.plot(history.history['loss'], label='Training Loss')
plt.plot(history.history['val_loss'], label='Validation Loss')
plt.axhline(y=test_loss, color='r', linestyle='--', label='Test Loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.title('Train vs Test Loss')
plt.legend()
plt.show()

return history

```

Applying Complex Architecture

```

[ ]: from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Flatten, Dense,
↪Dropout

def new_cnn_model(input_shape):
    model = Sequential([
        Conv2D(32, (3, 3), activation='relu', input_shape=input_shape),
        MaxPooling2D((2, 2)),
        Conv2D(64, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Conv2D(128, (3, 3), activation='relu'),
        MaxPooling2D((2, 2)),
        Flatten(),

```

```

        Dense(256, activation='relu'),
        Dropout(0.5),
        Dense(128, activation='relu'),
        Dropout(0.5),
        Dense(1, activation='sigmoid')
    ])
    return model

# Define input shape based on your image dimensions (e.g., (height, width,
↳ channels))
input_shape = (224, 224, 3)

# Create the new CNN model
new_model = new_cnn_model(input_shape)

# Compile the model
new_model.compile(optimizer='adam', loss='binary_crossentropy',
↳ metrics=['accuracy'])

# Print model summary
new_model.summary()

```

Model: "sequential_1"

Layer (type)	Output Shape	Param #
conv2d_3 (Conv2D)	(None, 222, 222, 32)	896
max_pooling2d_3 (MaxPooling2D)	(None, 111, 111, 32)	0
conv2d_4 (Conv2D)	(None, 109, 109, 64)	18496
max_pooling2d_4 (MaxPooling2D)	(None, 54, 54, 64)	0
conv2d_5 (Conv2D)	(None, 52, 52, 128)	73856
max_pooling2d_5 (MaxPooling2D)	(None, 26, 26, 128)	0
flatten_1 (Flatten)	(None, 86528)	0
dense_2 (Dense)	(None, 256)	22151424
dropout_1 (Dropout)	(None, 256)	0

dense_3 (Dense)	(None, 128)	32896
dropout_2 (Dropout)	(None, 128)	0
dense_4 (Dense)	(None, 1)	129

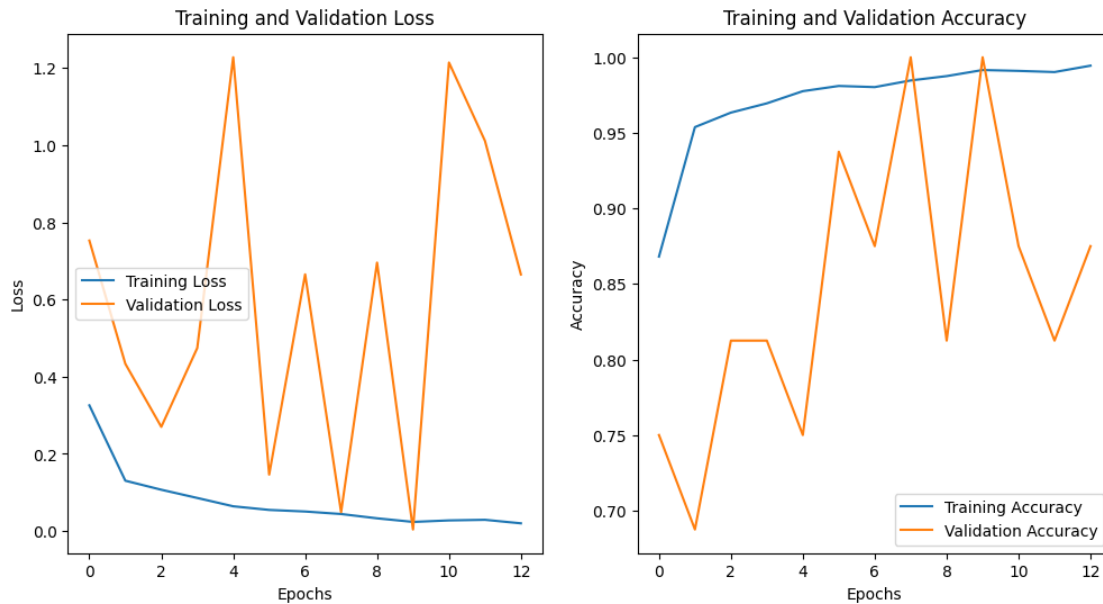
```
=====
Total params: 22277697 (84.98 MB)
Trainable params: 22277697 (84.98 MB)
Non-trainable params: 0 (0.00 Byte)
-----
```

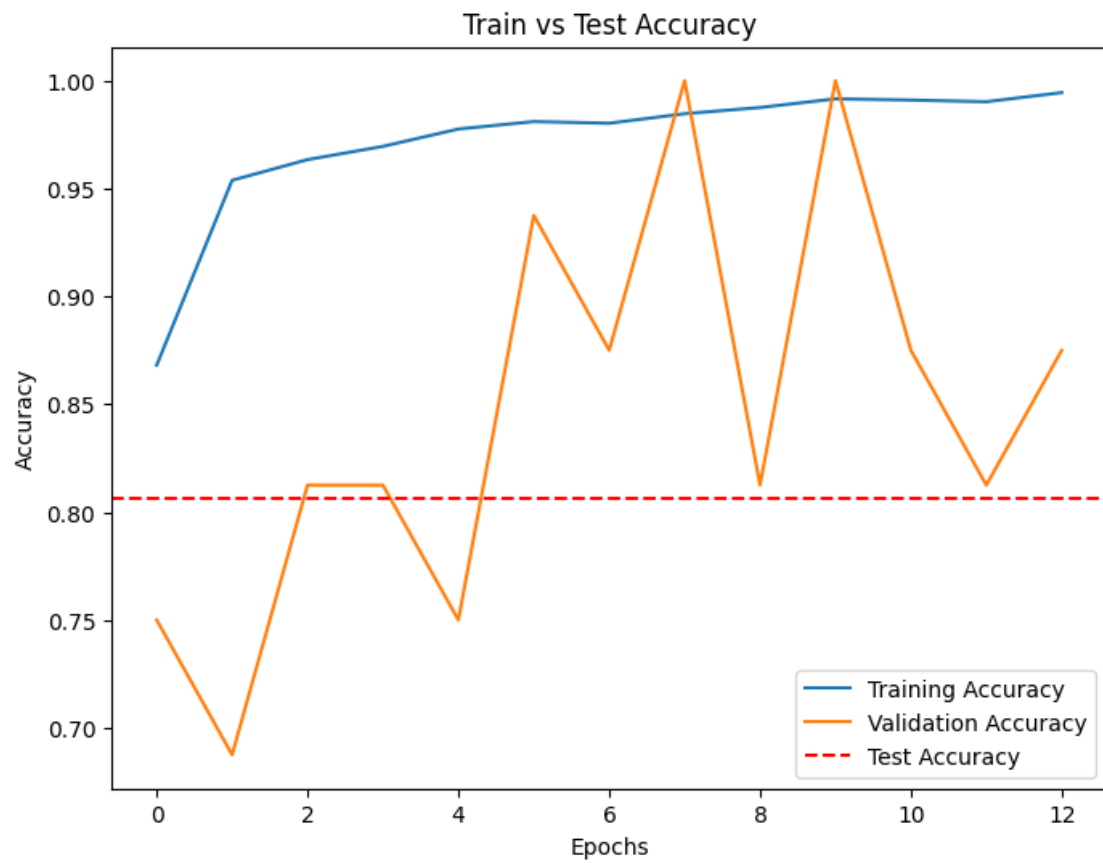
In the complex architecture the total parameters were 22277697 which are trainable and the total non-trainable parameters were 0 hence this shows that all the parameters were updated during processing, the model approximity was 84.98 MB

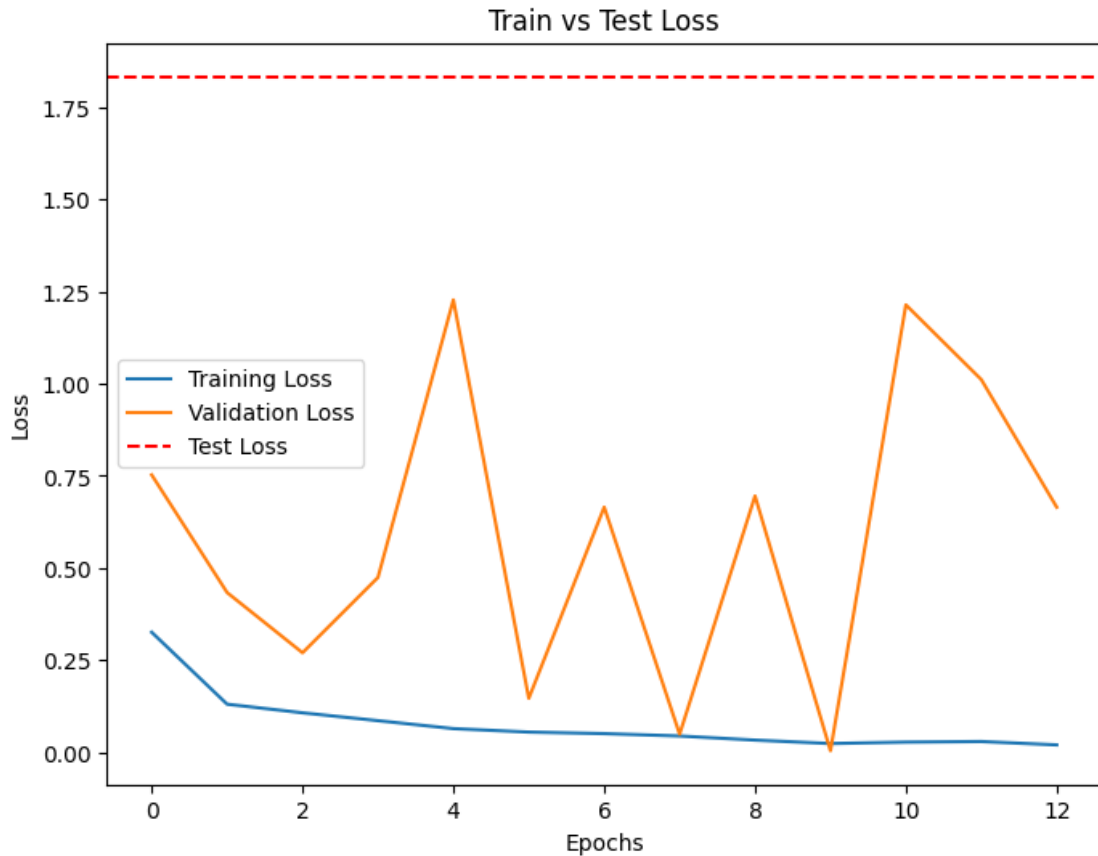
```
[ ]: # Train and evaluate the new model with early stopping
history_new_model = train_and_evaluate_model_es(new_model, train_generator,
↪validation_generator, test_generator, epochs=30)
```

```
Epoch 1/30
163/163 [=====] - 597s 4s/step - loss: 0.3256 -
accuracy: 0.8681 - val_loss: 0.7526 - val_accuracy: 0.7500
Epoch 2/30
163/163 [=====] - 580s 4s/step - loss: 0.1304 -
accuracy: 0.9538 - val_loss: 0.4333 - val_accuracy: 0.6875
Epoch 3/30
163/163 [=====] - 581s 4s/step - loss: 0.1070 -
accuracy: 0.9634 - val_loss: 0.2699 - val_accuracy: 0.8125
Epoch 4/30
163/163 [=====] - 579s 4s/step - loss: 0.0857 -
accuracy: 0.9695 - val_loss: 0.4742 - val_accuracy: 0.8125
Epoch 5/30
163/163 [=====] - 578s 4s/step - loss: 0.0641 -
accuracy: 0.9776 - val_loss: 1.2277 - val_accuracy: 0.7500
Epoch 6/30
163/163 [=====] - 578s 4s/step - loss: 0.0547 -
accuracy: 0.9810 - val_loss: 0.1462 - val_accuracy: 0.9375
Epoch 7/30
163/163 [=====] - 581s 4s/step - loss: 0.0505 -
accuracy: 0.9803 - val_loss: 0.6651 - val_accuracy: 0.8750
Epoch 8/30
163/163 [=====] - 575s 4s/step - loss: 0.0441 -
accuracy: 0.9847 - val_loss: 0.0489 - val_accuracy: 1.0000
Epoch 9/30
163/163 [=====] - 578s 4s/step - loss: 0.0329 -
accuracy: 0.9875 - val_loss: 0.6955 - val_accuracy: 0.8125
Epoch 10/30
```

163/163 [=====] - 578s 4s/step - loss: 0.0236 -
accuracy: 0.9916 - val_loss: 0.0040 - val_accuracy: 1.0000
Epoch 11/30
163/163 [=====] - 580s 4s/step - loss: 0.0275 -
accuracy: 0.9910 - val_loss: 1.2141 - val_accuracy: 0.8750
Epoch 12/30
163/163 [=====] - 577s 4s/step - loss: 0.0291 -
accuracy: 0.9902 - val_loss: 1.0113 - val_accuracy: 0.8125
Epoch 13/30
163/163 [=====] - 580s 4s/step - loss: 0.0199 -
accuracy: 0.9944 - val_loss: 0.6649 - val_accuracy: 0.8750
Validation Loss: 0.00396519061177969
Validation Accuracy: 1.0
Test Loss: 1.8333693742752075
Test Accuracy: 0.8060897588729858







The complex architecture validation accuracy was 1.0 and the test accuracy was 0.806. This shows that the more we try out different models the accuracy performance becomes better

Pre-trained ResNet50V2 Architecture

```
[ ]: from tensorflow.keras.applications import ResNet50V2
from tensorflow.keras.layers import Dense, Dropout, GlobalAveragePooling2D
from tensorflow.keras.models import Sequential

# Define the function to create the ResNet50V2 model
def resnet_model(input_shape):
    # Load pre-trained ResNet50V2 model without the top (fully connected) layers
    base_model = ResNet50V2(weights='imagenet', include_top=False,
    ↪input_shape=input_shape)

    # Freeze all layers of the pre-trained model
    for layer in base_model.layers:
        layer.trainable = False

    # Create a Sequential model
    model = Sequential(name='ResNet50V2')
```

```

# Add the pre-trained ResNet50V2 model to the Sequential model
model.add(base_model)

# Add global average pooling layer to reduce parameters
model.add(GlobalAveragePooling2D())

# Add a fully connected layer with fewer neurons
model.add(Dense(64, activation='relu'))

# Add dropout layer
model.add(Dropout(0.5))

# Add output layer for binary classification
model.add(Dense(1, activation='sigmoid'))

return model

# Define input shape based on your image dimensions (e.g., (height, width,
↳ channels))
input_shape = (224, 224, 3)

# Create the ResNet50V2 model
resnet_model_instance = resnet_model(input_shape)

# Compile the model
resnet_model_instance.compile(optimizer='adam', loss='binary_crossentropy',
↳ metrics=['accuracy'])

# Print model summary
resnet_model_instance.summary()

```

Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resnet/resnet50v2_weights_tf_dim_ordering_tf_kernels_notop.h5
 94668760/94668760 [=====] - 1s 0us/step
 Model: "ResNet50V2"

Layer (type)	Output Shape	Param #
resnet50v2 (Functional)	(None, 7, 7, 2048)	23564800
global_average_pooling2d (GlobalAveragePooling2D)	(None, 2048)	0
dense_5 (Dense)	(None, 64)	131136
dropout_3 (Dropout)	(None, 64)	0

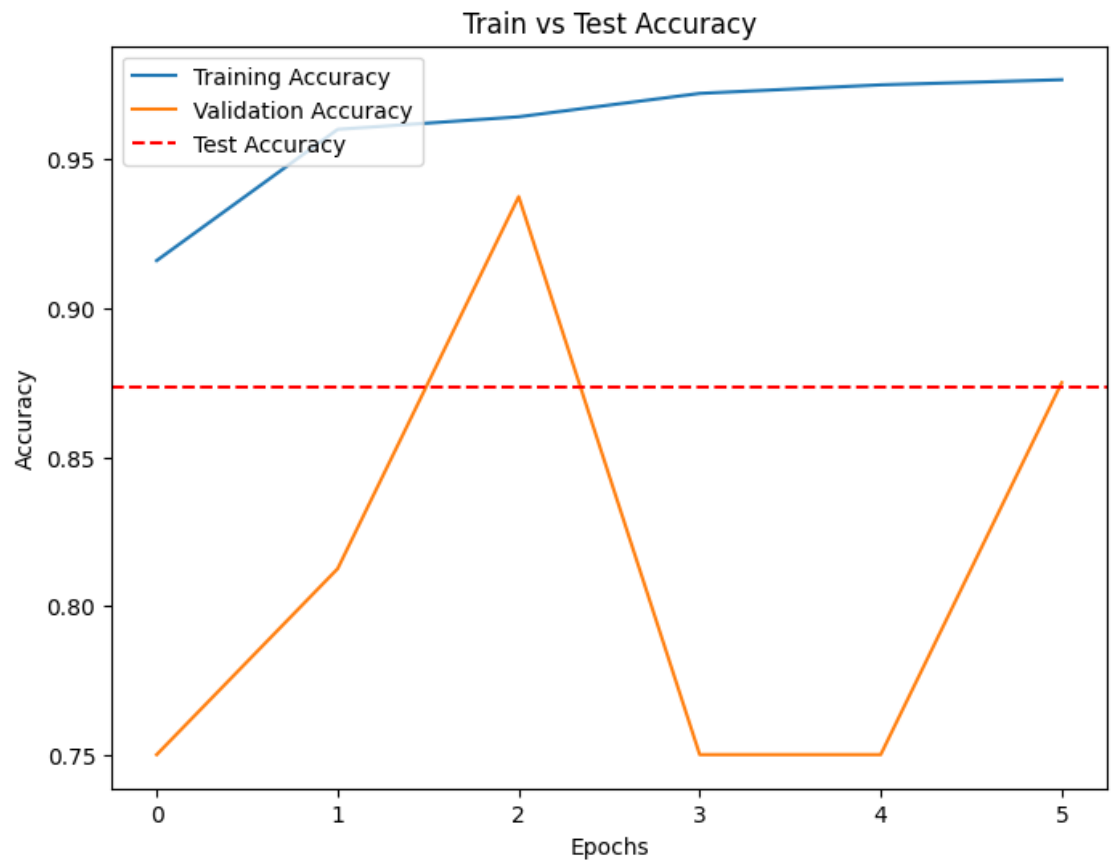
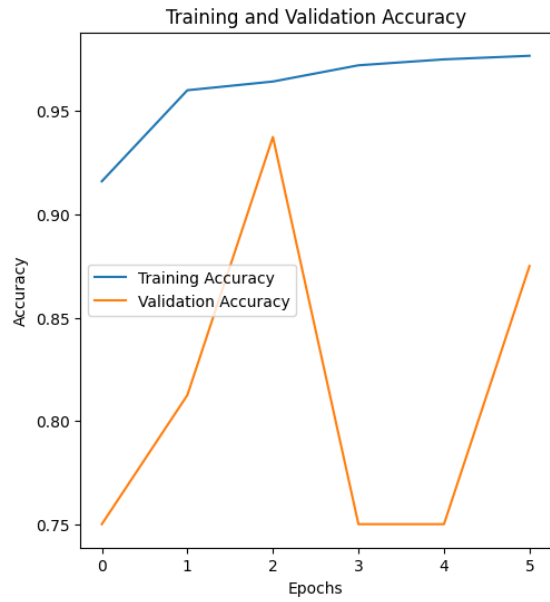
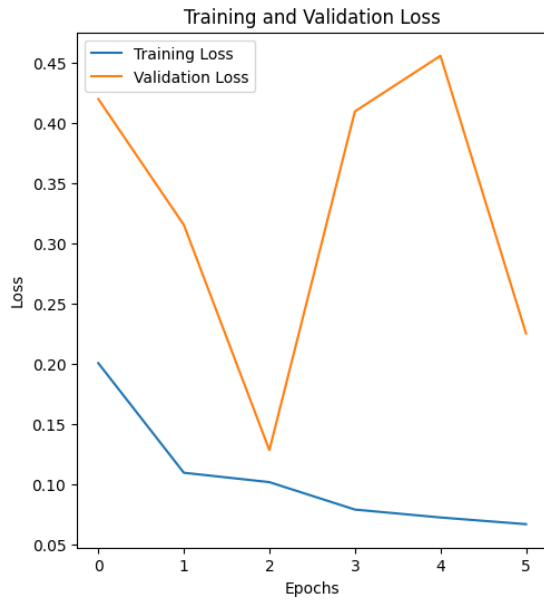
dense_6 (Dense) (None, 1) 65

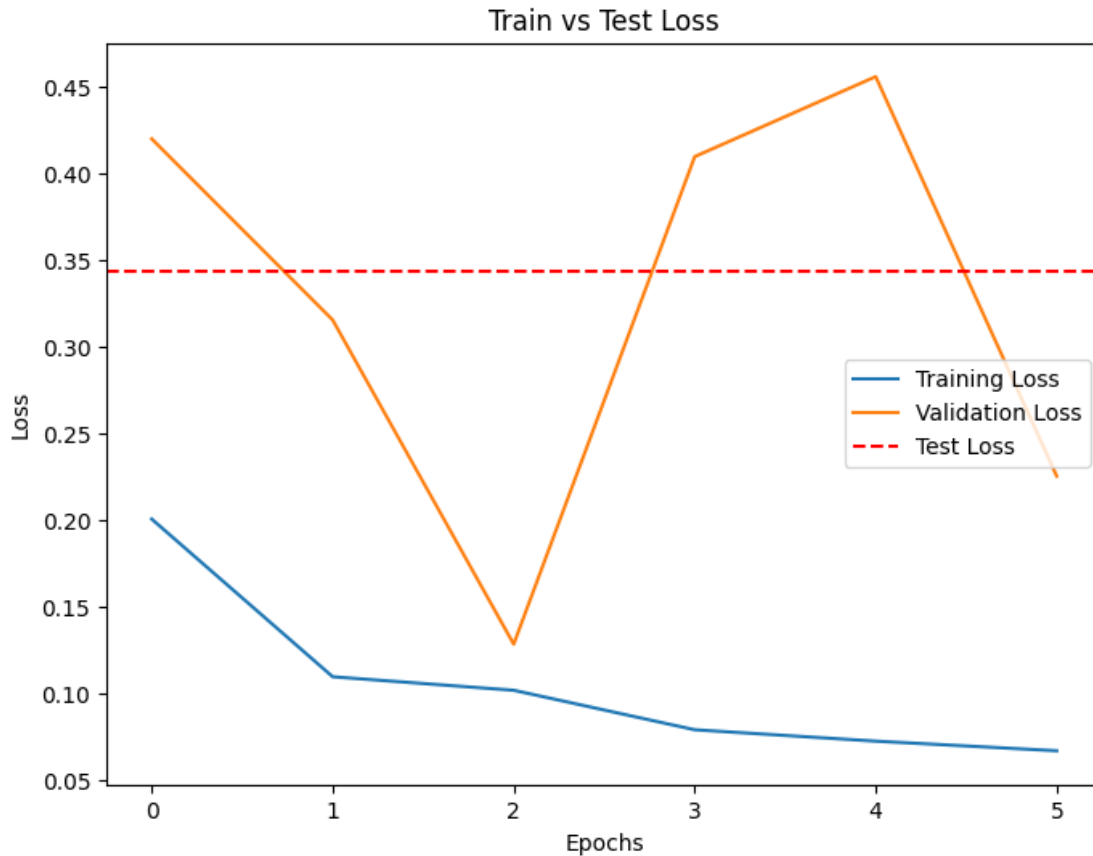
```
=====
Total params: 23696001 (90.39 MB)
Trainable params: 131201 (512.50 KB)
Non-trainable params: 23564800 (89.89 MB)
-----
```

For this model size was 90.39MB with the total parameters were 23696001, The total trainable parameters of 131201 with approxixty size of 512.50KB. The non trainable parameters were 23564800 with approximity size of 89.89MB

```
[ ]: history_resnet_model = train_and_evaluate_model_es(resnet_model_instance,
↳train_generator, validation_generator, test_generator, epochs=30)
```

```
Epoch 1/30
163/163 [=====] - 795s 5s/step - loss: 0.2007 -
accuracy: 0.9160 - val_loss: 0.4198 - val_accuracy: 0.7500
Epoch 2/30
163/163 [=====] - 844s 5s/step - loss: 0.1098 -
accuracy: 0.9601 - val_loss: 0.3154 - val_accuracy: 0.8125
Epoch 3/30
163/163 [=====] - 790s 5s/step - loss: 0.1021 -
accuracy: 0.9643 - val_loss: 0.1286 - val_accuracy: 0.9375
Epoch 4/30
163/163 [=====] - 783s 5s/step - loss: 0.0793 -
accuracy: 0.9722 - val_loss: 0.4095 - val_accuracy: 0.7500
Epoch 5/30
163/163 [=====] - 781s 5s/step - loss: 0.0728 -
accuracy: 0.9751 - val_loss: 0.4556 - val_accuracy: 0.7500
Epoch 6/30
163/163 [=====] - 775s 5s/step - loss: 0.0672 -
accuracy: 0.9768 - val_loss: 0.2254 - val_accuracy: 0.8750
Validation Loss: 0.12862785160541534
Validation Accuracy: 0.9375
Test Loss: 0.34378162026405334
Test Accuracy: 0.8733974099159241
```





Model Architecture:

The ResNet50V2 model is loaded with pre-trained weights from ImageNet, excluding the top layers (include_top=False). All layers of the pre-trained model are frozen to prevent them from being updated during training. The model is wrapped in a Sequential model. A GlobalAveragePooling2D layer is added to reduce the number of parameters. A Dense layer with 64 neurons and ReLU activation is added. A Dropout layer is added to prevent overfitting. A final Dense layer with a sigmoid activation function is added for binary classification.

The validation accuracy is 0.9375 while the test accuracy is 0.833

#Conclusion

Based on the execution time which decreases each time a new model is executed and the accuracy becomes better each time hence boosting performance.

The best model is the ResNET50V2, which has validation accuracy of 0.938 and took the shortest execution time of 1hr 30min 10 secs.

The least was Baseline model and the second improved model was complex architecture.

Early Stopping model helped in minimizing overfitting hence boosting performance.

Recommendation

Based on the evaluation results we recommend ResNET50V2 as the primary model of pneumonia diagnosis from chest Xrays. This model has exhibited the best overall performance, striking a balance between high accuracy, precision, and low loss. Its integration into hospital workflows and medical imaging analysis systems can significantly enhance the speed and accuracy of pneumonia diagnosis, ultimately leading to improved patient outcomes and more efficient healthcare processes.

If our dataset has imbalanced classes, consider techniques to address it for better overall performance.

#Next steps Pneumonia Severity Classification:

Instead of just a binary classification (pneumonia vs. normal), extend the model to classify the severity of pneumonia (mild, moderate, severe). This would provide even more actionable insights for doctors.

Pneumonia Type Classification:

Differentiate between bacterial and viral pneumonia. This information can guide treatment decisions as antibiotics are ineffective against viruses.

Localization of Pneumonia:

Pinpoint the specific regions of the lung affected by pneumonia in the X-ray image. This can be crucial for further investigation and treatment planning.