

Model Development Phase

Date	12 th July 2024
Team ID	SWTID1720195938
Project Title	CovidVision: Advanced COVID-19 Detection from Lung X-Rays with Deep Learning
Maximum Marks	10 Marks

Initial Model Training Code, Model Validation and Evaluation Report

The initial model training code will be showcased in the future through a screenshot. The model validation and evaluation report will include a summary and training and validation performance metrics for multiple models, presented through respective screenshots.

Initial Model Training Code (5 marks):

Paste the screenshot of the model training code

```
import pathlib
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import random
import shutil
import os
import cv2
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.applications import Xception
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Dense, Activation, Conv2D, MaxPool2D, Flatten, Dropout, BatchNormalization
from tensorflow.keras.optimizers import Adam
from sklearn.metrics import classification_report, confusion_matrix
from sklearn.model_selection import train_test_split
from google.colab import files
import seaborn as sns

!mkdir -p ~/.kaggle
!cp kaggle.json ~/.Kaggle
```

```
[ ] !kaggle datasets download -d tawsifurrahman/covid19-radiography-database
```

```
Dataset URL: https://www.kaggle.com/datasets/tawsifurrahman/covid19-radiography-database  
License(s): copyright-authors  
Downloading covid19-radiography-database.zip to /content  
100% 778M/778M [00:29<00:00, 38.4MB/s]  
100% 778M/778M [00:29<00:00, 27.8MB/s]
```

```
[ ] !unzip '/content/covid19-radiography-database.zip'
```

```
[ ] PATH_TO_METADATA = "/content/COVID-19_Radiography_Dataset/Normal.metadata.xlsx"  
df = pd.read_excel(PATH_TO_METADATA)  
df.head()
```

Show hidden output

```
[ ] !ls /tmp
```

Show hidden output

```
[ ] !mkdir /tmp/Xray_train_data
```

```
[ ] !cp -R "/content/COVID-19_Radiography_Dataset/COVID/images" "/tmp/Xray_train_data/"
```

```
[ ] !mv "/tmp/Xray_train_data/images" "/tmp/Xray_train_data/COVID"
```

```
[ ] !ls -l "/tmp/Xray_train_data/COVID" | wc -l
```

Show hidden output

```
[ ] !mkdir "/tmp/Xray_train_data/NORMAL"
```

```
[ ] cnt = 0  
for (i, row) in df.iterrows():  
    if (cnt < 3616):  
        filename = row["FILE NAME"].lower().capitalize() + "." + row["FORMAT"].lower()  
        image_path = os.path.join("/content/COVID-19_Radiography_Dataset/Normal/images", filename)  
        image_copy_path = os.path.join("/tmp/Xray_train_data/NORMAL", filename)  
        shutil.copy2(image_path, image_copy_path)  
        cnt += 1  
  
print(cnt)
```

```
[ ] !ls "/tmp/Xray_train_data"
```

 Show hidden output

```
[ ] !ls -l "/tmp/Xray_train_data/COVID" | wc -l
```

 Show hidden output

```
[ ] !ls -l "/tmp/Xray_train_data/NORMAL" | wc -l
```

 Show hidden output


```
[ ] train_data_dir= "/tmp/Xray_train_data"
```

```
[ ] IMAGE_SIZE = (299, 299)
IMAGE_SHAPE = IMAGE_SIZE + (3,)
```

```
[ ] img_height, img_width=IMAGE_SIZE
batch_size=16
train_datagen = ImageDataGenerator(validation_split=0.3)

train_generator = train_datagen.flow_from_directory(
    train_data_dir,
    target_size=(img_height, img_width),
    batch_size=batch_size,
    class_mode='binary',
    subset='training')
validation_generator = train_datagen.flow_from_directory(
    train_data_dir,
    target_size=(img_height, img_width),
    batch_size=batch_size,
    class_mode='binary',
    subset='validation')
```

```
xception_model = Sequential()
pre_model = tf.keras.applications.Xception(
    include_top=False,
    input_shape=(299, 299, 3),
    pooling='avg',
    weights='imagenet'
)
for layer in pre_model.layers:
    layer.trainable = False
xception_model.add(pre_model)
xception_model.add(Flatten())
xception_model.add(Dense(512, activation='relu'))
xception_model.add(Dense(1, activation='sigmoid'))
```

 Show hidden output

```
[ ] xception_model.compile(optimizer=Adam(learning_rate=0.0001),
    loss='binary_crossentropy',
    metrics = ['accuracy'])
```

```
[ ] es = tf.keras.callbacks.EarlyStopping(monitor = 'val_loss', mode = 'min', verbose = 2, patience = 4)

trainer=xception_model.fit(train_generator,validation_data=validation_generator,epochs=30)
```

Model Validation and Evaluation Report (5 marks):

Model	Summary	Training and Validation Performance Metrics
VGG16	<pre> VGG16_model.summary() Model: "sequential_1" Layer (type) Output Shape Param # ----- sequential (Sequential) (None, None, None, None) 0 conv2d (Conv2D) (None, None, None, 8) 224 max_pooling2d (MaxPooling2D) (None, None, None, 8) 0 conv2d_1 (Conv2D) (None, None, None, 16) 1168 max_pooling2d_1 (MaxPooling2D) (None, None, None, 16) 0 flatten (Flatten) (None, None) 0 dense (Dense) (None, 32) 1493024 dropout (Dropout) (None, 32) 0 dense_1 (Dense) (None, 1) 33 Total params: 1494449 (5.70 MB) Trainable params: 1494449 (5.70 MB) Non-trainable params: 0 (0.00 Byte) </pre>	<pre> es = tf.keras.callbacks.EarlyStopping(monitor='val_loss', mode='min', verbose=1, patience=4) trainer=VGG16_model_fit(train_generator,validation_data=validation_generator,epochs=30, callbacks=[es]) Epoch 1/30 112/112 [====] - 80s 80ms/step - loss: 22.0578 - accuracy: 0.6359 - val_loss: 50.1752 - val_accuracy: 0.5466 Epoch 2/30 223/223 [====] - 21s 67ms/step - loss: 12.7083 - accuracy: 0.6880 - val_loss: 5.8304 - val_accuracy: 0.7477 Epoch 3/30 333/333 [====] - 21s 65ms/step - loss: 9.3674 - accuracy: 0.6823 - val_loss: 6.3681 - val_accuracy: 0.6677 Epoch 4/30 443/443 [====] - 21s 67ms/step - loss: 4.5414 - accuracy: 0.7177 - val_loss: 7.6297 - val_accuracy: 0.7578 Epoch 5/30 553/553 [====] - 20s 62ms/step - loss: 2.7400 - accuracy: 0.7222 - val_loss: 2.2625 - val_accuracy: 0.7113 Epoch 6/30 663/663 [====] - 21s 67ms/step - loss: 2.0477 - accuracy: 0.7387 - val_loss: 1.9998 - val_accuracy: 0.7145 Epoch 7/30 773/773 [====] - 20s 64ms/step - loss: 1.5809 - accuracy: 0.7346 - val_loss: 1.4291 - val_accuracy: 0.7518 Epoch 8/30 883/883 [====] - 21s 67ms/step - loss: 1.3210 - accuracy: 0.7405 - val_loss: 1.2135 - val_accuracy: 0.7664 Epoch 9/30 993/993 [====] - 20s 62ms/step - loss: 1.1480 - accuracy: 0.7421 - val_loss: 1.2033 - val_accuracy: 0.7214 Epoch 10/30 1103/1103 [====] - 21s 68ms/step - loss: 1.0202 - accuracy: 0.7512 - val_loss: 1.2085 - val_accuracy: 0.7191 Epoch 11/30 1213/1213 [====] - 21s 65ms/step - loss: 0.9275 - accuracy: 0.7496 - val_loss: 1.8891 - val_accuracy: 0.7488 Epoch 12/30 1323/1323 [====] - 21s 65ms/step - loss: 0.8922 - accuracy: 0.7370 - val_loss: 1.8554 - val_accuracy: 0.7246 Epoch 13/30 1433/1433 [====] - 20s 65ms/step - loss: 0.7872 - accuracy: 0.7526 - val_loss: 0.8972 - val_accuracy: 0.7403 Epoch 14/30 1543/1543 [====] - 20s 61ms/step - loss: 0.7484 - accuracy: 0.7603 - val_loss: 0.9278 - val_accuracy: 0.7174 Epoch 15/30 1653/1653 [====] - 21s 68ms/step - loss: 0.7070 - accuracy: 0.7522 - val_loss: 0.7482 - val_accuracy: 0.7717 Epoch 16/30 1763/1763 [====] - 25s 78ms/step - loss: 0.6489 - accuracy: 0.7530 - val_loss: 0.7061 - val_accuracy: 0.7795 Epoch 17/30 1873/1873 [====] - 20s 64ms/step - loss: 0.6303 - accuracy: 0.7589 - val_loss: 0.8291 - val_accuracy: 0.7086 Epoch 18/30 1983/1983 [====] - 20s 64ms/step - loss: 0.6307 - accuracy: 0.7488 - val_loss: 0.7562 - val_accuracy: 0.7518 Epoch 19/30 2093/2093 [====] - 21s 65ms/step - loss: 0.6058 - accuracy: 0.7476 - val_loss: 0.7505 - val_accuracy: 0.6979 Epoch 20/30 2203/2203 [====] - 21s 67ms/step - loss: 0.5701 - accuracy: 0.7530 - val_loss: 0.6240 - val_accuracy: 0.7583 Epoch 21/30 2313/2313 [====] - 21s 66ms/step - loss: 0.5506 - accuracy: 0.7579 - val_loss: 0.6206 - val_accuracy: 0.7865 Epoch 22/30 2423/2423 [====] - 21s 78ms/step - loss: 0.5444 - accuracy: 0.7593 - val_loss: 0.5590 - val_accuracy: 0.7698 Epoch 23/30 2533/2533 [====] - 25s 78ms/step - loss: 0.5020 - accuracy: 0.7784 - val_loss: 0.5776 - val_accuracy: 0.7791 Epoch 24/30 2643/2643 [====] - 21s 67ms/step - loss: 0.5356 - accuracy: 0.7680 - val_loss: 0.5966 - val_accuracy: 0.7703 Epoch 25/30 2753/2753 [====] - 25s 78ms/step - loss: 0.4969 - accuracy: 0.7725 - val_loss: 0.5545 - val_accuracy: 0.7868 Epoch 26/30 2863/2863 [====] - 20s 61ms/step - loss: 0.5124 - accuracy: 0.7703 - val_loss: 0.5515 - val_accuracy: 0.7616 Epoch 27/30 2973/2973 [====] - 21s 68ms/step - loss: 0.4929 - accuracy: 0.7796 - val_loss: 0.5076 - val_accuracy: 0.7929 Epoch 28/30 3083/3083 [====] - 22s 70ms/step - loss: 0.4945 - accuracy: 0.7879 - val_loss: 0.5686 - val_accuracy: 0.7721 Epoch 29/30 3193/3193 [====] - 20s 64ms/step - loss: 0.4660 - accuracy: 0.7929 - val_loss: 0.5838 - val_accuracy: 0.7681 Epoch 30/30 3303/3303 [====] - 21s 67ms/step - loss: 0.4493 - accuracy: 0.8011 - val_loss: 0.5482 - val_accuracy: 0.7726 </pre>
CNN Model	<pre> CNN_model.summary() Model: "sequential_1" Layer (type) Output Shape Param # ----- sequential (Sequential) (None, None, None, None) 0 conv2d (Conv2D) (None, None, None, 8) 224 max_pooling2d (MaxPooling2D) (None, None, None, 8) 0 conv2d_1 (Conv2D) (None, None, None, 16) 1168 max_pooling2d_1 (MaxPooling2D) (None, None, None, 16) 0 flatten (Flatten) (None, None) 0 dense (Dense) (None, 32) 1968160 dropout (Dropout) (None, 32) 0 dense_1 (Dense) (None, 1) 33 Total params: 1969585 (7.51 MB) Trainable params: 1969585 (7.51 MB) Non-trainable params: 0 (0.00 Byte) </pre>	<pre> es = tf.keras.callbacks.EarlyStopping(monitor='val_loss', mode='min', verbose=1, patience=4) trainer=CNN_model_fit(train_generator,validation_data=validation_generator,epochs=30, callbacks=[es]) Epoch 1/30 122/122 [====] - 30s 62ms/step - loss: 104.9361 - accuracy: 0.6053 - val_loss: 27.2670 - val_accuracy: 0.7652 Epoch 2/30 233/233 [====] - 25s 80ms/step - loss: 16.4297 - accuracy: 0.6969 - val_loss: 15.8918 - val_accuracy: 0.6891 Epoch 3/30 343/343 [====] - 24s 75ms/step - loss: 8.8682 - accuracy: 0.7097 - val_loss: 6.6401 - val_accuracy: 0.7051 Epoch 4/30 453/453 [====] - 21s 73ms/step - loss: 4.3645 - accuracy: 0.7088 - val_loss: 4.6555 - val_accuracy: 0.6665 Epoch 5/30 563/563 [====] - 21s 73ms/step - loss: 3.8666 - accuracy: 0.6831 - val_loss: 3.7532 - val_accuracy: 0.6824 Epoch 6/30 673/673 [====] - 24s 75ms/step - loss: 2.4177 - accuracy: 0.6684 - val_loss: 3.2558 - val_accuracy: 0.6458 Epoch 7/30 783/783 [====] - 24s 74ms/step - loss: 2.8992 - accuracy: 0.6093 - val_loss: 2.4488 - val_accuracy: 0.6656 Epoch 8/30 893/893 [====] - 24s 74ms/step - loss: 1.6744 - accuracy: 0.6667 - val_loss: 1.9924 - val_accuracy: 0.6511 Epoch 9/30 1003/1003 [====] - 24s 75ms/step - loss: 1.5695 - accuracy: 0.6396 - val_loss: 1.6609 - val_accuracy: 0.6767 Epoch 10/30 1113/1113 [====] - 24s 75ms/step - loss: 1.2412 - accuracy: 0.6515 - val_loss: 1.6707 - val_accuracy: 0.6966 Epoch 11/30 1223/1223 [====] - 24s 77ms/step - loss: 1.1611 - accuracy: 0.6430 - val_loss: 1.4478 - val_accuracy: 0.6983 Epoch 12/30 1333/1333 [====] - 24s 75ms/step - loss: 1.0369 - accuracy: 0.6335 - val_loss: 1.8664 - val_accuracy: 0.7043 Epoch 13/30 1443/1443 [====] - 25s 78ms/step - loss: 0.9598 - accuracy: 0.6408 - val_loss: 0.9166 - val_accuracy: 0.7306 Epoch 14/30 1553/1553 [====] - 24s 76ms/step - loss: 0.9176 - accuracy: 0.6331 - val_loss: 0.8196 - val_accuracy: 0.7426 Epoch 15/30 1663/1663 [====] - 24s 76ms/step - loss: 0.8293 - accuracy: 0.6495 - val_loss: 0.7949 - val_accuracy: 0.7292 Epoch 16/30 1773/1773 [====] - 24s 76ms/step - loss: 0.7983 - accuracy: 0.6591 - val_loss: 0.7472 - val_accuracy: 0.7227 Epoch 17/30 1883/1883 [====] - 24s 75ms/step - loss: 0.7768 - accuracy: 0.6560 - val_loss: 0.7095 - val_accuracy: 0.7266 Epoch 18/30 1993/1993 [====] - 27s 80ms/step - loss: 0.7708 - accuracy: 0.6559 - val_loss: 0.7454 - val_accuracy: 0.7466 Epoch 19/30 2103/2103 [====] - 27s 78ms/step - loss: 0.7708 - accuracy: 0.6556 - val_loss: 0.7065 - val_accuracy: 0.7252 Epoch 20/30 2213/2213 [====] - 24s 75ms/step - loss: 0.7149 - accuracy: 0.6596 - val_loss: 0.6353 - val_accuracy: 0.7477 Epoch 21/30 2323/2323 [====] - 25s 78ms/step - loss: 0.6955 - accuracy: 0.6574 - val_loss: 0.6214 - val_accuracy: 0.7580 Epoch 22/30 2433/2433 [====] - 24s 75ms/step - loss: 0.6486 - accuracy: 0.6508 - val_loss: 0.6412 - val_accuracy: 0.7428 Epoch 23/30 2543/2543 [====] - 25s 78ms/step - loss: 0.6796 - accuracy: 0.6612 - val_loss: 0.6378 - val_accuracy: 0.7315 Epoch 24/30 2653/2653 [====] - 25s 77ms/step - loss: 0.6874 - accuracy: 0.6564 - val_loss: 0.6232 - val_accuracy: 0.7310 Epoch 25/30 2763/2763 [====] - 27s 80ms/step - loss: 0.6659 - accuracy: 0.6667 - val_loss: 0.6424 - val_accuracy: 0.7408 Epoch 26: early stopping </pre>

RESNET 50

```
resnet50_model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
resnet50 (Functional)	(None, 2048)	23587712
flatten (Flatten)	(None, 2048)	0
dense (Dense)	(None, 512)	1049088
dense_1 (Dense)	(None, 1)	513

Total params: 24637313 (93.98 MB)
Trainable params: 1049601 (4.00 MB)
Non-trainable params: 23587712 (89.98 MB)

```
es = tf.keras.callbacks.EarlyStopping(monitor='val_loss', mode='min', verbose=2, patience=4)
trainer_resnet50_model.fit(train_generator, validation_data=validation_generator, epochs=30)
```

```
Epoch 1/30: 73s 2296s/step - loss: 0.6809 - accuracy: 0.7774 - val_loss: 0.5748 - val_accuracy: 0.8092
Epoch 2/30: 78s 2456s/step - loss: 0.4480 - accuracy: 0.8278 - val_loss: 0.2618 - val_accuracy: 0.8099
Epoch 3/30: 73s 2296s/step - loss: 0.4781 - accuracy: 0.8302 - val_loss: 0.4561 - val_accuracy: 0.8381
Epoch 4/30: 74s 2296s/step - loss: 0.3375 - accuracy: 0.8547 - val_loss: 0.3648 - val_accuracy: 0.8551
Epoch 5/30: 76s 2486s/step - loss: 0.4112 - accuracy: 0.8499 - val_loss: 0.4189 - val_accuracy: 0.8094
Epoch 6/30: 76s 2296s/step - loss: 0.4151 - accuracy: 0.8628 - val_loss: 0.2508 - val_accuracy: 0.8667
Epoch 7/30: 73s 2306s/step - loss: 0.3745 - accuracy: 0.8594 - val_loss: 0.5273 - val_accuracy: 0.8811
Epoch 8/30: 78s 2566s/step - loss: 0.3838 - accuracy: 0.8817 - val_loss: 0.3708 - val_accuracy: 0.8688
Epoch 9/30: 73s 2296s/step - loss: 0.3617 - accuracy: 0.8641 - val_loss: 0.3066 - val_accuracy: 0.8186
Epoch 10/30: 72s 2296s/step - loss: 0.3880 - accuracy: 0.8859 - val_loss: 0.4895 - val_accuracy: 0.8408
Epoch 11/30: 73s 2306s/step - loss: 0.2986 - accuracy: 0.9117 - val_loss: 0.5645 - val_accuracy: 0.8456
Epoch 12/30: 78s 2466s/step - loss: 0.5891 - accuracy: 0.8511 - val_loss: 0.1570 - val_accuracy: 0.9278
Epoch 13/30: 73s 2306s/step - loss: 0.2740 - accuracy: 0.8975 - val_loss: 0.2023 - val_accuracy: 0.9167
Epoch 14/30: 73s 2206s/step - loss: 0.2546 - accuracy: 0.9028 - val_loss: 0.2842 - val_accuracy: 0.8880
Epoch 15/30: 73s 2296s/step - loss: 0.3117 - accuracy: 0.8892 - val_loss: 0.3899 - val_accuracy: 0.8863
Epoch 16/30: 78s 2466s/step - loss: 0.2440 - accuracy: 0.9119 - val_loss: 0.4040 - val_accuracy: 0.9182
Epoch 17/30: 73s 2296s/step - loss: 0.3884 - accuracy: 0.8961 - val_loss: 0.1788 - val_accuracy: 0.9181
Epoch 18/30: 74s 2296s/step - loss: 0.3814 - accuracy: 0.9108 - val_loss: 0.1499 - val_accuracy: 0.9198
Epoch 19/30: 76s 2296s/step - loss: 0.2776 - accuracy: 0.9086 - val_loss: 0.1901 - val_accuracy: 0.9218
Epoch 20/30: 78s 2466s/step - loss: 0.2405 - accuracy: 0.9143 - val_loss: 0.1937 - val_accuracy: 0.9182
Epoch 21/30: 73s 2296s/step - loss: 0.2186 - accuracy: 0.9252 - val_loss: 0.2078 - val_accuracy: 0.9240
Epoch 22/30: 73s 2206s/step - loss: 0.2596 - accuracy: 0.9111 - val_loss: 0.2227 - val_accuracy: 0.9258
Epoch 23/30: 72s 2206s/step - loss: 0.2118 - accuracy: 0.9282 - val_loss: 0.2811 - val_accuracy: 0.8881
Epoch 24/30: 73s 2206s/step - loss: 0.2110 - accuracy: 0.8993 - val_loss: 0.2151 - val_accuracy: 0.9224
Epoch 25/30: 72s 2206s/step - loss: 0.2919 - accuracy: 0.9884 - val_loss: 0.1812 - val_accuracy: 0.9591
Epoch 26/30: 72s 2206s/step - loss: 0.2776 - accuracy: 0.9074 - val_loss: 0.2729 - val_accuracy: 0.8971
Epoch 27/30: 72s 2206s/step - loss: 0.1727 - accuracy: 0.9344 - val_loss: 0.1238 - val_accuracy: 0.9403
Epoch 28/30: 73s 2296s/step - loss: 0.1968 - accuracy: 0.9117 - val_loss: 0.1838 - val_accuracy: 0.9193
Epoch 29/30: 72s 2206s/step - loss: 0.1888 - accuracy: 0.9319 - val_loss: 0.1099 - val_accuracy: 0.9117
```

Xception

```
xception_model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
xception (Functional)	(None, 2048)	20861480
flatten (Flatten)	(None, 2048)	0
dense (Dense)	(None, 512)	1049088
dense_1 (Dense)	(None, 1)	513

Total params: 21911081 (83.58 MB)
Trainable params: 1049601 (4.00 MB)
Non-trainable params: 20861480 (79.58 MB)

```
es = tf.keras.callbacks.EarlyStopping(monitor='val_loss', mode='min', verbose=2, patience=4)
trainer_xception_model.fit(train_generator, validation_data=validation_generator, epochs=30)
```

```
Epoch 1/30: 64s 3336s/step - loss: 0.3289 - accuracy: 0.8556 - val_loss: 0.2088 - val_accuracy: 0.9280
Epoch 2/30: 52s 1296s/step - loss: 0.2103 - accuracy: 0.9161 - val_loss: 0.1670 - val_accuracy: 0.9373
Epoch 3/30: 52s 1296s/step - loss: 0.1597 - accuracy: 0.9441 - val_loss: 0.1944 - val_accuracy: 0.9114
Epoch 4/30: 46s 1096s/step - loss: 0.1380 - accuracy: 0.9518 - val_loss: 0.1278 - val_accuracy: 0.9405
Epoch 5/30: 45s 1026s/step - loss: 0.1160 - accuracy: 0.9683 - val_loss: 0.1268 - val_accuracy: 0.9520
Epoch 6/30: 48s 2536s/step - loss: 0.1051 - accuracy: 0.9854 - val_loss: 0.1183 - val_accuracy: 0.9534
Epoch 7/30: 45s 2816s/step - loss: 0.0901 - accuracy: 0.9727 - val_loss: 0.1339 - val_accuracy: 0.9488
Epoch 8/30: 45s 2846s/step - loss: 0.0782 - accuracy: 0.9755 - val_loss: 0.1111 - val_accuracy: 0.9580
Epoch 9/30: 45s 2846s/step - loss: 0.0699 - accuracy: 0.9881 - val_loss: 0.1049 - val_accuracy: 0.9588
Epoch 10/30: 45s 2846s/step - loss: 0.0604 - accuracy: 0.9826 - val_loss: 0.1064 - val_accuracy: 0.9562
Epoch 11/30: 45s 2846s/step - loss: 0.0599 - accuracy: 0.9826 - val_loss: 0.1066 - val_accuracy: 0.9576
Epoch 12/30: 46s 2826s/step - loss: 0.0506 - accuracy: 0.9870 - val_loss: 0.0972 - val_accuracy: 0.9603
Epoch 13/30: 45s 2816s/step - loss: 0.0451 - accuracy: 0.9897 - val_loss: 0.1020 - val_accuracy: 0.9617
Epoch 14/30: 46s 2906s/step - loss: 0.0406 - accuracy: 0.9921 - val_loss: 0.0992 - val_accuracy: 0.9626
Epoch 15/30: 45s 2816s/step - loss: 0.0381 - accuracy: 0.9921 - val_loss: 0.0906 - val_accuracy: 0.9631
Epoch 16/30: 46s 2896s/step - loss: 0.0318 - accuracy: 0.9923 - val_loss: 0.1081 - val_accuracy: 0.9631
Epoch 17/30: 45s 2826s/step - loss: 0.0323 - accuracy: 0.9917 - val_loss: 0.0978 - val_accuracy: 0.9613
Epoch 18/30: 45s 2846s/step - loss: 0.0279 - accuracy: 0.9903 - val_loss: 0.1089 - val_accuracy: 0.9594
Epoch 19/30: 46s 2896s/step - loss: 0.0249 - accuracy: 0.9904 - val_loss: 0.1092 - val_accuracy: 0.9585
Epoch 20/30: 52s 3276s/step - loss: 0.0210 - accuracy: 0.9968 - val_loss: 0.0941 - val_accuracy: 0.9613
Epoch 21/30: 46s 2896s/step - loss: 0.0204 - accuracy: 0.9910 - val_loss: 0.0995 - val_accuracy: 0.9622
Epoch 22/30: 46s 2896s/step - loss: 0.0174 - accuracy: 0.9910 - val_loss: 0.1066 - val_accuracy: 0.9594
Epoch 23/30: 45s 2826s/step - loss: 0.0209 - accuracy: 0.9970 - val_loss: 0.0916 - val_accuracy: 0.9668
Epoch 24/30: 45s 2836s/step - loss: 0.0163 - accuracy: 0.9988 - val_loss: 0.0849 - val_accuracy: 0.9620
Epoch 25/30: 45s 2816s/step - loss: 0.0140 - accuracy: 0.9990 - val_loss: 0.0929 - val_accuracy: 0.9661
Epoch 26/30: 45s 2816s/step - loss: 0.0128 - accuracy: 0.9994 - val_loss: 0.0962 - val_accuracy: 0.9608
Epoch 27/30: 45s 2836s/step - loss: 0.0108 - accuracy: 0.9998 - val_loss: 0.0974 - val_accuracy: 0.9668
Epoch 28/30: 45s 2846s/step - loss: 0.0091 - accuracy: 0.9996 - val_loss: 0.1012 - val_accuracy: 0.9611
Epoch 29/30: 45s 2846s/step - loss: 0.0082 - accuracy: 0.9998 - val_loss: 0.0996 - val_accuracy: 0.9661
```